104

U.S. ENERGY OUTLOOK AND IMPLICATIONS FOR ENERGY R&D

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

SECOND SESSION

MARCH 14, 1996

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U.S. GOVERNMENT PRINTING OFFICE

26–794CC WASHINGTON : 1997

For sale by the U.S. Government Printing Office
Superintendent of Documents, Congressional Sales Office, Washington, DC 20402
ISBN 0-16-053992-7

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U.S. ENERGY OUTLOOK AND IMPLICATIONS FOR ENERGY R&D

THURSDAY, MARCH 14, 1996

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
Washington, DC.

The Subcommittee met at 9:35 a.m. in room 2318 of the Rayburn House Office Building, the Honorable Dana Rohrabacher, Chairman of the Subcommittee, presiding.

Members present: Representatives Rohrabacher, Roemer, Volkmer, Johnson, Largent, Jackson-Lee, Wamp, Ehlers, Cubin, Doyle, McHale, Brown, Davis, Baker, Olver and Rivers.

Chairman ROHRABACHER. Okay, this hearing of the Energy and Environment Subcommittee will come to order. Today, we will examine the U.S. energy outlook and its implications for energy research and development.

In January of 1985, the Department of Energy predicted that crude oil prices would rise to $55 a barrel by 1995. By 1993, that prediction for 1995 had been lowered to $21 a barrel. However, the actual price in 1995 turned out to be $16.81.

Similarly, the price projections for the year 2005 have sunk from $38 a barrel in 1990 to $21.86 a barrel in this year's forecast. It's clear that policy decisions based on those estimates such as funding large demonstration projects and synthetic fuels have been faulty.

In January of 1996, Department of Energy officials predicted—that's January 1996, Department of Energy officials predicted "an imminent oil crisis," saying increased demand, increased imports and instability in the Persian Gulf could lead to an oil crisis. This scenario was justification for advocating a massive increase in the fiscal year 1997 budget request for energy conservation.

At this hearing, we will look at the latest mid-term forecasts of energy supply and demand and prices by the Energy Information Administration. On January 11, EIA extended their projections to the year 2015 for the first time.

We will also examine the accuracy of past EIA forecasts and whether we should rely on current projections or how policymakers in the industry have used or misused certain energy forecasts. And, as well, we will look at what the implications of these forecasts are for the Department of Energy programs.

The world has seen some dramatic changes since the last oil crisis. Those changes include price decontrol and diversification of sources for our U.S. oil consumption.

The question is: do our energy policies and programs reflect those changes or do they reflect a 1970's time warp? To get the answer, we will hear from EIA officials there. And, we will hear from a policy official at the Department of Energy and two respected energy analysts with different views.

Let me also note what my opening statement doesn't say. And, that is, I remember the Global 2000 report which predicted that we would have a shortfall in just about everything.

And, I remember people trying to push that report on the people who were running for office in 1980. I remember they went to different cities and waving this report in their hands and demanded that each candidate make a statement about what his position on the Global 2000 report was. And, that turned out to be a bunch of liberal fantasy that could well have damaged decision-making in the United States government and some very serious decisions that had to be made in this area.

So, it's important that when we are talking about projections like this that we actually look at them in a realistic way and we do not ever condone or let people get away with this type of chicken-little scare tactics that could end up costing the people of this country a lot of money as well as their faulty decision-making in business and in government in terms of what needs to be made in terms of programming for not only our country but for the various corporations of our country.

Before I introduce our witnesses, I will ask my colleague from Indiana, the distinguished Ranking Minority Member, Mr. Roemer, for his opening remarks.

Mr. ROEMER. Thank you, Mr. Chairman. And, I appreciate the opportunity to have such a distinguished panel of witnesses. And, I appreciate your leadership, once again, in having what I think will be a very interesting and informative hearing.

Mr. Chairman, I am looking forward to this hearing. In fact, the best news that I've heard all week is that the Energy Information Agency has predicted that future energy prices will be lower than previously thought.

This is a conclusion that probably brings good news to consumers, the stock market and business. Now, I don't want to burst that bubble, but I suspect that during this hearing we will also discuss the track record of these energy price forecasts.

Back in the 1960's, energy forecasters thought that we would run out of oil in the 1990's. Now, forecasters think that prices will be fairly stable in the long term.

While energy forecasts can be very useful for many reasons, what the results tell me as a policy maker is that the future of energy prices is, at best, uncertain despite how much I want to believe that prices will fall. The policy question, then, is. What do we do in the face of such uncertainty?

The question is especially important since we are talking about the future energy supply, which is so important to the American economy, to the American people, to the American consumers, to the American businesses. I think that the only responsible approach to such uncertainty is not to do nothing, but to take a small insurance policy out on the future.

In this case, the insurance policy consists of energy R&D. And, luckily for us, this insurance policy provides great dividends along the way that have helped to keep the price of energy low.

For example, in 1986, DOE fossil energy R&D helped to develop a new drill bit for oil and gas exploration that reduced drilling time from 60 days to 8 days and produced savings of as much as $1 million per well. In another example, in the early 1980's, DOE R&D developed a new window coating that now captures 36 percent of the $4 billion per year new window market. Further research has yielded a window that loses less heat than a wall.

Also, in the 1980's, DOE photovoltaic research developed solar cell modules that allow the United States to lead the world in sales of this technology with over one-third of the $300 million per year market. And, the final example. After 10 years of work, the nuclear R&D program fostered new technologies to produce even greater energy extraction from nuclear fuels.

Certainly, these technologies increase energy extraction by 50 percent. And, new developments are expected to yield 100 percent increase in energy production.

An important point that should not be missed is that these same technologies, in addition to reducing energy costs, also help reduce pollution. In fact, energy efficiency advances in solar and renewables technology development are increasingly important parts of the fight to preserve the environment.

These technologies can help us to invent our way out of our pollution problems, which is surely a better approach than imposing federal mandates and new federal regulations. Another bonus of such energy technology development may be that the United States can become more self-sufficient and cease to depend on foreign energy imports.

Although U.S. companies now eye new reserves discovered off the coast of Nigeria and in Venezuela, we don't know if Americans will always have access to that oil and gas. I, for one, don't want the United States to have to fight another Persian Gulf war if we can avoid it. And, I think that spending a little on energy R&D to avoid the cost of such a war in the future, even in the distant future, is well worth the price.

The bottom line is that, with all the insurance policies, you don't drop them because you think everything is going to be fine for just awhile. You might shop around for a better deal to try to cut costs yourself, but you don't stop paying on your insurance policy.

We wouldn't do that with health insurance, so I don't see why we should do it with our energy insurance.

Finally, I just want to give you one thing that happened to me yesterday. I had a U.S. businessman from Bechtel in my office talking about what they were doing in Egypt and what the Egyptian government was doing in energy.

And, he said that here, in the heart of oil reserves that are so prominent for everybody there, that the Egyptians were pursuing all kinds of new solar and renewable energy resources to try to put not all their eggs in one basket but to have a myriad of options in the future. I think that's the role the United States should play.

And, I, again, thank the Chairman for the opportunity to have this important hearing.

Chairman ROHRABACHER. Well, thank you very much for that fine opening statement. I just would note that deregulating the price has something to do also with development of new technologies.

We went through a struggle to make sure that energy prices weren't kept artificially low, which would have impeded the development of new technologies and energy saving concepts like you were describing. So, it's not just government research but you have to make sure the marketplace is functioning well.

And, during the 1980's when you had high prices for energy, we developed a lot of those technologies—and especially if they can be put to use. But, your points were very well made.

Mr. Volkmer, do you have an opening statement? And, I would ask if the members of the Committee who have opening statements could keep them to a minimum, because we would like to get to the panel as soon as possible.

Mr. VOLKMER. Thank you, Mr. Chairman. I will be very brief.

I'm sorry I am not going to be able to stay for the full hearing. I find that the testimony of the witnesses is very interesting.

But, I am curious to know—or, at least, I would suggest to the Chairman, since there are other programs within the jurisdiction of this Subcommittee in regard to energy, that we should have hearings also on those programs, the energy research programs and energy conservation, before we go to markup. I suggest that some of us feel that those are just as important as the hearing here today.

Chairman ROHRABACHER. We will be very pleased to consider your suggestions. And, I've always been open to having witnesses, other witnesses, in other areas that you would like or even another hearing if you would like.

And, we will be very open to your suggestions.

And, it's either Ms. Johnson or Ms. Jackson-Lee. I don't know who arrived first. Okay, Ms. Johnson.

Ms. JOHNSON. Thank you very much, Mr. Chairman. And, I want to thank you for calling this hearing.

Clearly, being from an oil producing state, at least formerly an oil producing state, I'm very interested in what the witnesses have to say today and wish they would address some of the concerns about the reserves.

We seem to be riding high now. I hope we don't knee jerk and think we are on such safe ground.

We are importing so much of our oil, which is always a guesstimate as to whether that's stable. I think that this is the time that you prepare. This is insurance time.

You know, you have insurance policies to be there when you need it. And, I hope that we will have an insurance policy for our country so that we can, if necessary, be independent of energy sources from outside our shores.

The world is a volatile place. And, we just don't know.

But, I hope that today we will get some guidance and direction. And, I thank you for the opportunity.

[The prepared statement of Ms. Johnson follows:]

Opening Statement

The Honorable Eddie Bernice Johnson

Energy and Environment Hearing

Energy Outlook

3/14/96

I thank you for recognizing me and for calling this hearing this morning, Mr. Chairman. For my home of Texas, the energy market and the outlook for the market in the future are of critical importance.

As we take a look at this issue today, I am reminded of some staggering statistics about energy production in this country. Crude oil production in the lower 48 states has now dropped to its lowest level since 1946, while our imports of oil from foreign, often somewhat unstable sources continues to hover around the 50 percent level. From a labor standpoint, about 500,000 jobs have been lost in the oil industry since the early 1980's.

During this hearing, we will examine models which suggest that the price of energy will continue to decline in the near term. Unfortunately, this may lead some to urge for a severe reduction in the Department of Energy's energy research and development program. I believe this would be a poor choice for this committee to make.

While lower energy prices are indeed a great assistance to the economy, we all must be aware that these prices, which are in the hands of foreign oil producers, can rapidly change. The lessons of the oil embargo of the 1970's should be well-remembered, as should the example of the recent Gulf War. Despite increased production on the part of Saudi Arabia, and President Bush's use of the Strategic Oil Reserve near the end of the conflict, the price of oil rose to about $33 per barrel. That figure accounts for a near doubling of the price in a very short time frame.

Research and development programs for energy have contributed to the present low price of energy. To abandon successful initiatives now is ill-advised. The possible costs of this strategy, including increasing our dependence on foreign energy sources, are simply too high a cost to pay.

Chairman ROHRABACHER. Thank you very much. Ms. Jackson-Lee.

Ms. JACKSON-LEE. Mr. Chairman, thank you, first of all, for a rapid series of hearings that we've had since I've joined the Committee. And, I am delighted for the focus that we've had the opportunity to generate and to sense your commitment and interest in continually being apprised of the current agenda and current issues.

For that reason, I would like us not to forget our history and recognize that about 25 years ago we would not have been concerned about the future and availability of our natural energy resources. We remember the long lines in the 1970's, however, that not only caused policymakers to change their minds but citizens all over this nation began to take up a cry against long lines at gasoline stations.

So, we had faced a crisis. It was out of that climate that was spawned the commitment to energy conservation and alternative energy production and R&D programs.

We began to seek out new ways to preserve our sanctity and insecurity, in fact, of this nation. We've come a long way.

And, to the credit of those programs, they produced results. The rate of energy consumption per capita has been reduced and new sources of energy are yielding success.

But, regardless of our past achievements, Mr. Chairman, the fact remains that the United States still depends on foreign countries for 50 percent of its oil needs. Oil accounts for a major portion of our unbalanced/balance of trade problem.

And, we are still economically vulnerable. And, that means that our national security is at risk.

For years, as a practitioner of the oil and gas industry, we have discussed in the industry the call for a domestic energy policy and one that would allow us to be dependent solely or, at least, in the majority sense on resources that we produce here at home. I think it is still a problem that faces our nation.

And, so it is important that we maintain a steady hand on research and development that goes along with conservation but, as well, with developing our domestic energy resources in a safe, environmentally safe, and affordable manner. We cannot rely upon the good days of today, the low cost and rates of today, for the days in the future and the days of tomorrow.

So, the government must guard against complacency and remember the past, for we have come a long way but there is still yet quite a distance to go.

And, I would like to put the balance of my statement, Mr. Chairman, in the record. And, I yield back my time.

And, I look forward to participating in the hearing. And, let me qualify, as well, and say that I might not be able to stay continuously because of the anti-terrorist legislation on the Floor of the House.

Thank you.

[The prepared statement of Ms. Jackson-Lee follows:]

OPENING STATEMENT BY CONGRESSWOMAN JACKSON LEE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

MARCH 14, 1996

Until about twenty-five years ago, not many of us would have been concerned about the future and availability of our natural energy resources. The energy crisis of the 1970's changed all of that and brought to the forefront, the issue of our limited fossil fuel reserves and the dependence this country has on foreign nations for its energy needs.

It was that time of crisis which spawned many of the energy conservation, alternative energy production and R&D programs that were aimed at reducing this country's vulnerability to energy shortages like that experienced in 1972. And to their credit, those programs have produced results: the rate of energy consumption per capita has been reduced and new sources of energy are yielding success.

Regardless of our past achievements, the fact remains that the United States still depends on foreign countries for 50% of its oil needs; oil accounts for a major portion of our unbalanced balance of trade problem and we are still economically vulnerable and that means that our national security is at risk.

With these problems still facing our nation, and the environment of competition only becoming more ferocious, I believe we must not only lessen our dependence on other nations for our most basic of needs, but to do so at a reasonable rate. Just because a gallon of gas is affordable doesn't mean there is not a problem. This government must guard against complacency and remember the past, for we have come a long way, but there is yet quite a distance to go.

Chairman ROHRABACHER. Thank you very much. And, without objection, your full statement will be made part of the record.

Mr. Largent from Oklahoma, another oil producing state.

Mr. LARGENT. Thank you, Mr. Chairman. I just want to make very brief remarks and say that I am interested in hearing what this panel has to say about what the Department of Energy, in particular, is doing in relationship to oil and gas exploration, domestic oil and gas production.

I am sure you all are aware that the State of Oklahoma, in fact, my district, Tulsa, Oklahoma, is referred to as the oil capitol of the world, that 80 percent of the production, domestic production, comes from independent producers, not the Exxons and Texacos that so many people think. But, 80 percent, in fact, come from independent producers.

We have lost 500,000 jobs since the 1980's in the domestic oil and gas production. That's alarming, not only because I represent the 1st District where a lot of those jobs have been lost, but more importantly I think that what we have seen—and Mr. Romm I read in your remarks—really represents a very grave national security problem. When we have come to rely on nearly 60 percent of our oil that comes from foreign sources, that is a very real national security problem.

And, the fact is that a lot of the heavy regulatory burden that's on the oil and gas industry has really made it cost prohibitive for these independent producers, the small ranchers, farmers, that have two or three oil wells on their property that are producing—they are stripper wells that produce somewhere between three and eight barrels of oil a day, the little guy, it really becomes cost prohibitive because of the regulatory burden that he has to suffer under for him to even continue production. And, so we've seen a steep decline in those small producers.

And, so I am going to be interested in hearing the comments from representatives from the Department of Energy about what we are doing to address this heavy regulation that is placed upon the small oil and gas and independent producers so that we can make this not so prohibitive, make it more efficient and still provide an environmentally sound condition because, as I said, we are facing some very grave national security issues if we don't face this sooner than later.

Thank you, Mr. Chairman.

Chairman ROHRABACHER. Thank you very much, Mr. Largent. And, Mr. Wamp, do you have an opening statement?

Mr. WAMP. Mr. Chairman, I won't make a statement, but I would commend an article in the "Atlantic Monthly" called "Mideast Oil Forever?" by Joseph Romm and Charles B. Curtis to the entire Committee for their consideration.

[The article referred to appears on page XX of the Appendix.]

Chairman ROHRABACHER. We will add that to the record. And, as you know, Mr. Romm will be testifying.

[The prepared statements of Mr. Doyle and Mr. Minge follow:]

OPENING STATEMENT

HON. MIKE DOYLE [PA-18]

ENERGY & ENVIRONMENT SUBCOMMITTEE

HEARING ON EIA REPORT

Mr Chairman, I want to thank you for holding this hearing. Last year, I was greatly disturbed by the sweeping policy changes this committee made in energy R&D policy without the benefit of a substantial hearing record. Thus, I am grateful for this opportunity to examine these issues before we embark upon significant departures from established policy.

Today's hearing has been called in order for us to examine the results of EIA's annual report, which I believe is a worthwhile endeavor. However, I believe that we should be extremely cautious in drawing too many conclusions from this study. First of all, I have some serious misgivings about the integrity of the models used by EIA, and I expect that this concern will be explored by myself and other members in detail during the questioning of the witnesses. Clearly, it would not be responsible for this committee to base its decisions on energy policy on flawed models.

Furthermore, even if we were to accept the accuracy of EIA's analysis, I am not convinced that the scope of their examination—which is primarily economic—provides a sufficient basis for developing a long-term energy policy. Energy supply is a major underpinning of our economic security, and thus we should look at this as a national security concern. In doing so, we must ask ourselves whether or not we would be pursuing the same strategy towards our nation's defense budget that we seem to be taking towards energy policy by relying on such limited economic analysis.

Statement of the Honorable David Minge

Hearing on U.S. Energy Outlook and Implications for Energy R&D

Subcommittee on Energy and Environment

Mr. Chairman, I am concerned that this committee will use this hearing as a pretext to further cut federal renewable energy research and development programs. That would be pennywise and pound foolish.

Most of my colleagues would not disagree on the benefits derived from pursuing the development of renewable energy technologies. However, I am concerned about the lack of information available about renewable fuels. This became apparent to me last year during the debate on the Department of Energy budget. Funding for renewable energy came under attack—not because it was wasteful over-spending or because it would result in "pork-barrel" projects—but because Members of the House simply had no knowledge of the benefits of energy technologies. The House eventually—almost reluctantly—passed an amendment calling for $45 million for renewable energy funding in the Department of Energy's budget. The lack of information about this debate clearly demonstrates the need to increase exposure to the importance of renewable energy.

As the Energy Information Agency points out in its latest midterm forecast, real prices for energy remain low and are forecast to remain that way for the next 20 years, so the perception that renewable energy has lost some of its relevance or importance to this country pervades. And yet, there are several important benefits to finding new sources of energy that are often overlooked.

The most powerful argument is the opportunity to offset fuel imports. As a nation we are tremendously dependent on the Middle East as a source of oil. With each new breakthrough in renewable fuels, this country moves closer to the day when we can significantly reduce our dependence on imported oil and become more self-sufficient in all forms of energy. It will ease our chronic trade deficit problem. Roughly 50% of our trade deficit is caused by imports of foreign oil. That also augers well for our national security, enabling us to become less vulnerable to interruptions in supply from overseas sources of oil. The Gulf War of 1990 was fought in large part over the threat to our oil supply.

Expanding the development of renewable energy is also beneficial to our national economy. With the prosperous development of new energies, exports of these technologies is a significant opportunity. American entrepreneurs and national labs in our country represent the cutting edge of this industry. We must not pull the plug on them and lose out on this untapped potential.

I know first-hand in my own district that the economic benefits of renewable energy technologies provide a boost to our rural communities. Ethanol plants have already brought new jobs to many declining rural communities who depend on corn production. Wind energy is another cutting edge energy technology that is already up and running in my district and holds promise throughout the windy Plains states. Rural communities are not only in need of innovative approaches to agricultural production, they are often best suited to develop these expandable technologies. One example is the development of biomass energy and feedstock production based on alfalfa leaves and stems. This energy technology will enable many communities to find a niche in a new agricultural market.

We must not overlook the environmental benefits that renewable energy technologies provide. As clean technologies like wind, biomass, solar, geothermal and hydro continue to displace coal and oil, the air we breathe will improve and the United States will be better situated to meet our Rio Treaty emissions objectives. Again, my district offers a good example of how renewable energy technologies may be able to solve an unpleasant environmental consequence of agricultural production. Large hog feedlots produce strong odors which may contribute to health problems. A project currently under development captures the manure in a covered feedlot that will both generate electricity from the methane recovered and substantially reduce odors.

In short Mr. Chairman, Congress must look at the long-term when allocating resources for energy research and development. It would be tragic for our country's long-term competitiveness and security if we used this forecast as an excuse to cut energy R&D even further.

Chairman ROHRABACHER. As you know, we have a panel of witnesses today. And, before I introduce you, I would just like to remind all of you that this is—I handle my situations, my Committee meetings, in a different way than a lot of other chairmen.

I would like there to be a dialogue between the members of the Committee and, of course, the witnesses. But, also I would like the witnesses to feel free to comment on testimony they have just heard and have a dialogue with each other.

I was always dismayed—and I've said this before, many times before—that we would end up with one set of witnesses with one mind-set being heard. And, then the other witnesses with another point of view would be hours later.

And, I don't think that that's the way that we are going to determine what the facts are.

And, I would encourage all of you to take notes of what your fellow panelists are talking about and make your comments. And, then we will make sure that each of you get a chance to have a rebuttal period as well.

We have a panel of witnesses today—Mr. Hakes, the Administrator of the Energy Information Administration at the Department of Energy; Glenn Schleede, the President of Energy Market and Policy Analysis, in Reston, Virginia; Joseph Romm, the Acting Deputy Assistant Secretary of Energy Efficiency and Renewable Energy at the Department of Energy; and Michael Lynch, a Research Affiliate with the Center for International Studies at Massachusetts Institute of Technology, MIT.

So, thank you all very much. And, Mr. Hakes, would you like to begin?

And, if you could, keep your opening statements down to five minutes. And, then we can get on to questions and some interchange.

Thank you.

STATEMENT OF DR. JAY E. HAKES, ADMINISTRATOR, ENERGY INFORMATION ADMINISTRATION, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Dr. HAKES. Thank you, Mr. Chairman. I appreciate this opportunity to appear before the Committee. It has been a number of years since EIA has been before the Committee.

Let me just mention to the Members that we are an independent part within the Department of Energy. Our data and forecasts are done independently.

We function somewhat like the CBO functions for the Congress. We try not to have an ax to grind in the debate. And, we are policy-independent in our operations.

Our data and forecasts are widely used by industry, by government and by the public. The model that we are talking about today is the National Energy Modeling System, which is used to put forth projections of energy price, supply and demand.

This model is used extensively by policymakers to do "what if" games. People want to know what happens if taxes go up, what will that do to energy, the energy world.

Last year, the Congress was interested in what would happen if exports from the North Slope of Alaska were permitted. And, we did that kind of analysis.

So, it is a service that is provided to the Congress, to the Executive Branch and to the public to analyze energy issues. And, we think that it has been a valuable contribution.

If the issue is were there mistakes made years ago, we probably don't need a real long discussion of that because I think everyone admits that is the case. However, we are well prepared, I think, to defend the rationale behind our current projections.

In looking at the world of energy, this is, indeed, a big subject. And, I think it is well known to most people that the United States is still the major producer of energy in the world today, not just the largest consumer.

And, almost all fuels are available, at least, in the United States or in contiguous nations to meet our needs. But, the one exception is oil. And, therefore, since oil is a more sensitive issue, I thought I would focus just a few brief remarks on oil.

One of the issues that comes up—and it's in the first poster here to my right—is what are the projections for the price of oil. And, what the Energy Information Administration shows this year is a very gradual increase in the price of oil that would take us in real dollars in the year 2015 to a price of about $25 a barrel.

This is a more moderate increase than has been shown in any of our previous forecasts and reflects a perception that even with great increases in world demand that the oil is likely to be there. This chart does—you will see two parts to this chart, however.

You will see a historical part, which starts in the year 1970. And, the lines are very jagged. They reflect a lot of historical events that many of us remember.

In the future, the line gets to be fairly smooth. And, that's just simply because in a model or in a forecast it's hard to anticipate where the jags will come. But, history shows us that the lines go up and they go down.

The second issue that I will just address briefly is the issue of imports. Currently, net imports in the United States run about 45 percent. Total imports are in the range of 50 percent.

Our calculations generally use net imports. And, we project that by the year 2015 that the import level will be 56 percent.

Now, like almost all of our charts that project into the future, we have ranges of uncertainty. And, some might even argue these ranges are not great enough.

But, we realize that there are no facts about the future. And, we try to show what the world would be like if the price of oil was higher or lower or the economy grew faster or slower.

And, so the range here in our projections would be from the mid-1940's up to about 68 percent depending on the rate of economic growth and other factors.

Another issue is the role of the Persian Gulf. You can do calculations based on the OPEC or on the Persian Gulf. Today we are using the Persian Gulf.

And, we project that in the year 2015 that the Persian Gulf will be producing about 43 percent of the world's oil. The Persian Gulf has an abundance of oil.

It is easy to find and easy to produce. They have constrained production there somewhat, but we feel that they will allow the investment necessary to meet rising world demand.

The role of the Persian Gulf in producing oil is somewhat understated, I believe, by just a consumption number, because the power of the Persian Gulf comes not just from the fact that they produce a lot of oil but the fact that they don't consume very much of the oil. Because they don't consume a lot of the oil, they have a lot to export.

And, so if we look at the role of the Persian Gulf and the amount of oil in the world that is available for export, the numbers go up considerably. And, we see that in the year 2015, we project that roughly three quarters of the world's exportable oil would come from the Persian Gulf.

Now, this can change based on a number of factors. To make these judgments, one has to make assumptions about the rate of technological progress, the economic and political environment in a number of countries. But, this is our basic estimate.

I think it is useful, too, in talking about oil to just bring to your attention one historical situation that you are all familiar with. And, that is the Persian Gulf war.

And, we have here a time line of what happened in the Persian Gulf war. This is history, so we are not dealing here with models.

But, we see that when Iraq invaded Kuwait that a lot of oil came off the world market from the two warring countries and that in that period the price of oil basically doubled to $33 a barrel. The Saudi Arabian government was strongly supporting the allied position and came in with a lot of excess capacity and started to produce quickly.

So, we had what you will call a short price spike where the interruption in world supply did cause a sudden price increase. The price then came back down fairly rapidly.

But, the impact—I think if we can go to the next poster and actually my last poster—shows that price spike was associated with three quarters of negative economic growth, which some people would refer to as a recession. And, the country has had three recessions in the last 25 years; and, virtually all of them have had a pattern very much like that where the price went up in a spike—the earlier spikes were of longer duration—and the economy seemed to hit the skids.

Economists and other careful scholars are hesitant to talk about causal effects, but there is a very close correlation between the last three economic downturns and spikes in the price of oil.

Chairman ROHRABACHER. I will let you go on, because you have overshot the five minutes but you have a lot to say here. And, you are the one under the gun.

But, let me just ask one question. Isn't that also the time period when the 1990 tax increase kicked in just at that same time when you had the recession?

Dr. HAKES. Does anyone know the date of the——

Chairman ROHRABACHER. I think it is, but we will go through that when we go through the——

Dr. HAKES. It was also reduction in government spending at that time.

Chairman ROHRABACHER. Who was President? That was George Bush. He said, "Read my lips." There's the recession.

[Laughter.]

Dr. HAKES. Well, I put in the caveat of backing away a little bit from causal connections.

Mr. Chairman, this is a convenient place for me to stop. I understand there is some interest in our nuclear power projections, and I can deal with that now or I could deal with that in the question period, whatever you prefer.

Chairman ROHRABACHER. Why don't we move on?

Dr. HAKES. Sure.

[The prepared statement of Dr. Hakes follows:]

STATEMENT OF

JAY HAKES

ADMINISTRATOR, ENERGY INFORMATION ADMINISTRATION

DEPARTMENT OF ENERGY

before the

SUBCOMMITTEE on ENERGY AND ENVIRONMENT

of the

COMMITTEE on SCIENCE

UNITED STATES HOUSE of REPRESENTATIVES

MARCH 14, 1996

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss the Energy Information Administration's (EIA) projections of energy supply, demand, and prices through the year 2015, how they have changed in recent years, and some of the uncertainties associated with the forecast. I will also address some issues dealing with the uses of our past projections, and what EIA and other parts of the Department of Energy are doing to assure that the forecasts are used in the most appropriate ways possible. While EIA does not and cannot monitor all of the uses made of its data, analyses, and forecasts, we have made significant efforts to assure that users of our material are made fully aware of their limitations and the unavoidable uncertainties that underlie energy forecasting, as well as alternatives to our projections (such as those made by private forecasters, or committed long-term contracts that assume price risks).

Before continuing, I would like to emphasize that EIA is an independent agency of the Department of Energy, charged with providing objective data, and nonpartisan analyses and forecasts concerning domestic and international energy markets. We do not take a position on policy proposals of the Department or the Administration. Our job is to help the Department, Congress, and the public understand the energy implications of such proposals. In keeping with this objectivity, all of our mid-term baseline forecasts assume the continuation of current laws and regulations as of October 1 of the year prior to the release of the Outlook. In this way, we are able to respond to our customers' requirements for balanced and objective analysis of the impacts of proposed policy changes, such as changes in energy taxes, carbon mitigation efforts, and efficiency standards. The ability to provide such objective analysis is a major strength of EIA's program. We are proud that our role in providing objective data has helped to resolve many of the debates regarding energy policy that have occurred over the last two decades. We also recognize that our forecasts, by necessity, are affected by judgment, but we would maintain that our judgment has <u>not</u> been partisan. The purpose of our forecasts has always been to enlighten our users concerning the impacts of various policies on possible energy futures, rather than to guarantee that we know what the future holds.

The Outlook for Energy Supply, Demand, and Prices Through 2015

EIA's Annual Energy Outlook is published in accordance with Section 205c of the Department of Energy Organization Act of 1977 (Public Law 95-91), which requires the Administrator of EIA to prepare an annual report that contains trends and projections of energy consumption and supply. These projections are based on current laws and regulations and essentially provide a baseline so that the costs and benefits of proposed new policies, laws, and regulations can be examined.

The Annual Energy Outlook 1996 (AEO96) is the first Annual Energy Outlook with 20-year projections to the year 2015. Key areas of analysis include the availability and economics of domestic fossil fuel resources, the penetration of new, more advanced energy technologies, and the projected decline of nuclear generation. Each of these areas has a major impact on this year's forecast, with the overall picture being one of lower prices and higher supply than in previous outlooks. The following is a summary of our most recent forecast.

Prices

Because of higher expectations for oil production from the Organization of Petroleum Exporting Countries (OPEC), oil prices are projected to be slightly lower than in AEO95 (Figure 1). In 2010, the average price is about $24 per barrel (all prices are expressed in inflation-adjusted 1994 dollars), nearly $1 a barrel lower than last year's projection. The 2015 price is expected to be about $25 a barrel, with the low and high price cases ranging from $16 (about 5 percent below the estimated 1995 value) to $34 a barrel (Figure 2). Underlying the oil price projection are three key factors:

- OPEC, with its vast store of readily accessible oil reserves, is expected to be the source of marginal supply to meet future incremental demand. By 2000, OPEC supply in the reference case approaches 35 million barrels per day, a figure that is consistent with

Figure 1. World Oil Price Projections, 1970-2015: AEO95 and AEO96 Compared (1994 dollars per barrel)

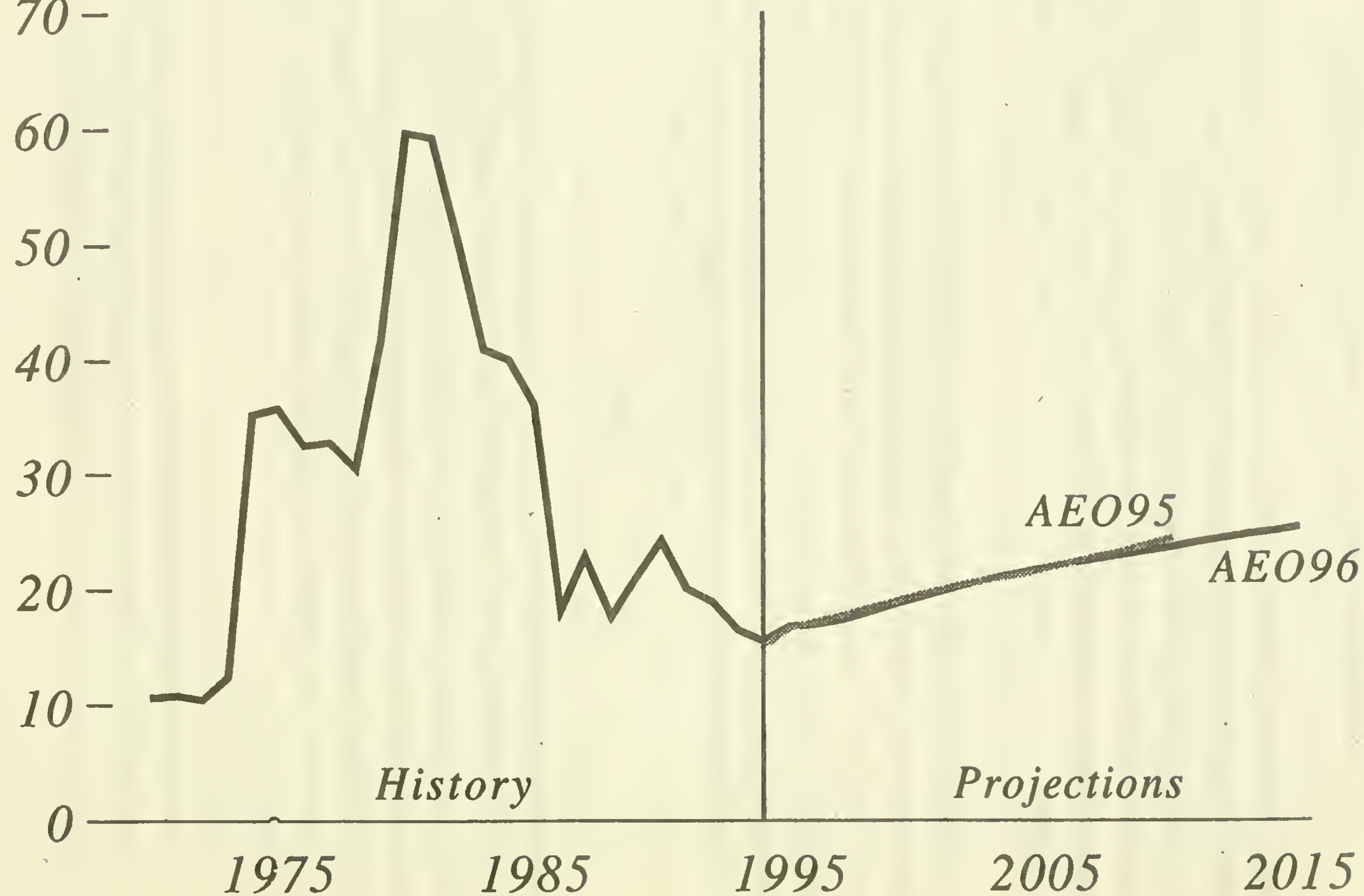
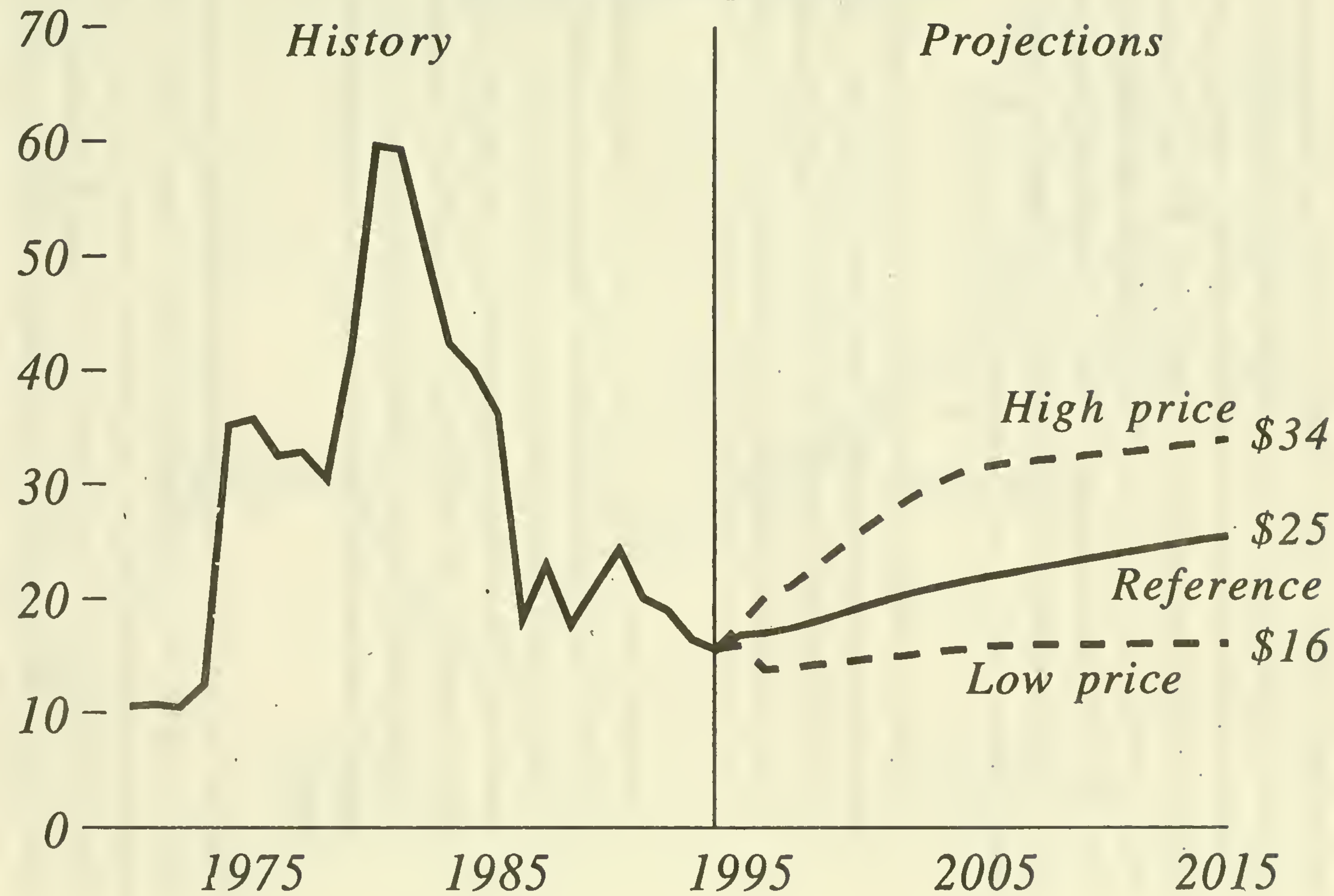


Figure 2. World Oil Prices in Three Cases, 1970-2015
(1994 dollars per barrel)



announced plans for capacity expansion by OPEC. By 2015, OPEC production in the reference case is just over 52 million barrels per day, or about twice its level of production in 1990. Crude oil production from the Persian Gulf is expected to be about 40 million barrels per day by 2015, compared to about 20 million barrels per day in 1994 (Figure 3). With world oil consumption rising to 93 million barrels per day by 2015 (Figure 4), Persian Gulf supplies will provide 43 percent of the world's oil consumption by 2015 (Figure 5), compared to about 30 percent in 1994. In terms of internationally traded oil, the Persian Gulf share should be even higher, reaching 74 percent in 2015 (Figure 6), compared to under 50 percent in 1994.

- Oil production in non-OPEC nations has received boosts from new discoveries as well as technical innovations that have delayed production declines in mature fields. Assuming a continuation of this trend, production in non-OPEC nations is projected to continue creeping slowly upward, reaching just over 41 million barrels per day in 2010, then declining slightly to 40 million barrels per day (near the 1994 level) in 2015.

- A substantial increase in world oil consumption is expected over the next 20 years. With rapid gains in energy demand anticipated for the developing countries, world oil consumption of about 69 million barrels per day in 1995 will rise to more than 74 million barrels a day by the end of the decade and reach as high as 100 million barrels a day (in the low-price case) by 2015. Much of the growth in demand for oil is concentrated in the developing nations of Asia, where demand growth greater than 5 percent a year is expected. Annual growth in oil demand of less than 1 percent is anticipated for the OECD nations.

Projections of the average wellhead price of natural gas in AEO96 are significantly lower than in AEO95. The AEO96 average wellhead price in 2010 is $2.15 per thousand cubic feet (compared with almost $3.50 in AEO95), rising to $2.57 per thousand cubic feet in 2015 (Figure 7). Higher assessments of domestic resources, lower drilling costs, and a change in methodology to account for more direct investment in future gas exploration and production projects contribute to the

Figure 3. Persian Gulf Oil Production in Three Cases
(million barrels per day)

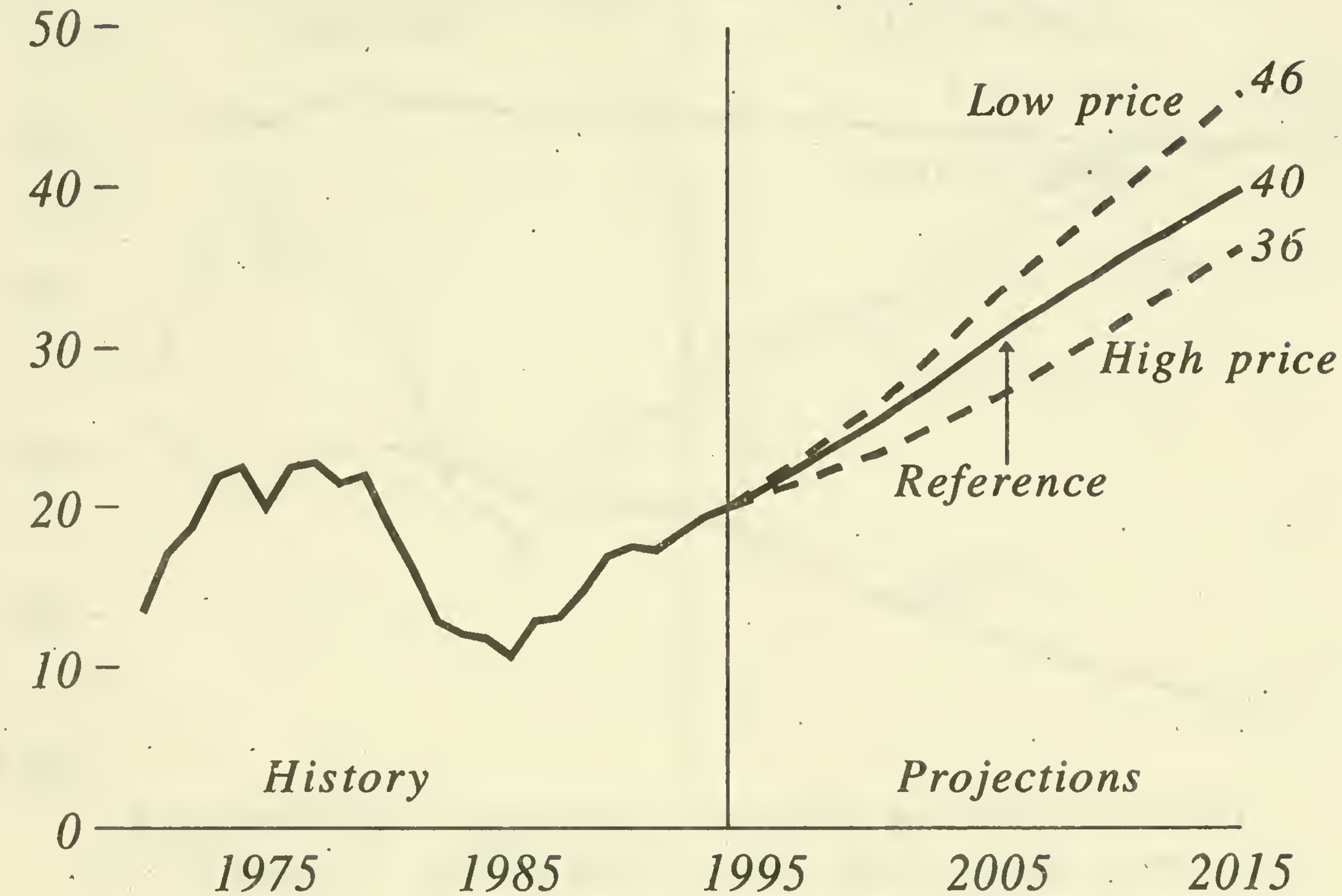


Figure 4. World and United States Petroleum Consumption, 1975-2015 (million barrels per day)

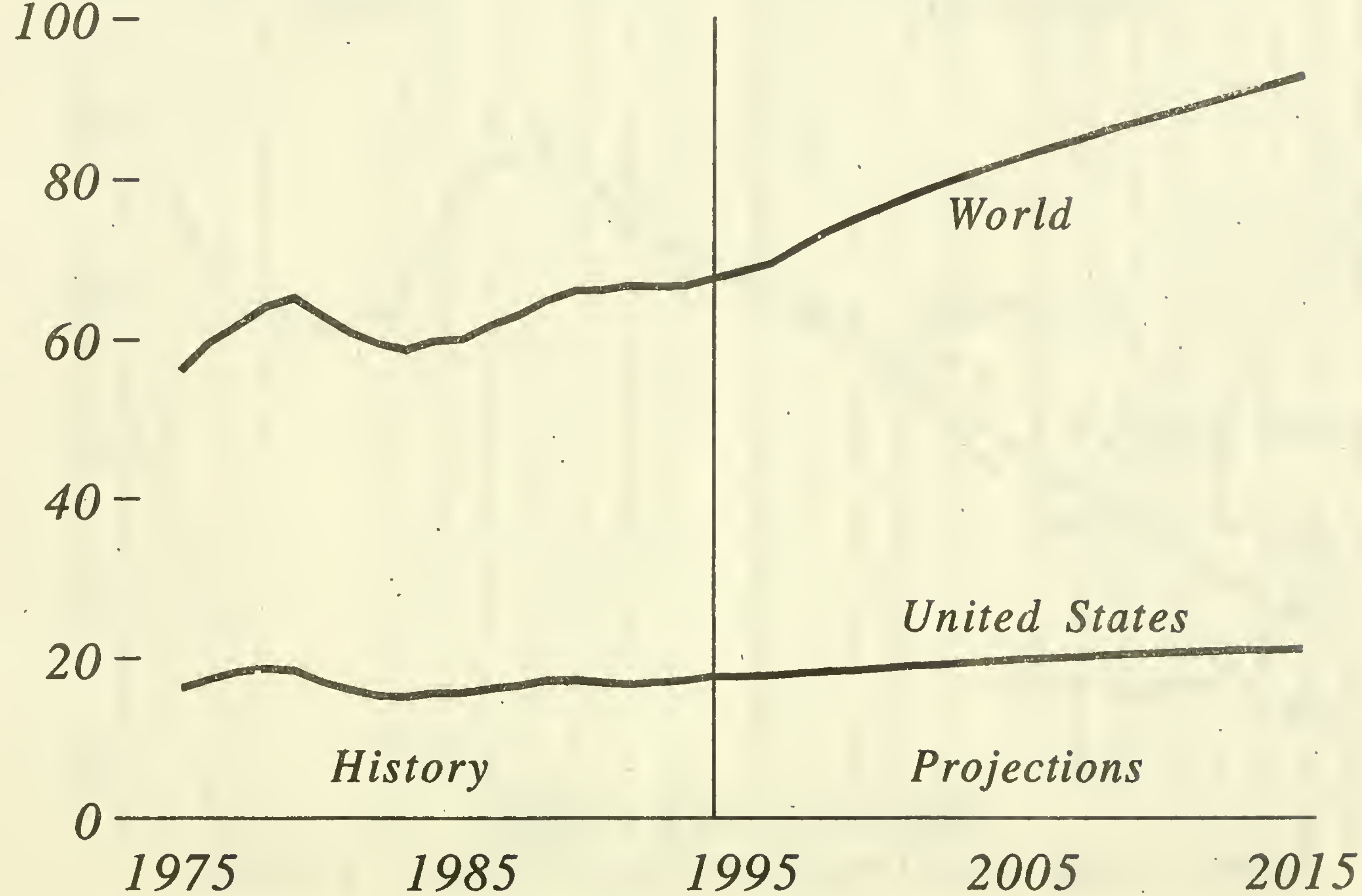


Figure 5. Persian Gulf Oil Production as a Percent of World Oil Consumption in Three Cases (percent)

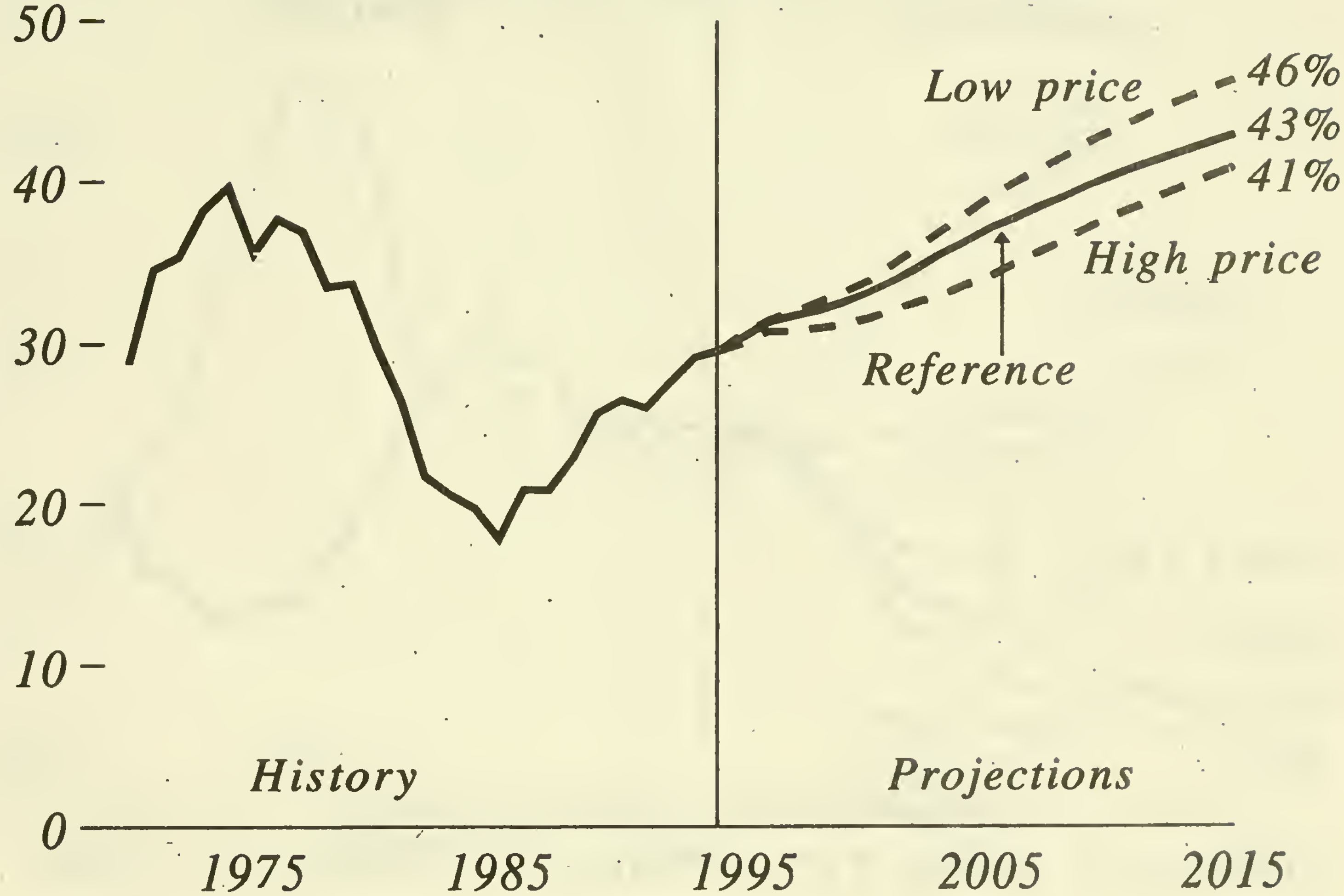


Figure 6. Persian Gulf Oil Exports as a Percent of World Oil Exports in Three Cases (percent)

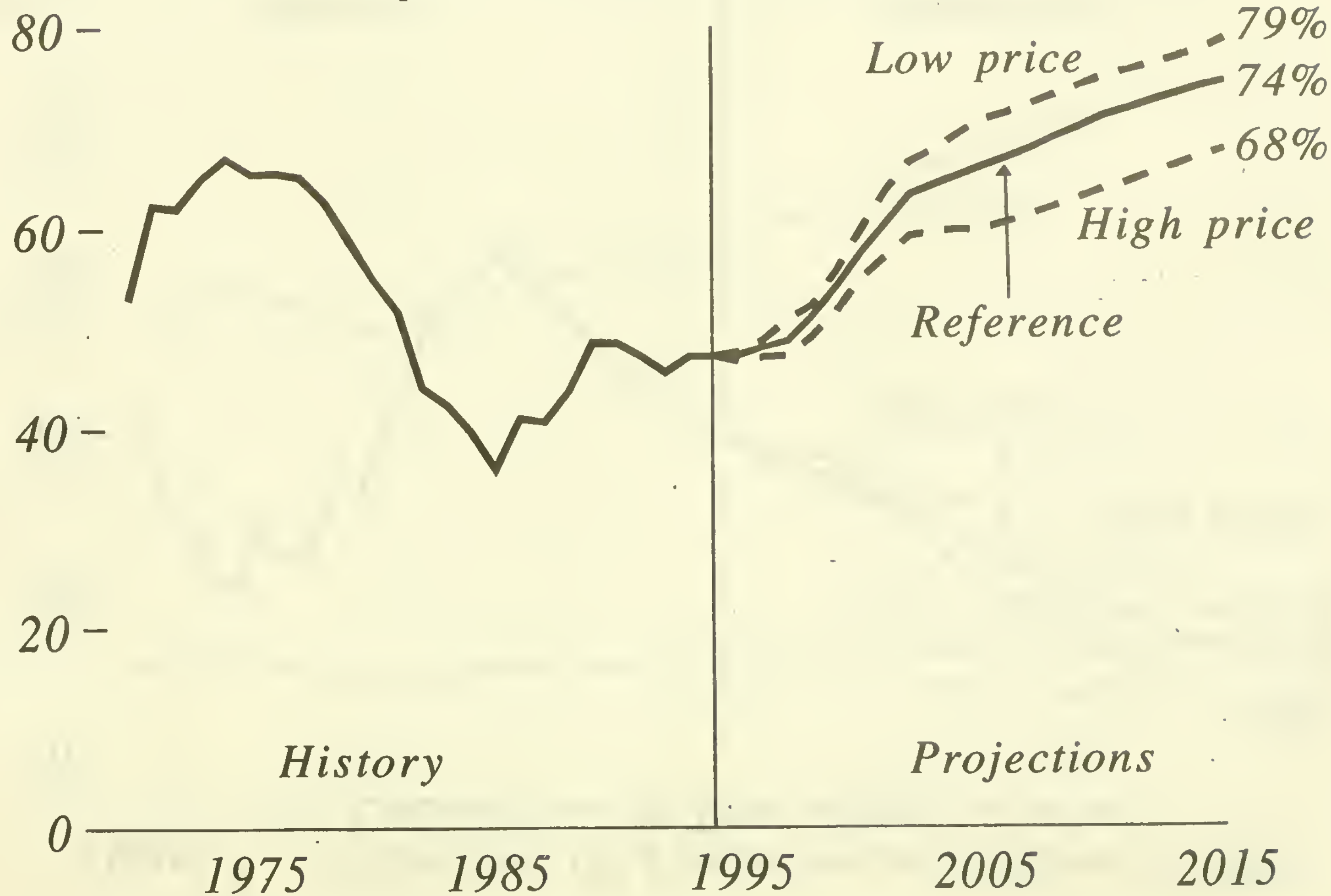
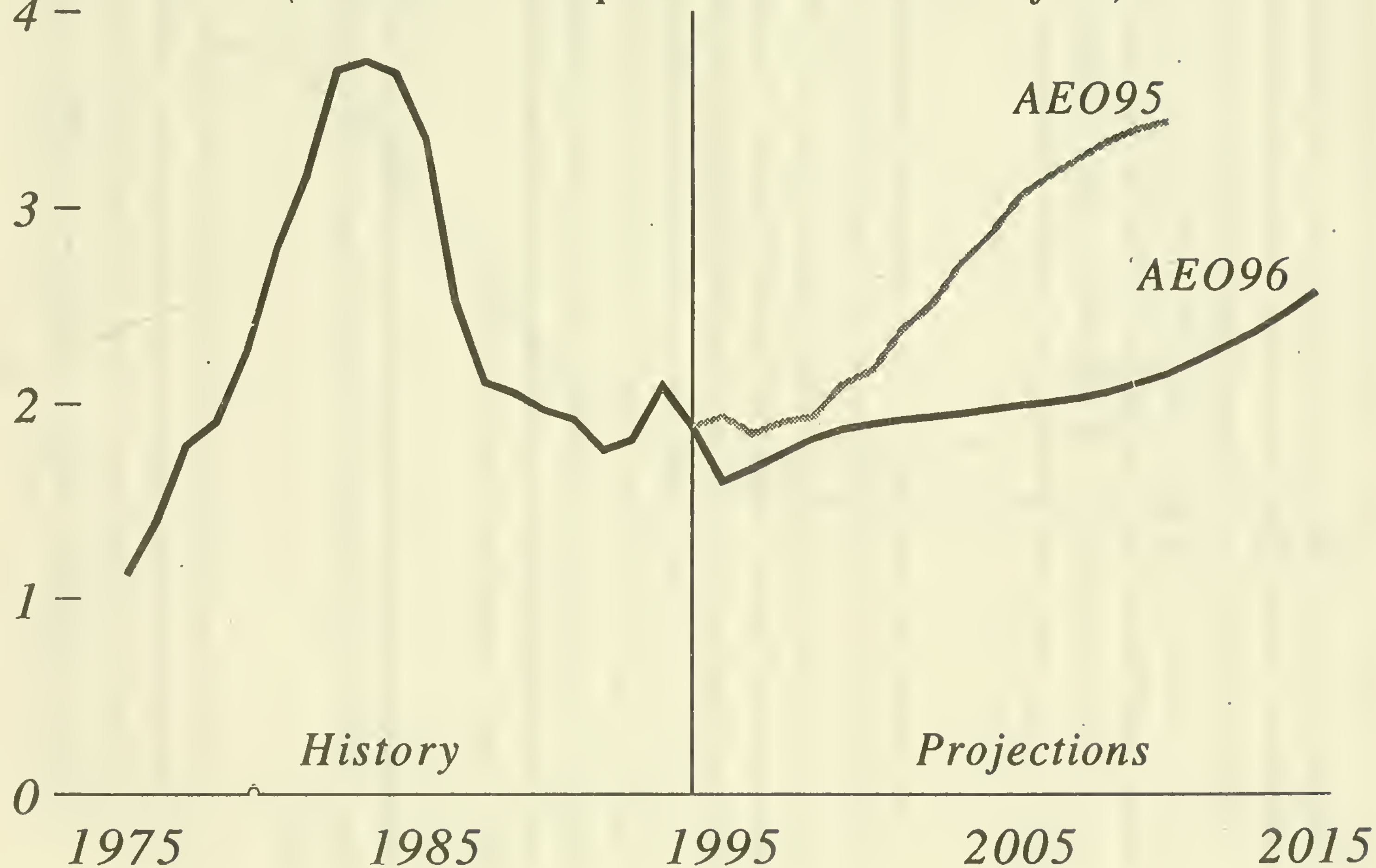


Figure 7. Natural Gas Wellhead Price Projections, 1975-2015: AEO95 and AEO96 Compared (1994 dollars per thousand cubic feet)



reduced price projections. In contrast to domestic oil prices, natural gas prices are less affected by changing world oil prices, largely because oil and natural gas do not compete directly in all domestic markets. However, wellhead prices are expected to increase from the 1995 level of about $1.60 per thousand cubic feet, as increasing demand and the effects of resource depletion raise prices, although not as much as projected in AEO95. Little change in consumer prices is projected through 2008, as declines in transmission and distribution margins generally offset moderate increases in wellhead prices. After 2008, the upward pressure on supply prices from rapidly increasing demand and resource depletion, and the need for new downstream infrastructure, force end-use prices for all sectors to rise moderately.

U.S. coal minemouth prices, currently about $19 per ton, are projected to decline slightly over the forecast horizon, due to increasing productivity, flat real wages, more low-cost production from the Western states, and competitive pressures on long-term contracts. In 2010, the minemouth price is $17 per ton, compared with $23 in AEO95 (Figure 8). Productivity improvements first outpace, then lag behind cost growth as thicker, shallower low-sulfur coal reserves are depleted. As a result of productivity gains, the number of coal miners is forecasted to decline by 43 percent between 1994 and 2015. The average price of delivered coal to all domestic sectors (about 90 percent of which goes to electricity generators), is moderated by the decline in minemouth prices and the competition between transporters, particularly the railroads, falling from $1.39 per million Btu in 1994 to $1.28 by 2015.

Average real electricity prices, which are expected to remain essentially flat through 2015, are slightly lower than in AEO95 (Figure 9). The main factors responsible for the projected decline include:

- Capital costs associated with the recovery of investments in power plants and transmission and distribution facilities are expected to decline by 0.6 percent annually from 1994 to 2015. The decline is made possible by increased utility reliance on wholesale power purchases (which more than triple over the forecast), lower construction

Figure 8. Coal Minemouth Price Projections, 1975-2015: AEO95 and AEO96 Compared (1994 dollars per ton)

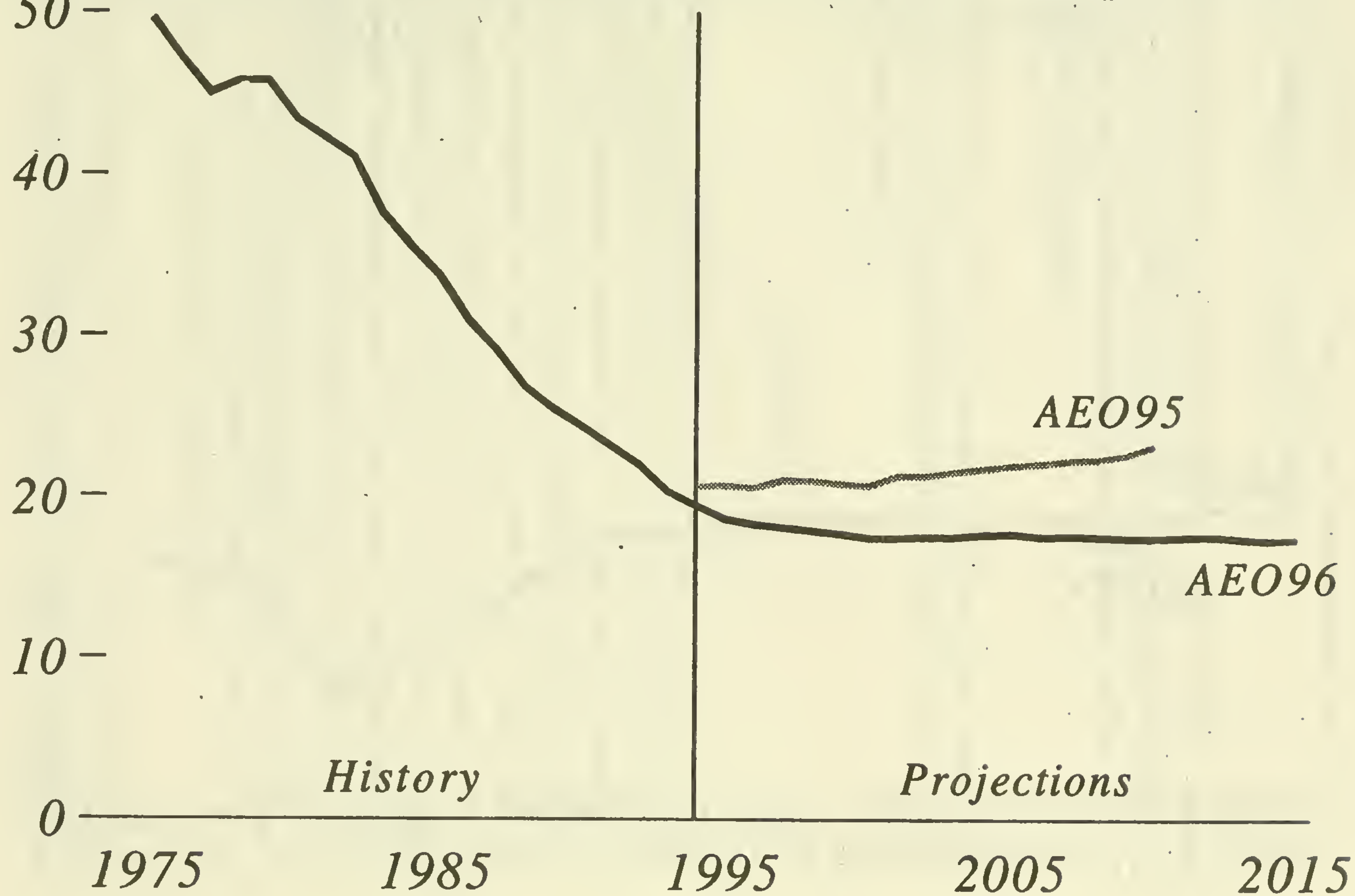
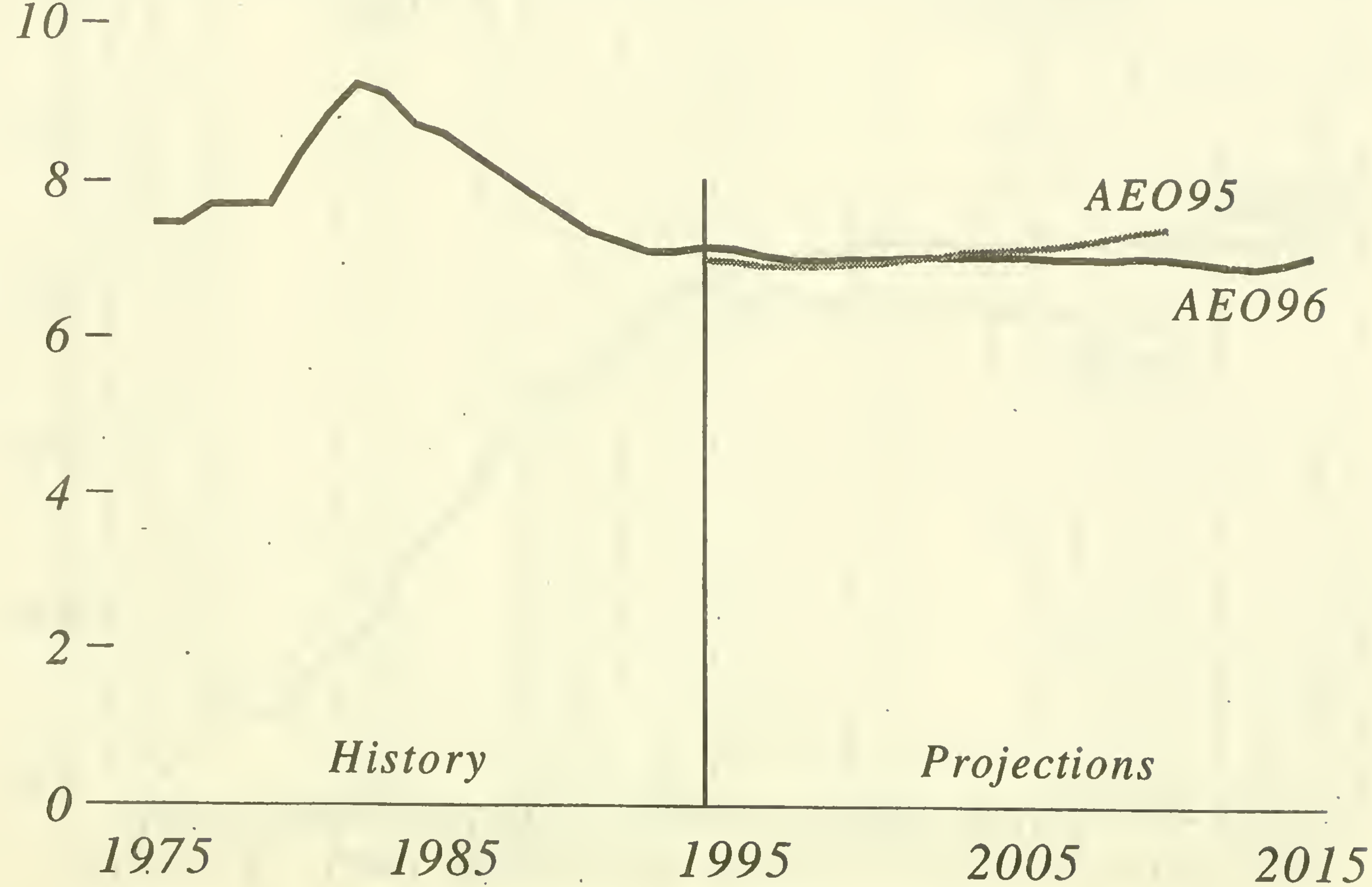


Figure 9. Average Electricity Price Projections, 1975-2015: AEO95 and AEO96 Compared (1994 cents per kilowatthour)



costs for new combustion turbine and combined-cycle generating technologies, and the availability of adequate capacity for current generation needs.

- A yearly 0.2-percent decline in operating and maintenance costs is also expected, as more turbine-based capacity is installed and operated. For a typical 300-megawatt plant, operating and maintenance costs for advanced gas turbines are about half those for conventional coal-fired generators.

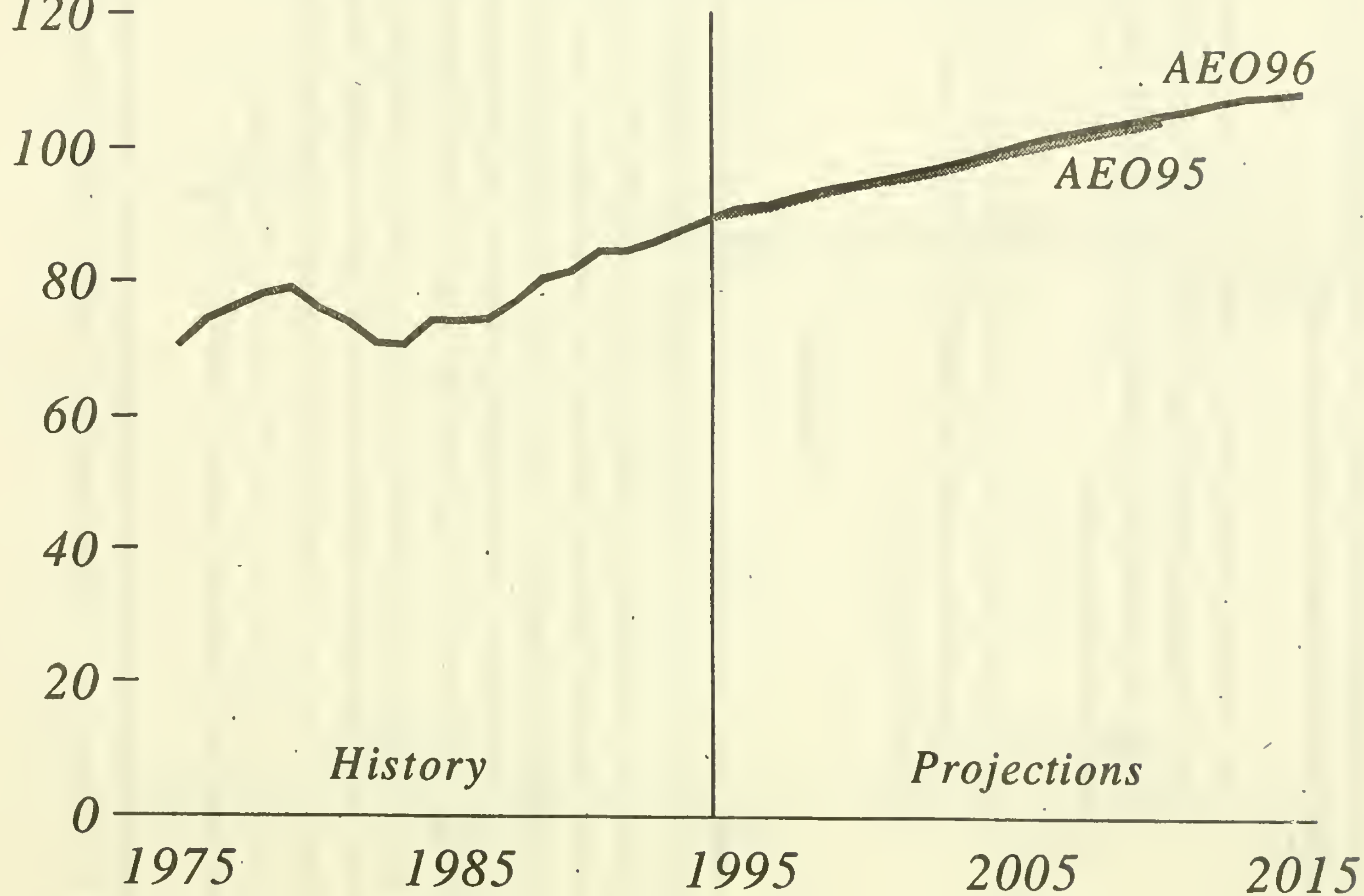
- Weighted average fuel costs to electricity generators are essentially flat in the forecast, as a 0.3 percent decline in coal prices more than offsets the 1.4 percent annual rise in gas prices between 1994 and 2015.

Consumption

Although energy prices in AEO96 are lower than those in AEO95, total consumption in 2010 is expected to be about the same, at 105 quadrillion British thermal units (Btu) (Figure 10). Energy consumption in the residential sector is projected to rise by 3.6 quadrillion Btu or 20 percent between 1994 and 2015, with most of the increase due to heating requirements for new homes, and continued growth in appliance use. Projections for the commercial sector depict growth slowing overall, with shares for all fuels essentially stable over the forecast horizon, for two reasons: 1) Commercial floorspace growth increases by only 1.1 percent a year between 1994 and 2015, compared with an average increase of 1.5 percent a year over the past two decades; and 2) energy consumption per square foot declines by 0.3 percent a year, due to efficiency standards, voluntary government programs aimed at improving efficiency, other technology improvements, and efficiency gains in electricity generation. Primary energy use in the commercial sector is expected to equal about 16 quadrillion Btu in 2015.

Primary energy use in the industrial sector is projected to increase by 18 percent over the forecast, from 34 quads in 1994 to 40 quads by 2015, a modest increase in comparison with

Figure 10. Total Energy Consumption, 1975-2015: AEO95 and AEO96 Compared (quadrillion Btu)



growth in manufacturing output and gross domestic product, as improvements in efficiency continue to drive energy requirements per unit of industrial output down. By 2015, total energy demand for transportation will exceed 30 quadrillion Btu, compared with 23 quadrillion Btu in 1994. Petroleum products continue to dominate energy use in the transportation sector through 2015, but with the emphasis of current environmental and energy legislation on reducing oil use, alternative fuels (such as ethanol) are expected to displace nearly 400,000 barrels of oil equivalent per day by 2015.

Electricity, Fossil Fuel Production, and Renewables

In general, electricity and other domestic energy supply sources are expected to grow sufficiently to meet the increasing demand for energy, with the notable exception of crude oil. Declining reserves and lower-cost foreign supplies will cause domestic crude oil production to continue its long-term decline. However, after 2005, higher prices and improving technology should arrest that decline, with production in 2015 gaining more than half a million barrels per day over the 2005 level. Natural gas and coal, with fewer ties to world markets, will continue to show moderate growth in production. In terms of percentage growth, renewables should show the greatest improvement, but less than in AEO95 because of lower fossil fuel prices in AEO96.

Electricity: Fossil fuels, which in 1994 accounted for 70 percent of electricity generation, are projected to account for 79 percent in 2015 (Figure 11). Much of the increase is in the use of natural gas, which currently fuels 14 percent of total generation but grows to 27 percent by 2015, supplanting nuclear energy as the Nation's second largest electricity source. The outlook assumes that 37 gigawatts of nuclear capacity are assumed to be retired by 2015, with no new nuclear orders on the horizon. The retirements take place under the assumption that, on average, existing nuclear generating units retire at the end of their 40-year license periods.

Oil and Gas Production: Although projected world oil prices in AEO96 are almost $1 a barrel lower in 2010 than they were in AEO95, the projection for domestic crude oil production is

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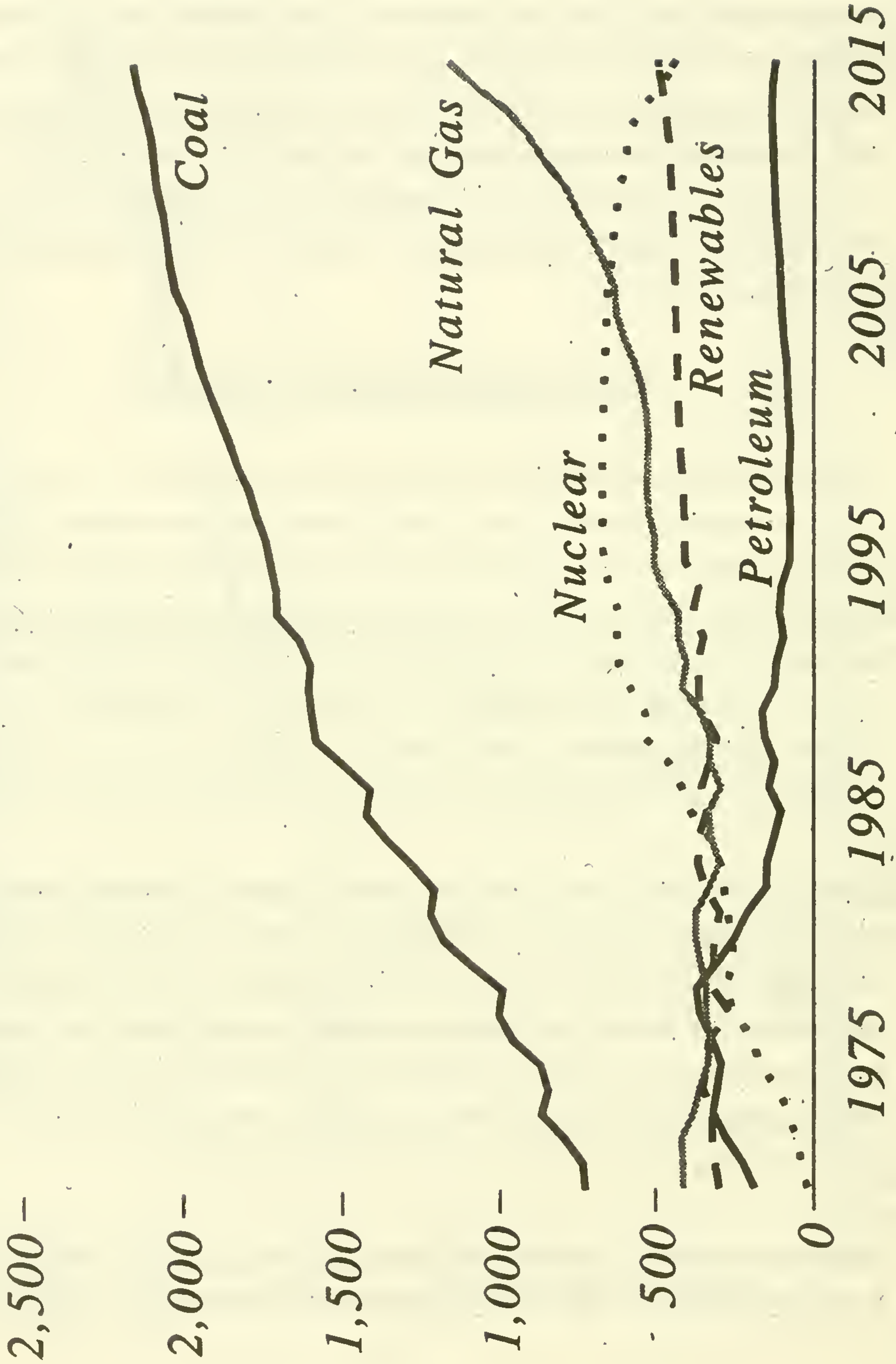
Figure 11. Electricity Generation by Fuel, 1970-2015
(billion kilowatthours)



similar to last year's. Production declines from 6.7 million barrels per day in 1994 to 5.3 million barrels per day in 2005, then rebounds from 2005 to 2015 as a result of technology improvements and rising prices (Figure 12). In 2010, estimated domestic oil production is 5.4 million barrels a day (the same as last year's projection), rising to 5.8 million barrels a day in 2015. Of the sources of domestic production, the output from Alaska is expected to decline the fastest, to about 700,000 barrels per day by 2015, less than half of current levels. Overall, U.S. oil production declines over the projection period, and the share of petroleum consumption met by net imports reaches 57 percent (measured in barrels per day) in 2005 and remains at about that level through 2015, compared with 45 percent in 1994. As a share of U.S. oil consumption, net imports range from 45 percent in the high world oil price case to 68 percent in the low world oil price case (Figure 13).

Driven primarily by the growth in consumption, natural gas production increases at an average annual rate of 1.3 percent between 1994 and 2015. By 2015, total dry gas production is almost 25 trillion cubic feet (tcf), compared to less than 19 tcf in 1994 (Figure 14). In terms of the components of supply, the largest contributor to the growth is non-associated conventional production in the lower-48 states; however, a significant increase in offshore production is also seen.

Coal Production: In 2015, production is forecast to reach 1,240 million tons (Figure 15). Most of the growth in production, historically and in the forecast, stems from the growing market share of western mines. Production in the West is projected to reach 623 million tons in 2015, as the demand for low-sulfur coal to meet the requirements of the Clean Air Act Amendments of 1990 is met largely by low-cost surface-mined coal from Wyoming's Powder River Basin.

Renewables: With lower prices projected for fossil fuels, renewable energy production, including hydropower, is 0.8 quadrillion Btu lower in AEO96 in 2010 than it was in AEO95 (Figure 16). Lower prices, particularly for natural gas, delay the penetration of some renewable technologies. In the AEO96 forecast, renewable energy production is 7.8 quadrillion Btu in 2010,

Figure 12. U.S. Crude Oil Production by Source, 1970-2015
(million barrels per day)

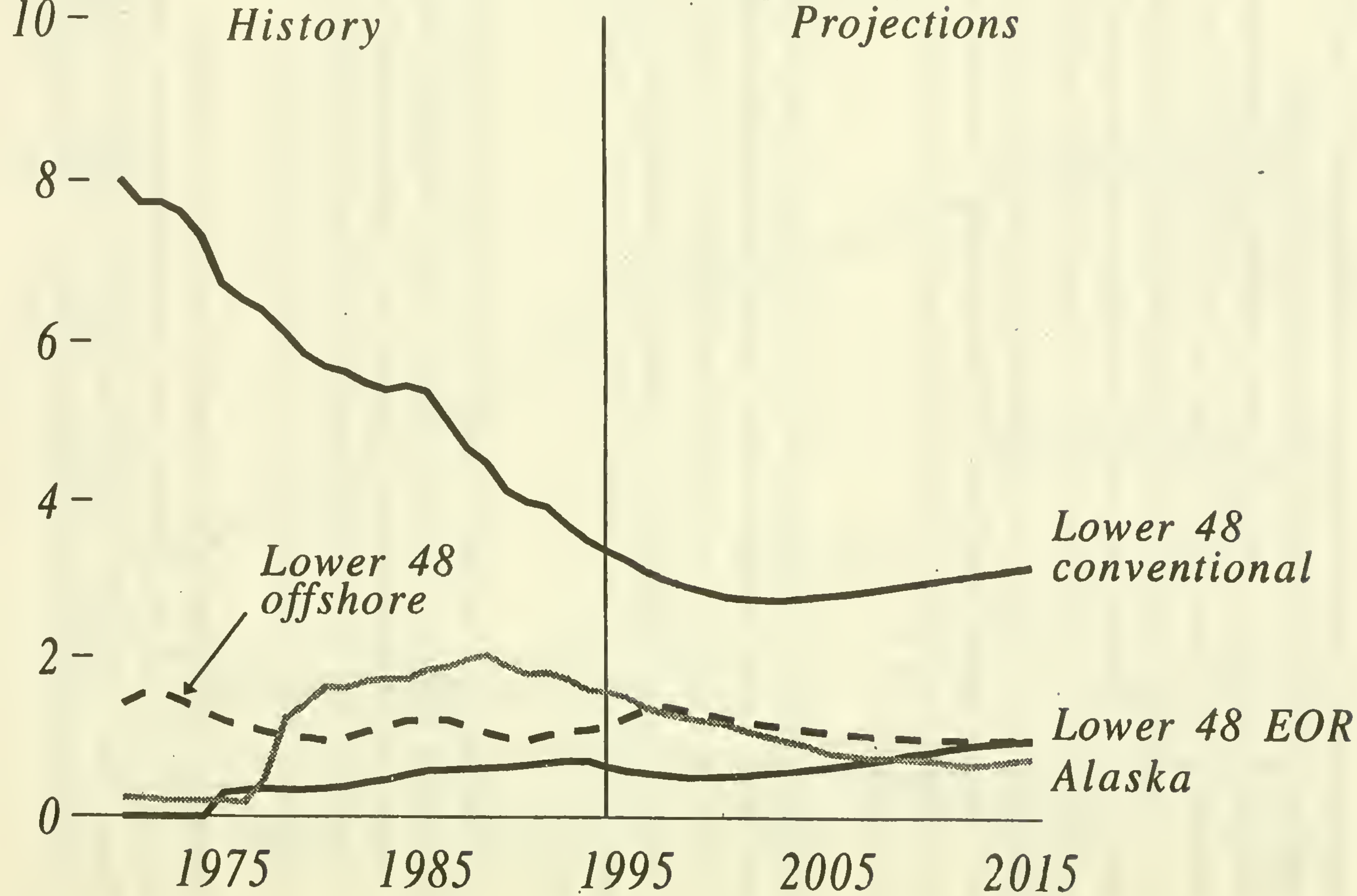


Figure 13. United States Net Oil Imports as a Percent of United States Oil Consumption in Three Cases (percent)

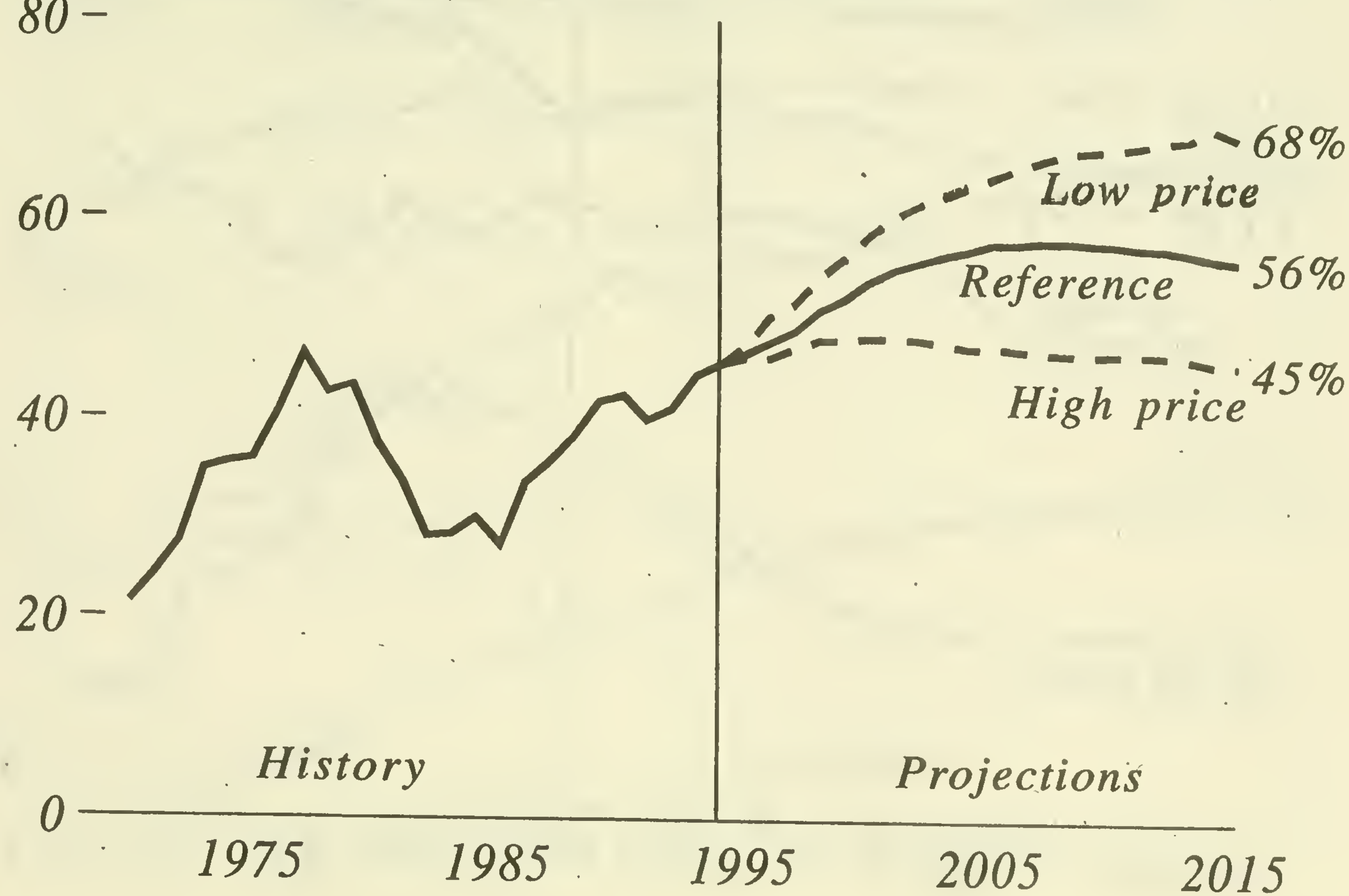


Figure 14. U.S. Natural Gas Production by Source, 1970-2015 (trillion cubic feet)

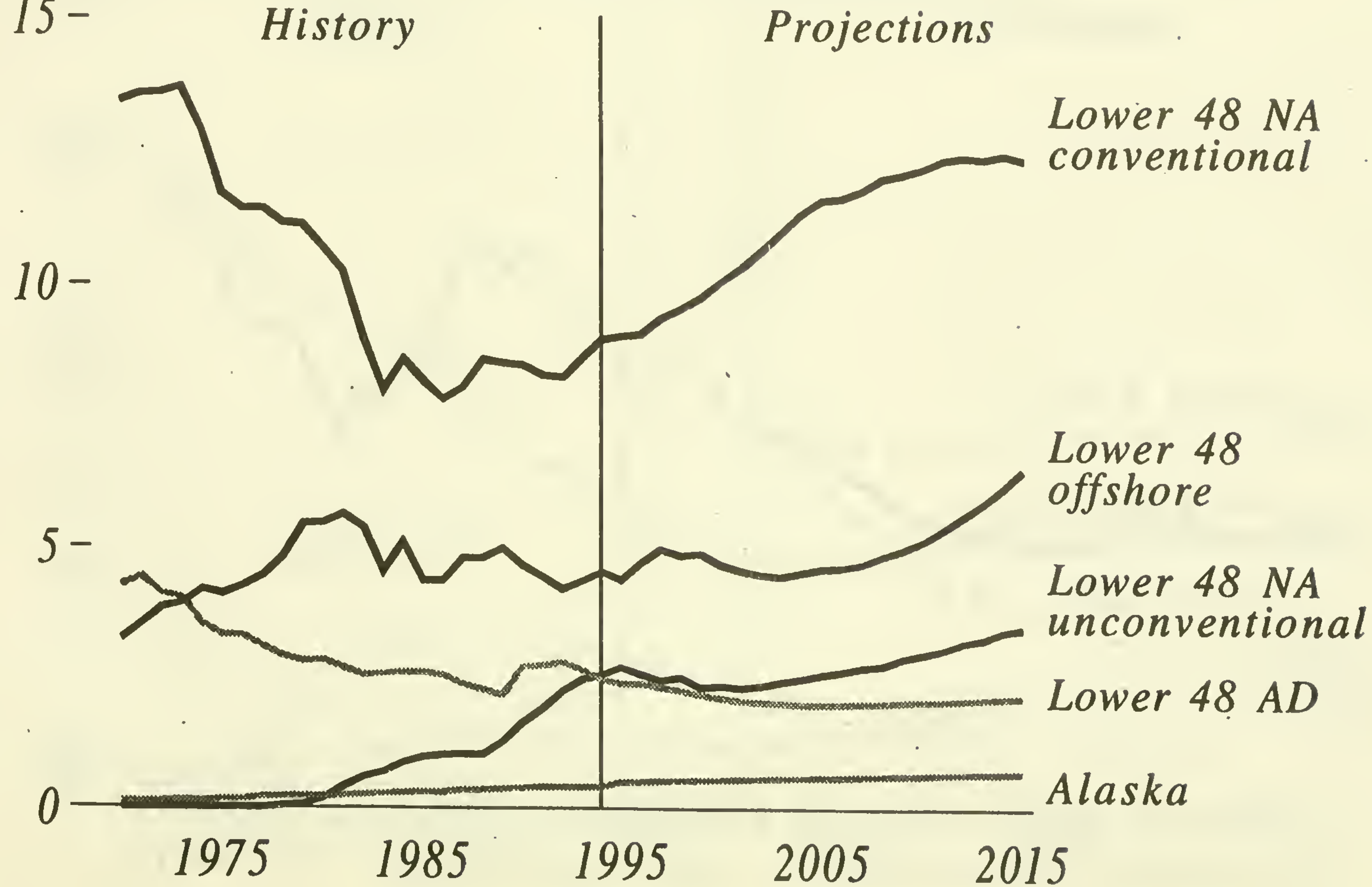


Figure 15. Coal Production by Region, 1970-2015
(million short tons)

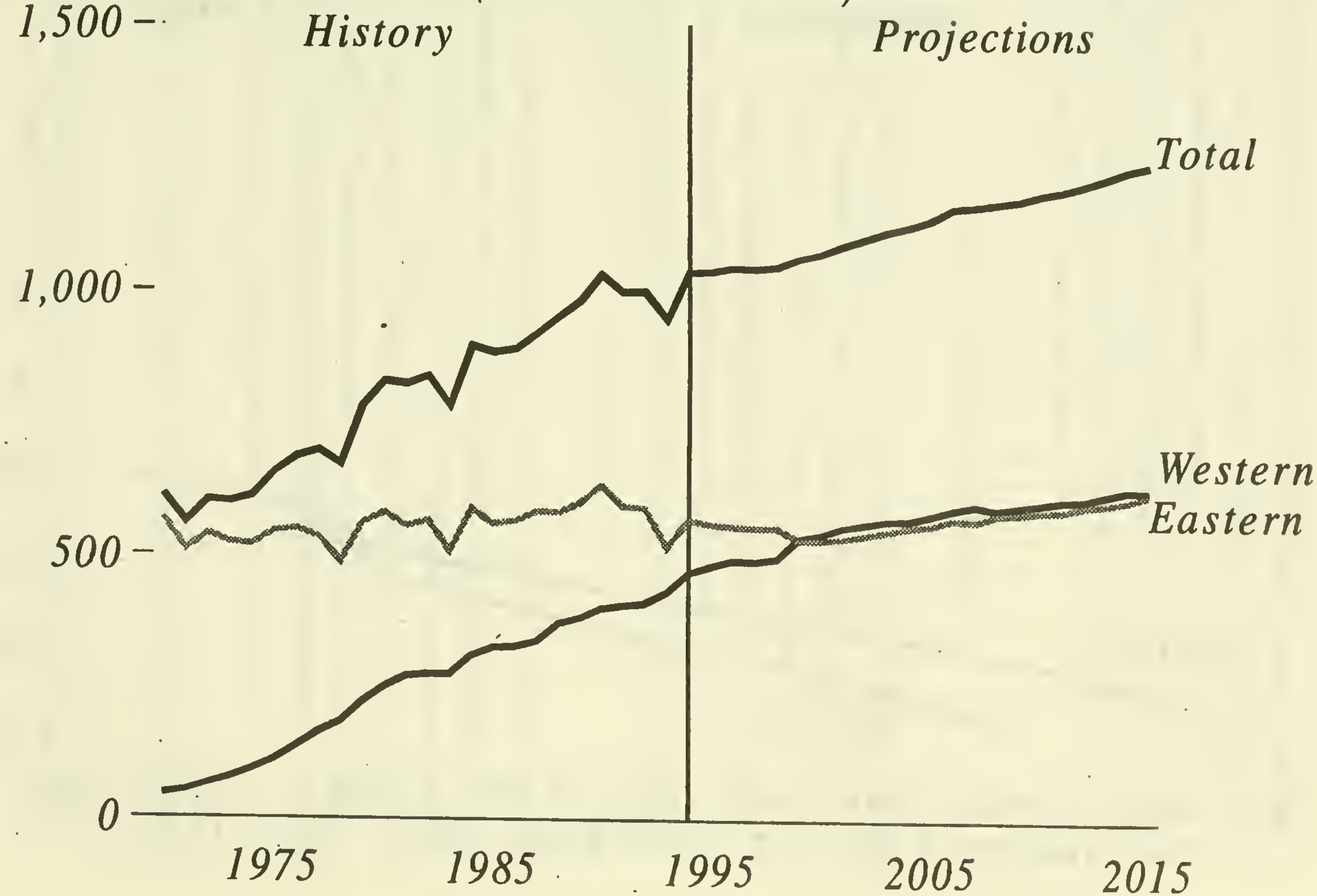
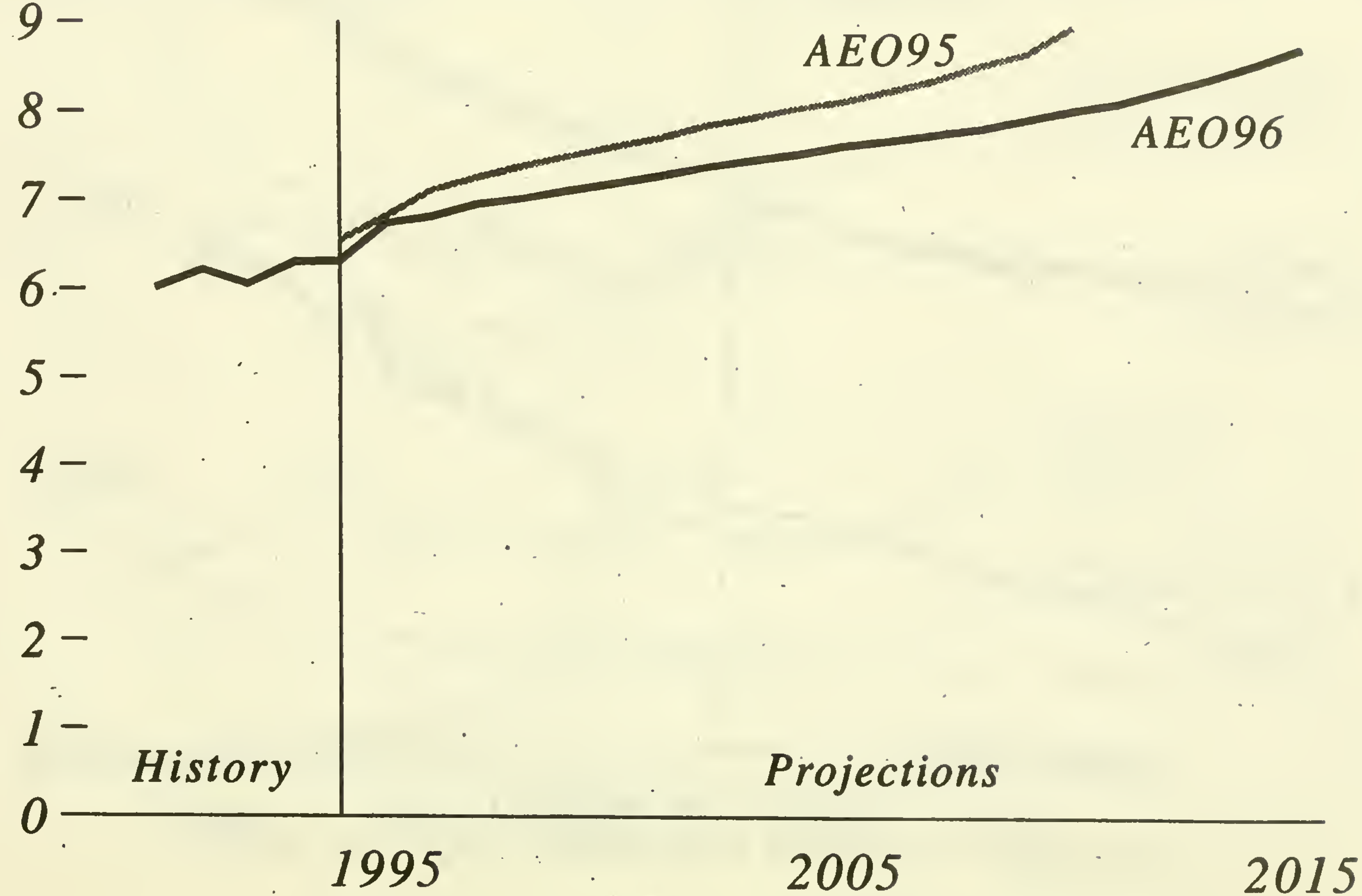


Figure 16. Total Renewable Energy Consumption, 1990-2015: AEO95 and AEO96 Compared (quadrillion Btu)



rising to 8.5 quadrillion Btu in 2015. The bulk of renewables is used for electricity generation, with wind, solar, and municipal solid waste showing the largest percentage increases over the forecast horizon. Wind in particular, because of increasing efficiency and declining costs of wind turbines, increases its contribution to electricity generation at an annual rate of 11 percent from 1994 to 2015. Its outlook is less robust than in AEO95, however, as lower natural gas prices negatively impact the penetration of wind power.

Changes from Previous Years' Outlooks

The AEO (and the modeling and analysis tools used to produce it) is a document that evolves and responds to changing conditions and improved information in world and domestic energy markets. When the first AEO was published in May of 1983[1], the energy community was still reeling from the effects of two major oil price shocks, both of which had occurred within the previous decade. Not surprisingly, many of the themes of that first AEO dealt with the reaction of energy markets to price and supply uncertainty, although even then the outlines of OPEC's demise as a monolithic price-setter were beginning to be seen.

In contrast, more recent AEOs have concentrated on topics more relevant to today's situation, including the increasing pace of technological improvements in both supply and demand, the emergence of renewables as a viable supply alternative, and efficiency improvements leading to lower projected growth rates (or even declines) for both demand and prices. EIA has never considered the AEO and its associated modeling constructs to be static or "finished" in any sense. In order to be a relevant policy tool for government and the public, EIA has sought out and acted upon constructive comments and criticisms of its assumptions and methodology.

As an example of how the forecasts have changed over recent AEOs, Table 1 presents changes in

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[1]Prior to 1983, EIA published its mid-term forecasts in other documents, particularly the *Annual Report to Congress*.

prices, demand, and supply for key variables from the last five forecasts:

Table 1. EIA Forecasts of Key U.S. Energy Variables, 2010

Forecast	AEO92	AEO93	AEO94	AEO95	AEO96
Imported Crude Oil Price (1994 dollars per barrel)	37.17	31.42	29.37	24.63	23.70
Lower 48 Gas Wellhead Price (1994 dollars per thousand cubic feet)	5.18	3.95	3.62	3.46	2.15
Coal Minemouth Prices (1994 dollars per short ton)	35.20	33.21	32.20	23.25	17.43
Total Energy Consumption (quadrillion Btu)	106.1	106.7	105.2	103.9	104.7
Oil Production (million barrels per day)	5.51	5.66	5.10	5.39	5.44
Natural Gas Production (trillion cubic feet)	19.30	20.07	20.19	20.88	22.83
Coal Production (million short tons)	1445	1362	1223	1137	1184

As the table shows, while there has been a downward trend in the 2010 projections for fossil fuel prices, the record on supply and demand is decidedly mixed. Total energy consumption projections for 2010 have been very stable, with current projections only slightly lower than those from four years ago. Oil production has varied, with the view of 2010 today only slightly lower than in AEO92, but somewhat higher than the more pessimistic forecasts made two years ago. Natural gas production forecasts have risen steadily; however, projections for coal production declined over the four Outlooks from AEO92 through AEO95, then rose in the most recent release. Projections of natural gas production have risen as demand for gas, particularly in the electricity sector, has been seen as an economic alternative to other sources of energy.

Similarly, as gas has been projected to displace coal in electricity generation, and as electricity demand projections have declined, the forecasts for coal production have also declined, until AEO96. The main reason for the reversal this year is a shift in favor of Western coal production--which on average has a lower energy content per ton than Eastern coal--due to the low-sulfur coal requirements of the Clean Air Act Amendments of 1990.

Price forecasts have tended to show relatively strong patterns of decline. A major reason, among others, is that the pace of technological improvement and new discoveries has been under-estimated in past AEOs. Improved technology in oil, gas, and coal production has enabled those industries to produce more domestic energy at lower prices than was initially projected. As examples of the factors that have affected our 2010 forecasts in AEO96 compared to AEO95, consider the cases of natural gas and coal:

Natural gas: For natural gas, the factors include the incorporation of the recent reassessment by the U.S. Geological Survey (USGS) of ultimate recovery from known fields (primarily inferred reserves), reduced drilling costs, and a revised representation of the domestic oil and natural gas supply industry.

In February 1995, the USGS released its latest assessment of U.S. oil and gas resources, almost tripling the conventional onshore inferred reserves estimate from the 1989 USGS assessment. Because EIA had previously increased the inferred reserve estimates to levels higher than the 1989 USGS assessment, incorporating the new USGS estimate roughly doubled the inferred reserve base for onshore nonassociated gas, from 114 trillion cubic feet in AEO95 to 232 trillion cubic feet in AEO96.

Drilling costs for natural gas were reduced to reflect current conditions and refined to better portray the economics of a representative project. The rates of technological progress applied to drilling and production costs were also reestimated, yielding lower costs throughout the forecast period than previous estimates. The greatest rates of technological change are expected to occur in offshore regions, where new technologies are continuing to be introduced in the Gulf of Mexico, and many large gas prospects are expected to be found.

Finally, a revised representation of the oil and gas supply industry was used in producing the AEO96 forecast. Historically, most oil and gas drilling was motivated by the search for oil; gas was usually viewed as a byproduct of oil-directed efforts. However, the increasingly prevalent view of gas as an abundant energy resource, coupled with its environmental advantage, has tended to place natural gas on a more equal footing with oil, so that levels of drilling activity are now determined by the economics of each fuel separately. For AEO95, expenditures for oil and gas combined were estimated at an aggregate level and then disaggregated on the basis of econometric estimates that simulated their interfuel and regional allocation according to relative profitability. For AEO96, expenditures were estimated at regional levels separately for oil and gas.

Coal: In the area of coal minemouth prices, AEO96 assumes flat wage rates for miners throughout the forecast, compared with an annual increase of about 1 percent in AEO95. Both recent history and the anticipated shift of production to more productive western mines precipitated the more conservative wage assumption. AEO96 also assumes lower increases in transportation costs for coal originating in Western States, an assumption that increases the amount of production from those States, which have lower minemouth coal prices. Finally, in AEO95, new mines were constructed only when existing production capacity was fully utilized. In AEO96, new mine construction is triggered at lower utilization levels. This change was made to reflect the industry practice of developing reserve capacity that would be needed if long-term contract options for higher tonnages were exercised.

Comparisons with Other Forecasts: As a further example of changes in the outlooks, we have examined changes in projections for world oil prices and wellhead natural gas in the year 2010, both for the AEO and for other forecasters. For world oil prices, forecasts from Data Resources, Inc. (DRI) and WEFA, two private forecasting firms, and the Gas Research Institute (GRI), were compared to EIA's forecasts. For natural gas prices, those forecasts and additional ones from the American Gas Association (AGA) were also included.

The most salient feature of projections of world oil prices (Figure 17) has been the steady decline in the expected price in year 2010. From a range of $35 to $43 per barrel for forecasts released in 1990 to $16 to $25 for the most recently released forecasts, the projections of world oil prices by all forecasters have shown a steady progression downward with each successive forecast. Typically, EIA has been near or on the high side of the range of the four forecasts compared. However, EIA is also the first to publish in a given year and so tends to lag the other forecasters in the drop in projected prices.

A principal reason for the lowered expectations has been the stability and even a slight increase in the current and expected future production from non-OPEC nations, compared to our previous assessments for declining non-OPEC production. Improvements in technology have extended the life of maturing fields and reduced development and production costs in new areas. Profitability for oil investment has been increased through government policies affecting taxes and royalties and by profit sharing agreements and financial restructuring within the industry. The Middle East is still expected to provide the major portion of oil required to meet increasing demand into the next decade, but its share of total supply is expected to increase more slowly than projections several years ago.

EIA's natural gas price projections for 2010 declined by more than two-thirds from the 1990 forecast through the 1996 forecast. Over these seven forecasts, the 2010 reference case projections for natural gas wellhead prices were generally higher than the two commercial forecasting services, and were always higher than the industry forecasts (Figure 18). The closest forecast to EIA's was that of Data Resources, Inc. In some cases, significant year-to-year drops occurred in forecasts of the 2010 price, because of reassessment of methodology, new data, a changing market, or other factors. EIA's natural gas wellhead price forecasts for 2010, for example, showed a significant decline in the 1993 forecast, because of a reassessment of the

Figure 17. World Oil Price Projections for 2010 From Four Sources, 1989-1996 (1994 dollars per barrel)

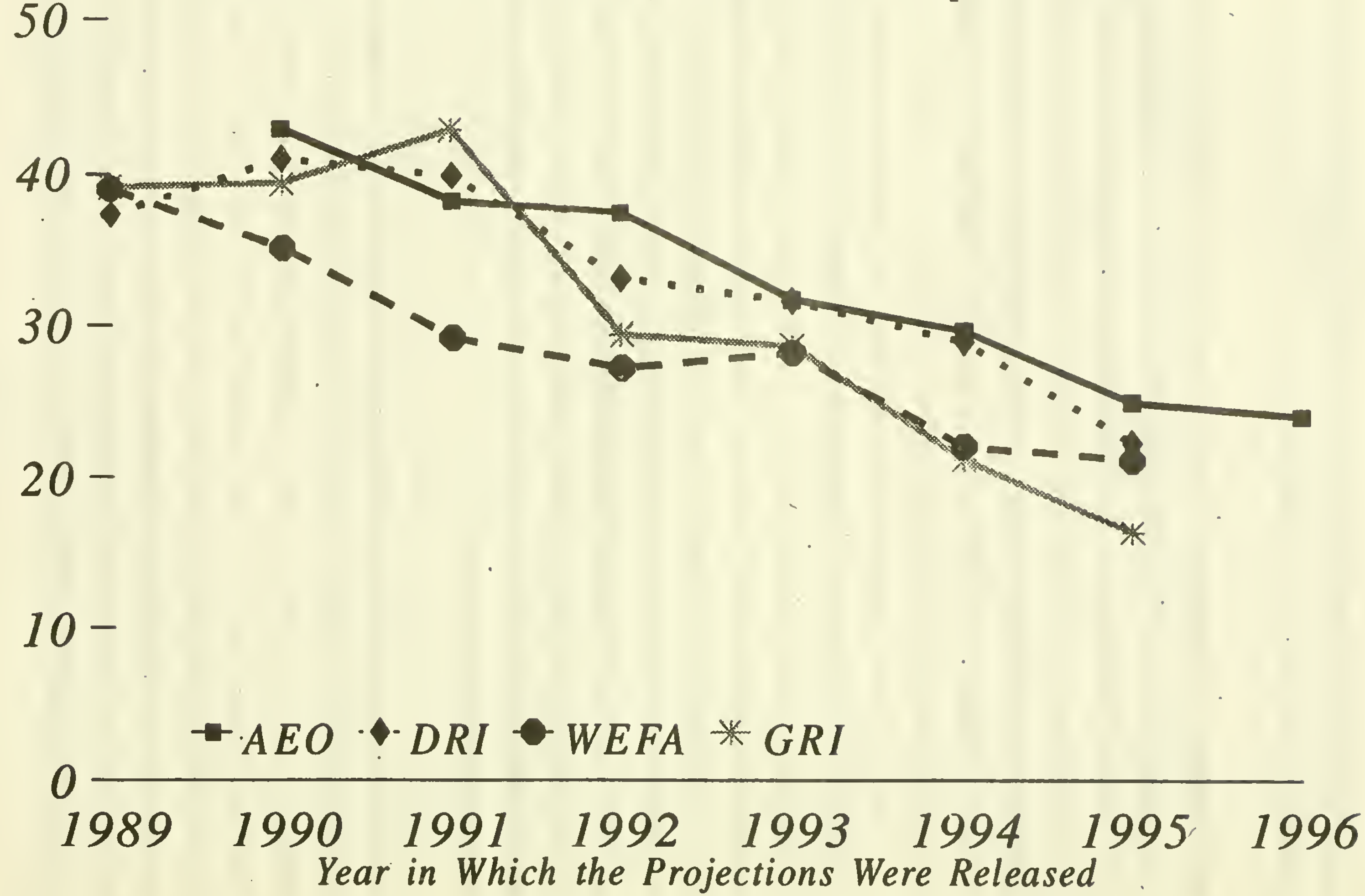
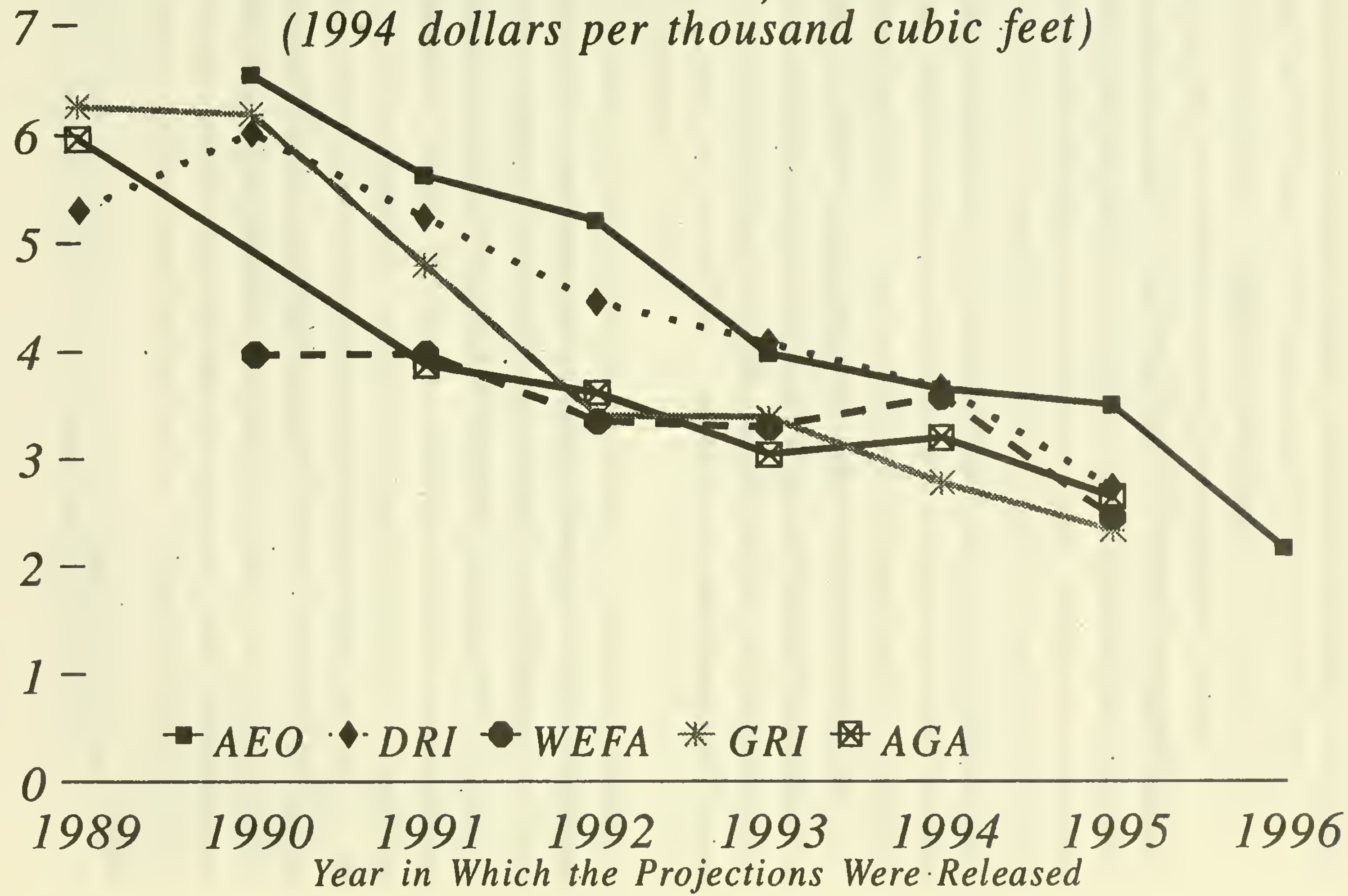


Figure 18. Natural Gas Wellhead Price Projections for 2010 From Five Sources, 1989-1996 (1994 dollars per thousand cubic feet)



availability of Canadian imports and the costs of shipping Alaskan gas to the Lower 48 States.

The Accuracy of the AEO

On an ongoing basis, EIA monitors its year-to-year performance, and makes appropriate changes in assumptions and methodology in order to assure that its representation of energy markets is relevant and current as possible. Clearly, an examination of past AEOs would show areas of strengths and weaknesses. The strengths, based on preliminary work on a more complete evaluation of the AEO record, would likely be in the areas of domestic energy consumption and production. The weaknesses would be in the area of prices, especially the world oil price and the wellhead price of domestic natural gas. Both of these variables are extremely volatile, and many of the assumptions made in the early 1980s concerning the strength of OPEC as a cohesive unit, and the pace of the transition of the natural gas industry from highly-regulated to less-regulated, did not prove to be correct. In general, the closer to the year being forecasted, the better the accuracy. This was not, however, always the case.

As a part of its internal audits, EIA has performed two formal analyses of its accuracy for specific models. The first was performed for the Electricity Market Module (EMM) in 1992, and analyzed the results for the four AEO projections from 1985 through 1988 for the years 1985 and 1990 (only the AEO85 was analyzed for 1985). Overall, the EMM projections of utility generating capacity were very close to the actual values for 1985 and 1990. The average forecast error nationally was less than 2 percent for the projection of 1985 summer capability and just over 1 percent for the projections of 1990 summer capability. The average error nationally for utility generation for 1985 was less than 1 percent and the average error for the six forecasts of 1990 is just over 2 percent. However, the forecasts of 1990 electricity prices were consistently overestimated by the EMM. The average error nationally for the four forecasts was 13.0 percent. As might be expected, the EMM forecasts produced larger model errors for longer period forecasts.

The second analysis was performed for the Transportation Energy Demand Model (TEDM) in 1993. In that report, five AEO forecasts for 1990 were compared with the actual data. Overall, the average error for total transportation consumption was 2.9 percent. Errors for specific fuels were 6.1 percent for jet fuel; 3.6 percent for distillate; and 2.1 percent for gasoline, by far the most important fuel in this sector. The fuel prices used by the TEDM had higher average errors, ranging from 10.3 percent for gasoline to 11.7 percent for jet fuel, and were consistently underestimated, except for AEO85.

Finally, a recent analysis[2] of the long-term accuracy of the AEO projections concluded the following:

- In the last twenty years mid-term energy projections have improved dramatically, in part because of the conversion of the energy industry from an industry that is highly-regulated to one that is characterized by more competition. Projections for natural gas production in 1995, for example, have improved from a 23 percent error for a forecast made in 1980, to less than five percent in a 1990 forecast.

- Prices have always been much more difficult to forecast than quantities, and this is likely to continue. Even as late as 1990, forecasts for the world oil price in 1995 were overstated by 40 percent. The corresponding forecast error for petroleum production was less than 4 percent.

- The relative inelasticity of energy supply and demand with respect to prices means that other factors, such as the rate of penetration of new technologies and demographic trends, are more important in the projections of those quantities.

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[2] Cohen, Barry; Peabody, Gerald; Rodekohr, Mark; and Shaw, Susan, "A History of Mid-Term Energy Projections: A Review of the Annual Energy Outlook Projections," February 1995, unpublished manuscript.

Disruption Analysis

Although EIA has not assumed that a disruption will occur over the forecast horizon of its mid-term outlook, EIA monitors current developments in oil markets to facilitate its short-term forecasts, and to provide contingency analysis in the event of a supply disruption. EIA has also performed analysis of potential disruptions that could occur in 2000. The following summarizes our most recent evaluation of current supply issues in the Middle East, and also of the impacts of a supply disruption in 2000.

Recent Trends: Since the 1950's, there have been 13 disruptions of Middle East oil supply (Table 2). Major disruptions (defined as an initial shortfall of at least 2 million barrels per day) have occurred six times since 1956. The largest disruption during this period in gross terms was associated with Iraq's invasion of Kuwait in August 1990, which led to an initial shortfall of 4.6 million barrels per day. Within 2 months of the invasion, world oil prices reached above $35 (nominal dollars) per barrel (Figure 19), more than double their pre-invasion levels. But by October, prices peaked and began to fall again, as the U.S. troop buildup brought a measure of psychological stability to world oil markets, and as surge production from other oil producers offset the initial loss. The greatest impact of the loss in production was not felt until after the first month, since oil already in transit continued to reach markets (Figure 20). Most surge production came from Saudi Arabia, which had (and still has) most of the world's excess production capacity. By November, world crude oil trade had returned to a level higher than its pre-invasion level.

Most of the world's measured excess capacity to produce crude oil is located in the OPEC nations (Figure 21). In 1995, OPEC (outside of Iraq) had an estimated 3.2 million barrels per day of excess production capacity (more than 90 percent of the estimated 3.5 million barrels per day worldwide). Most of the excess is in the Middle East. Saudi Arabia and Kuwait alone account for almost two-thirds of the world's excess capacity. Today, OPEC is producing at more than 90 percent of capacity (assuming sanctions on Iraq continue and its capacity is not counted),

Table 2. Oil Supply Disruptions, 1951-1990

When Did the Net Disruption Occur?	How Long Did the Disruption Last? (In Months)	How Big Was the Initial Gross Supply Shortfall? (Million B/D)	What Caused the Disruption?
March 1951-October 1954	44	0.7	Iranian oilfields nationalized May 1, following months of unrest and strikes in Abadan area.
November 1956-March 1957	4	2.0	Suez War
December 1966-March 1967	3	0.7	Syrian Transit Fee Dispute
June-August 1967	2	2.0	Six Day War
May 1970-January 1971	9	1.3	Libyan price controversy; damage to Tapline
April-August 1971	5	0.6	Algerian-French nationalization struggle
March-May 1973	2	0.5	Unrest in Lebanon; damage to transit facilities
October 1973-March 1974	6	2.6	October Arab-Israeli War; Arab oil embargo
April -May 1976	2	0.3	Civil war in Lebanon; disruption to Iraqi exports through Lebanon
May 1977	1	0.7	Damage to Saudi oil field
November 1978-April 1979	6	3.5	Iranian revolution
October-December 1980	3	3.3	Outbreak of Iran-Iraq War
August-October 1990	3	4.6	Iraqi invasion of Kuwait

Figure 19. World Oil Prices During the Iraqi Invasion of Kuwait (nominal dollars per barrel)

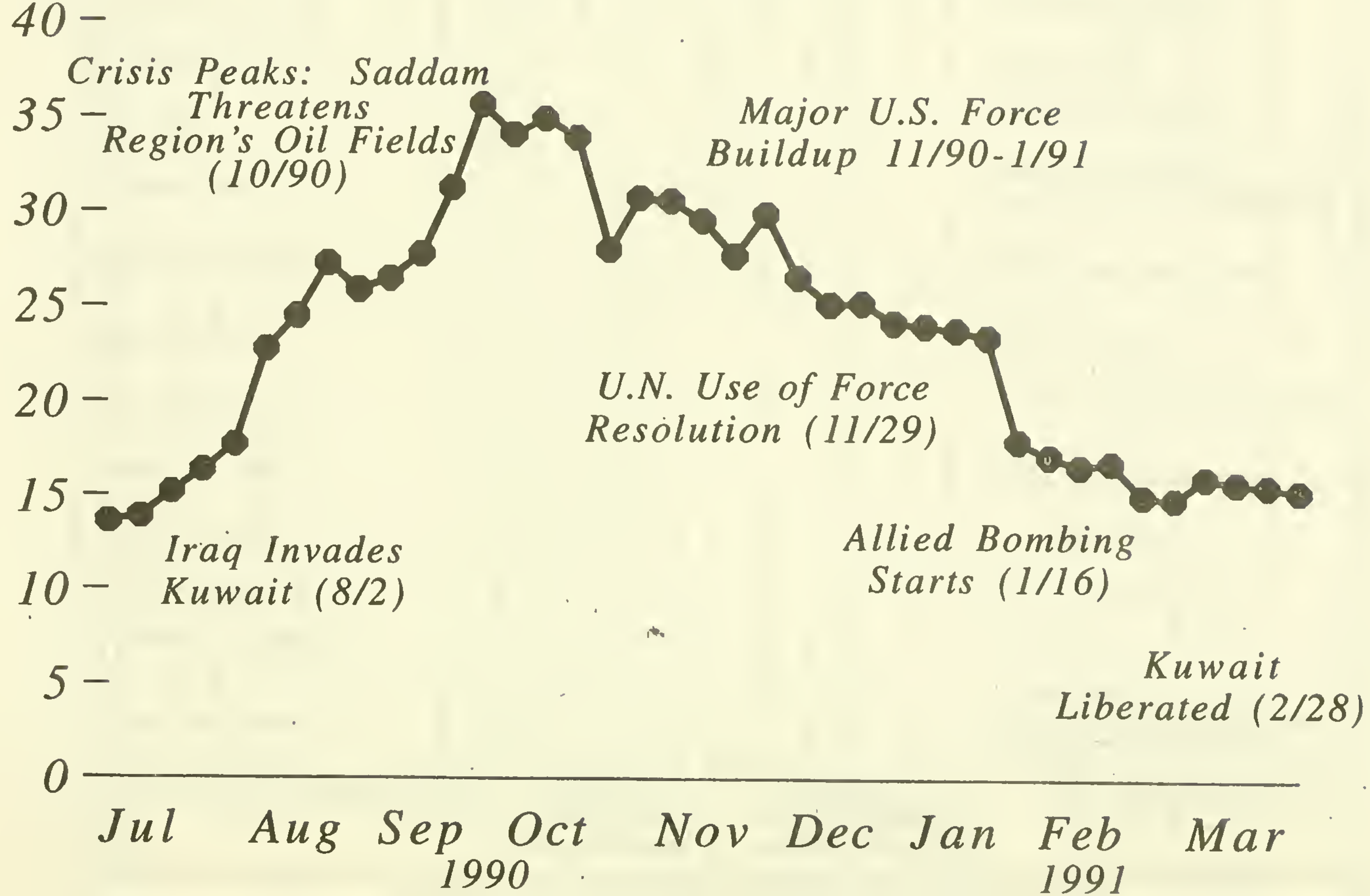


Figure 20. Changes in World Oil Trade During the Iraqi Invasion of Kuwait (million barrels per day)

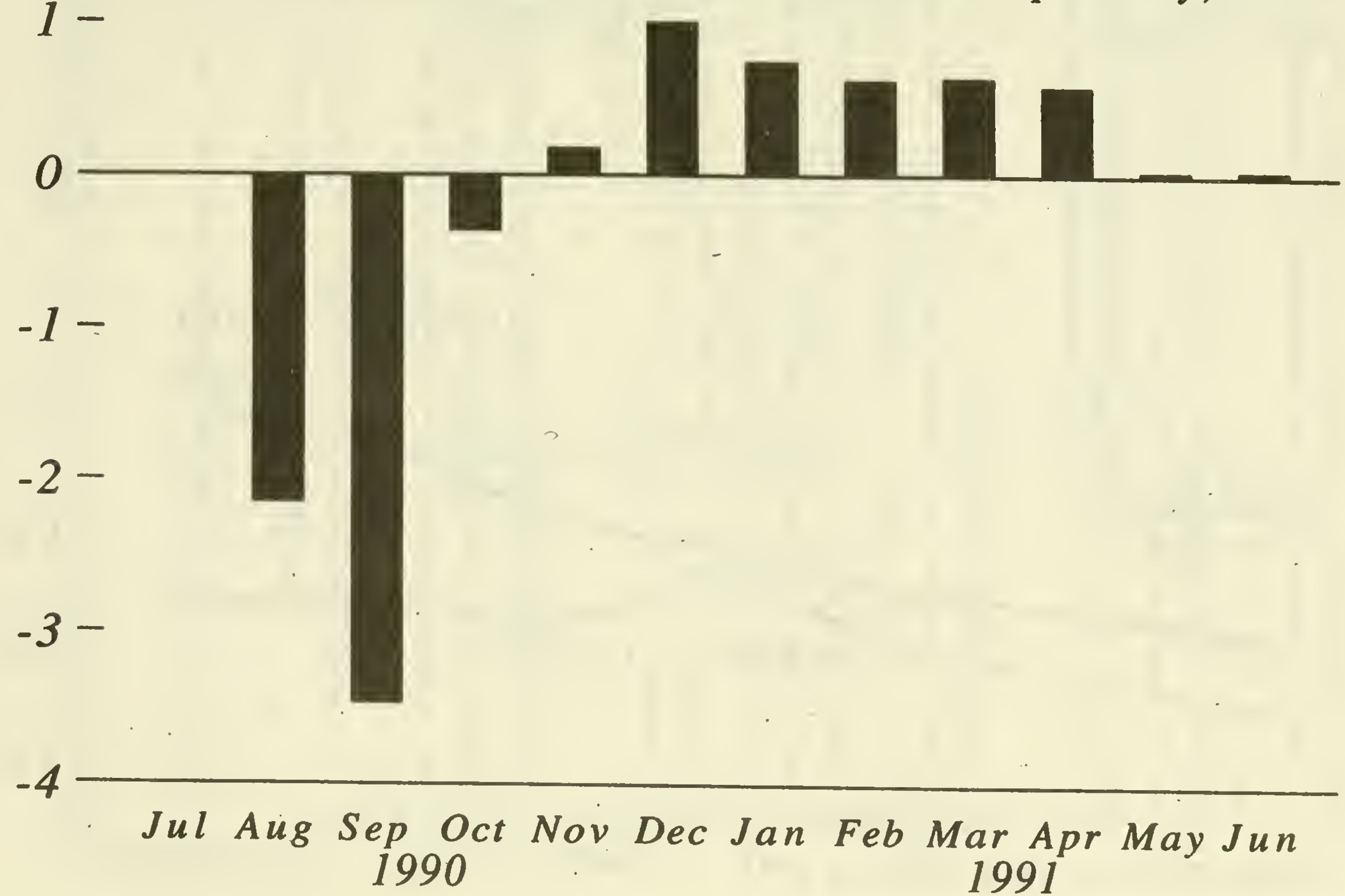
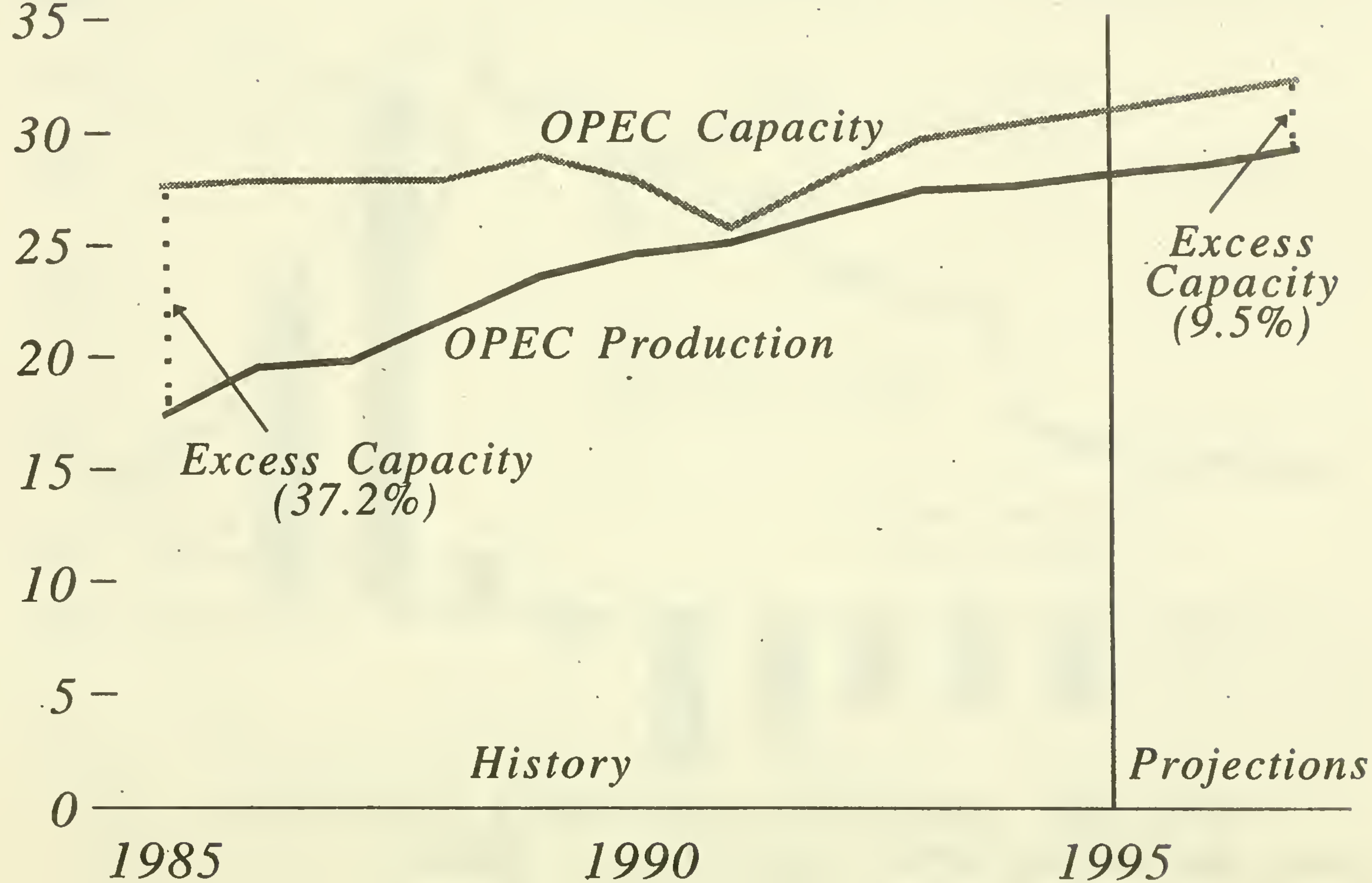


Figure 21. OPEC Capacity and Crude Oil Production, 1985-1997 (million barrels per day)



compared with only 63 percent in 1985. Thus, the cushion to increase production in the event of another supply disruption may be significantly smaller than it was as recently as 1989.

World oil market disruptions have traditionally hurt economic growth. High world oil prices in 1990-91 corresponded to a period of declining GDP in the United States (Figure 22). In the past 25 years, there were 3 periods of negative economic growth in the U.S.--each preceded by a major increase in world oil prices due to a disruption.

The real cost of oil imports into the U.S. is now less than half the value during the Iranian Revolution of 1979-80. While real GDP has continued to grow, the oil import bill in real terms is roughly the same today as it was in 1986 (Figure 23). The main reason for the stability has been the decline of crude oil prices. Based on the AEO96, future trends are expected to see a return to higher levels of oil import costs, reaching annual costs similar to those of the early 1980s by 2015. However, while high prices were the main reason for the high import bills of the 1980s, the main reason for the expected increase through 2015 is higher levels of petroleum imports, with the U.S. importing almost 12 million barrels per day by 2015, compared to only 8 million barrels per day in 1994.

The Impact of an Oil Supply Disruption in 2000: [3] This section outlines possible reactions to several hypothetical disruptions. While it is not possible to predict the timing, size, and duration of a disruption, these assumptions are necessary to develop a meaningful disruption scenario.

The analysis of the impacts of an oil supply disruption is based on several alternative assumptions about the magnitude, timing, and response to the disruption:

o Two different levels of supply disruptions in the Persian Gulf - 4 and 6 million barrels per

[3] This analysis is an updated version of that appearing in the International Energy Outlook 1994, DOE/EIA-0484(94), Washington, D.C., July 1994.

Figure 22. Changes in U.S. Gross Domestic Product (percent) and World Oil Prices (nominal dollars per barrel), 1989-1991

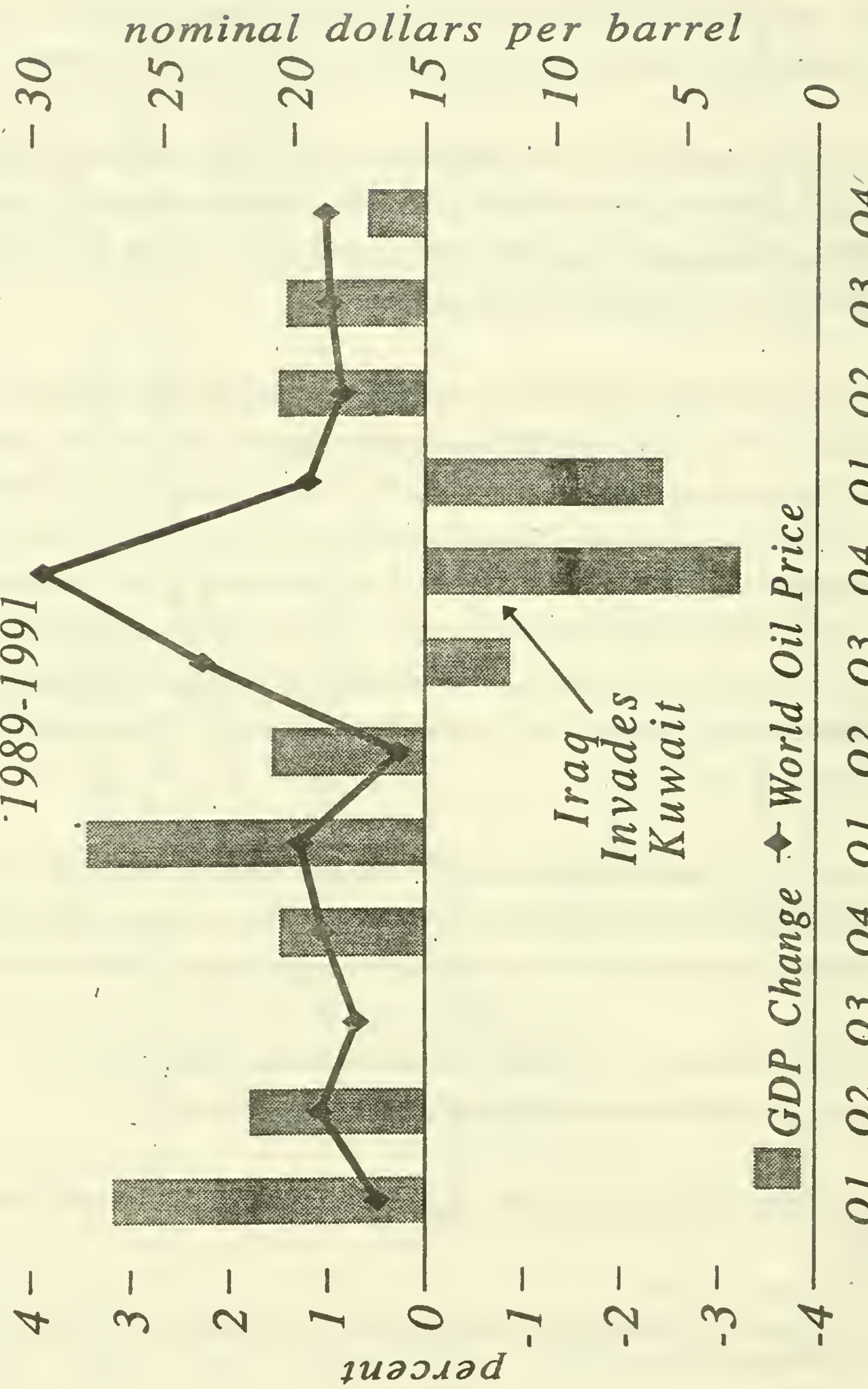
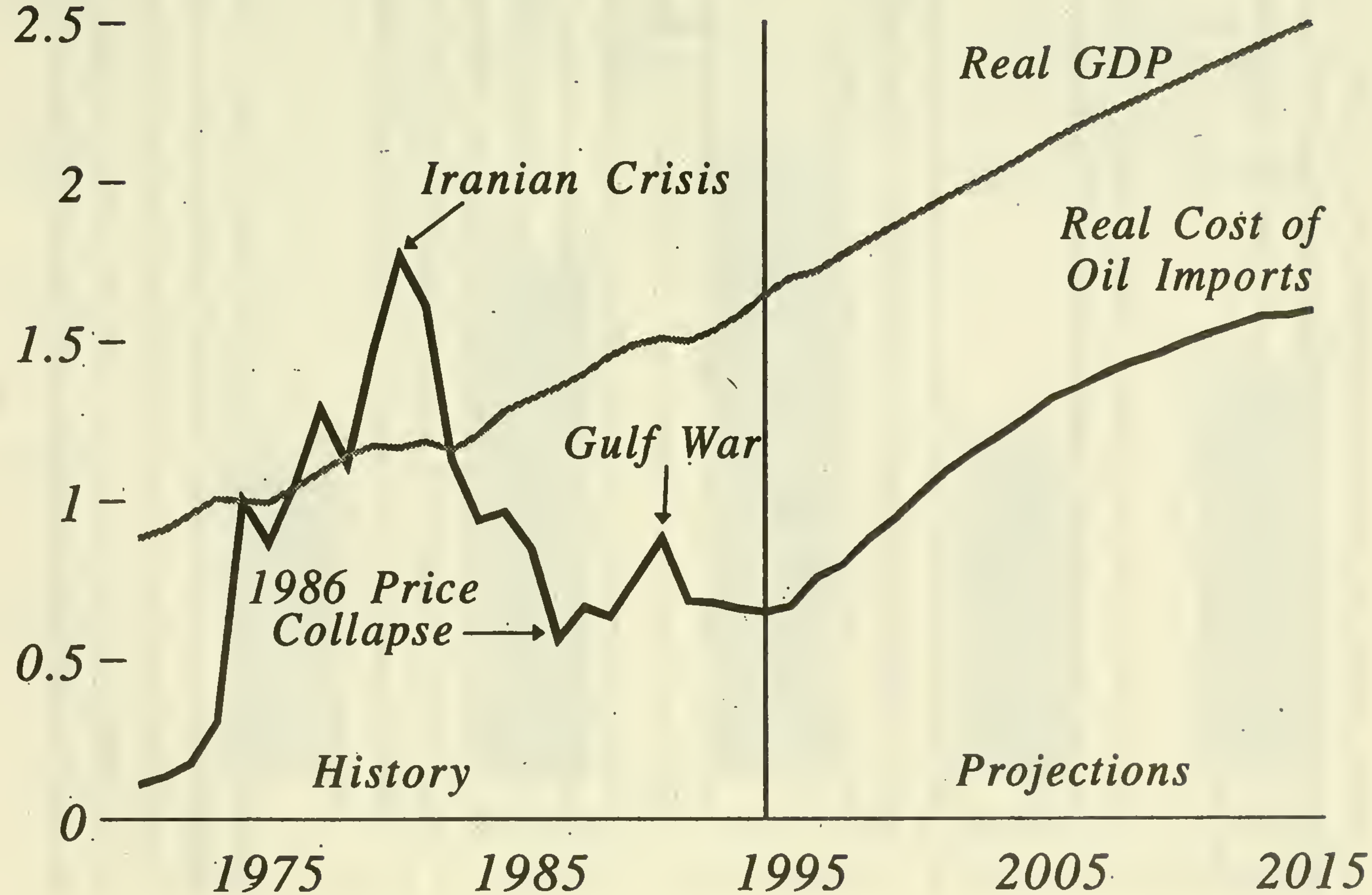


Figure 23. Changes in Real Oil Import Costs and Real U.S. Gross Domestic Product, 1970-2015 (index, 1974 = 1.0)



day (MMBD) - were evaluated, with the disruption assumed to take place in 2000. The 4-MMBD loss of supplies is comparable to the historical experience during the 1990 Persian Gulf War. The use of the year 2000 is arbitrary. Over the past 20 years, a major supply disruption has occurred every 7 to 10 years.

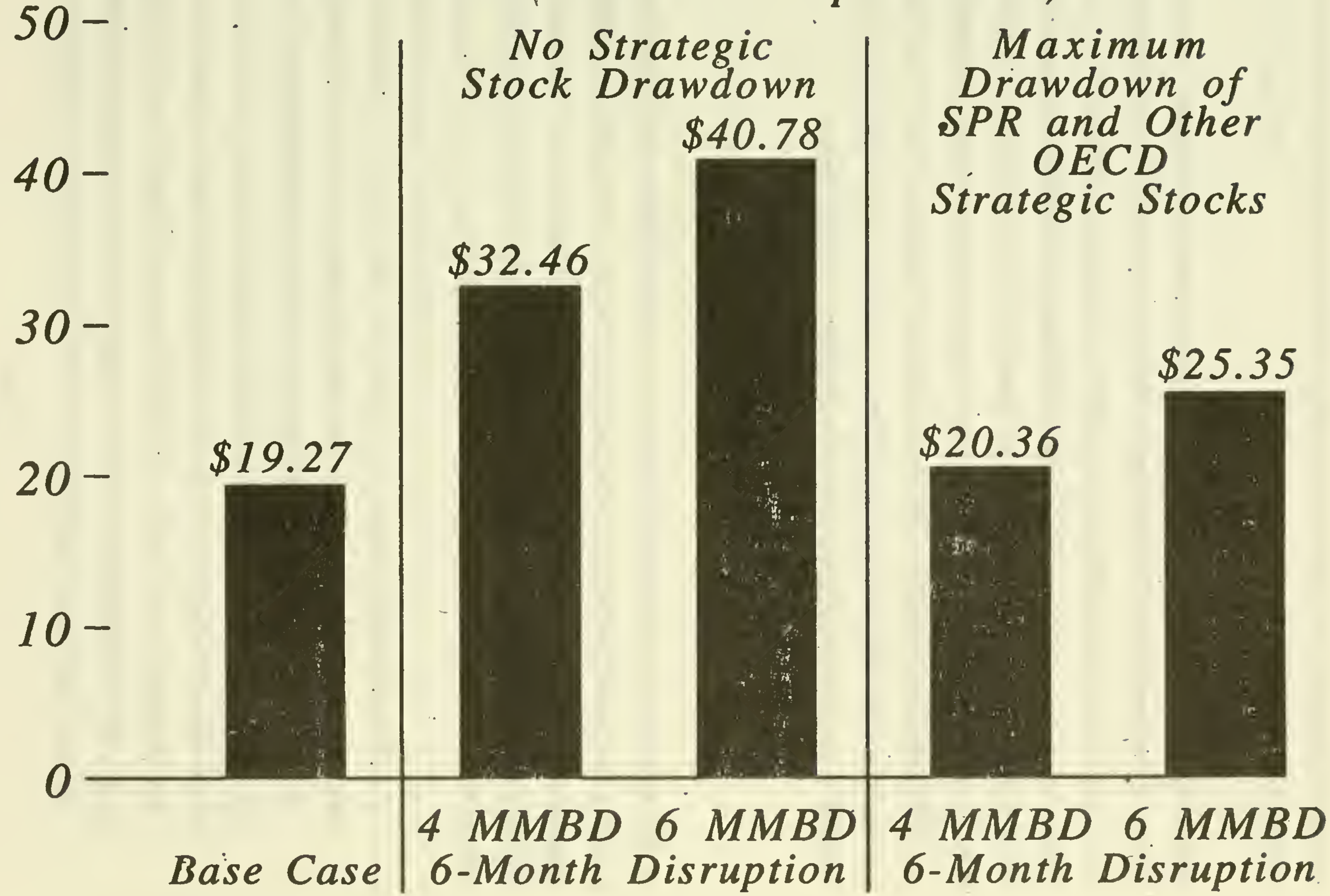
- o The disruptions are assumed to last 6 months. While the duration of supply disruptions can vary, these assumptions are consistent with a major supply disruption caused by some political event that is not easily resolved.

- o Prices are assumed to return to Base Case levels within a year after the disruption has ended, reflecting the fact that markets do not instantly adjust to a new production environment. Tanker sailing times and stock rebuilding could all contribute to the delay in returning to Base Case levels.

- o For each level of supply disruption, two cases are considered involving the use of strategic stocks. In one case, it is assumed that no strategic stocks are used. In the second, it is assumed that the U.S. Strategic Petroleum Reserve (SPR) is drawn down by the maximum amount possible during the disruption, but not exceeding the net disruption. The maximum drawdown rates assumed in this analysis are 3.1 MMBD in the first quarter and 1.4 MMBD in the second quarter. For purposes of this analysis, it is assumed that the strategic stocks in Japan and Germany are also drawn down. These two contrasting cases illustrate the potential impact of using the strategic stocks during a disruption.

The impacts of the various disruptions on annual oil prices are shown in Figure 24. The 4-MMBD disruption has a price rise of $13.19 per barrel if the strategic stocks are not used. Using the strategic stocks would result in a price of $20.36 per barrel, a decrease of $12.10 per barrel. For the 6-MMBD disruption, the price increases to $40.78 per barrel with no strategic stock drawdown. Use of the strategic stocks would lower the price to $25.35. The use of the U.S. SPR

Figure 24. Price Impacts of an Oil Supply Disruption, Year 2000 (1994 dollars per barrel)



and our allies' strategic stocks to offset some of the disruption in supplies significantly reduces the impact of the disruption.

Historically, supply disruptions have been associated with more negative impacts than just an increase in petroleum prices. Typically, major supply disruptions have also been associated with increases in consumer prices, increased unemployment, and a decline in gross domestic product (GDP). A smaller disruption (4 MMBD), and the effective use of the OECD strategic stocks, including those of the U.S., would result in less than a 0.1 percent loss in GDP. At the other end of the spectrum, if the economy were to experience a larger disruption of 6 MMBD, the annual loss of GDP could be 1.1 percent. The use of the strategic stocks helps to ameliorate the price shock and the impact of GDP. In the 6 MMBD case, use of the strategic stocks lowers the one-year GDP impact from $40 billion to $10 billion, a difference of $30 billion.

Uncertainties

As previously stated, although the AEO baseline assumes no policy changes, it is often used by some as a "best guess" predictor of the future. In fact, however, periods when energy policy has remained stable are rare. It is reasonable to believe that policies will continue to change and as a result, the assumption of no policy change is probably the largest uncertainty in the forecasts. Other sources of uncertainty include:

- The AEOs are published once a year. During the annual cycle, new information about legislation and market conditions becomes available that could change the forecast. For example, industry restructuring has had a major impact on the projections for natural gas and electricity, with additional competition creating lower costs and greater efficiencies for gas-fired technologies in the electricity sector, resulting in greater consumption of natural gas and less coal in this year's AEO as compared to last year's projection. Other policy examples that have had significant impact on the projections include the National Appliance and Energy Conservation Act of 1987, the Clean Air Act Amendments of

1990, the Energy Policy Act of 1992, and the Administration's Climate Change Action Plan, among others.

- Nearly all energy forecasts, including our own, in past years have overestimated the future prices of fossil fuels. This tendency was most notable in the 1970s and early 1980s: predictions of energy prices made during those years have been proven to be dramatically overstated. Major factors that were not incorporated or not well understood at that time and which produced sharply lower prices include (1) decreased government regulation of energy markets, leading to (2) increased competition among energy suppliers, (3) significant penetration of new exploration and drilling technologies that reduced costs and increased the size of the U.S. domestic resource base for oil and natural gas, (4) the demise of OPEC as a monolithic force in setting world oil prices, and (5) the response of non-OPEC countries to make their production more competitive (i.e., lowering domestic taxes) in light of OPEC's market power.

- Growth in Gross Domestic Product and industrial output have often been overstated and have resulted in higher than achieved energy demands and higher rate of projected energy consumption. The principal factors that influence U.S. economic growth include changes in demographics; federal fiscal and monetary policies; relative prices of capital, labor and materials; the productivity of capital and labor; the U.S. industrial mix; and the world economy and international trade.

- Demand also has been reduced because of high energy prices, policy initiatives, and the use of more efficient technology. Electricity demand, for example, grew 2.5 percent annually from 1984 to 1994; in the forecast, we are expecting an annual growth rate of 1.4 percent due to changing demographic trends and improving efficiencies of electric appliances and equipment. However, greater market penetration of new uses of electricity (e.g., electric cars) could in fact change the composition of demand.

- There is substantial uncertainty in the estimated level of fossil fuel resources. The AEO is based on point estimates drawn from the best current information. If actual resources differ significantly from the AEO's point estimates, then actual future values for energy production levels, consumption levels, and prices may also differ significantly from the AEO projections. The uncertainty surrounding such point estimates arises because the measurement of energy resources is an inherently uncertain process based on sampling techniques, indirect observation, and differing geological and historical interpretations.

- The projections contained in the AEOs do not reflect the volatility contained in the historical record. Models are based largely on smooth economic adjustments and no unexpected disruptions. Changes in the future could come in sudden spurts rather than gradual adjustments resulting in much more pronounced impacts on consumer choice and other economic variables.

This year's AEO displays part of the underlying uncertainty by publishing high and low cases for economic growth, the world price of oil, and penetration of more efficient technologies, a higher demand case for electricity, and the impact of different assumptions for nuclear retirements. While alerting readers to the ranges of uncertainty, these alternative cases do not necessarily provide the "right" assumptions for a particular decision that would be impacted by future energy supply, demand, or price. There is merit in using a variety of projections and information, such as those provided by futures markets or long-term contracts, when making such decisions. Also, EIA can provide political decisionmakers with other cases that examine proposed policies within the appropriate context.

Uses of EIA Forecasts

Policymakers in the public and private sector have used EIA's forecasts, or more appropriately the tools upon which they have been based, to examine the impacts of proposals for environmental protection, changes in level of taxation, new import/export regulations, and changes in energy-using and producing technologies. Examples include:

- EIA was asked in January 1990 by the House Committee on Energy and Commerce to evaluate various proposals of acid deposition control. EIA's work helped to frame the Clean Air Act Amendments of 1990, which required SO_2 emissions to be reduced by 10 million tons from 1990 levels in two phases of which the first occurred in 1995, and the second will take effect in 2000.

- EIA was asked by DOE's Office of Policy, Planning and Analysis to participate, using its analytical tools, in the analysis of the 1991/1992 National Energy Strategy. EIA's analysis of options helped to frame the Energy Policy Act of 1992.

- EIA was asked again by the Office of Policy, Planning and Analysis in 1993 to assist in the evaluation of alternate tax proposals on the energy market and the economy. While various tax proposals were considered with EIA's assistance, Congress and the Administration eventually passed a Federal tax on highway fuels, which was contained in the Omnibus Reconciliation Act of 1993.

- EIA was also asked in 1995 by the Office of Policy, Planning and Analysis to provide updated projections of Alaskan crude oil production (North Slope and other) under various price assumptions. These projections were used as the basis for environmental impact scenarios required by November 1995 legislation to lift the ban on Alaskan North Slope oil exports. The scenarios were provided to an interagency team including the National Economic Council, the Council on Environmental Quality, the Office of Management and Budget, and the Department of Commerce. Results of the interagency reviews will be provided to Congress by the President on March 28, 1996.

- EIA is currently working with the Environmental Protection Agency (EPA) to look at various cases of technological improvement which may have beneficial impacts on reducing carbon emissions.

- EIA is currently supporting the General Accounting Office (GAO) in looking at the costs and benefits of oil imports to the U.S. energy economy. This is part of a request for analysis to GAO from Congressman Kasich, Chairman of the House Budget Committee.

- EIA has supported a number of offices within the DOE to examine the impact of various technological programs on energy supply and demand. EIA's modeling system which integrates the various energy sectors is able to avoid potential double-counting that occurs when programs are evaluated on an independent basis.

- Many Government agencies use EIA's forecasts as input to their own specific analysis. For instance, the Department of Labor's Employment Standards Administration uses regional projections of U.S. coal production and prices to estimate the level of the Black Lung Disability Trust Fund. These are updated periodically as coal production and price forecasts change.

- DOE's Federal Energy Management Program (FEMP) uses EIA price forecasts to calculate energy price indices, energy price escalation rates, and discount rates for life cycle cost analysis. The report, which is published by the National Institute of Standards and Technology in <u>Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis</u> each October, is released approximately 10 months after EIA's AEO. Several actions have been taken by DOE to make this report more timely and to offer alternative price projections. First, FEMP has agreed to do an update upon the release of EIA's AEO each year. Second, users will be encouraged to input their own contract or utility specific prices for energy or to use an alternative set of prices to EIA's forecasts.

- One electric utility has used EIA's forecasts to publicly advertise delivered prices of natural gas and electricity to residential end users. However, the advertisement neglected to include other important factors for evaluating the life cycle cost of alternative heating technologies, including capital and operating costs as well as the efficiencies of the technologies. EIA will be publishing a paper shortly on a comparative analysis that includes these costs as well as other factors of importance to consumers.

- The Pennsylvania House Appropriations Committee is using gasoline price elasticities of demand from EIA's transportation model to evaluate the effects of a gasoline tax upon gasoline prices and consumption.

- The U.S. Enrichment Corporation is using EIA's industrial electricity price forecasts to evaluate the possible impact of having its current electricity rates changed as a result of privatization.

- A private firm is using EIA's regional forecasts of wholesale electricity prices to evaluate potential sales of nuclear power generating plants in the United States.

In February, the Professional Audit Review Team (PART), which is chaired by the General Accounting Office, released its evaluation of the performance of the Energy Information Administration, as required by the Department of Energy Organization Act (P.L. 95-91, August 4, 1977). In its report, PART reported on a survey it conducted of 601 recipients of the Annual Energy Outlook to obtain respondents' comments on the reports' usefulness, reliability, and timeliness. About 80 percent of the respondents were extremely to moderately confident in the information in the AEO. Over 75 percent said that the AEO was extremely or moderately useful for trend information, basic facts, and forecasting, with over 85 percent reporting that it was also timely for these purposes. On the basis of the responses and comments to its questionnaire, PART believes that the AEO is "of high quality, useful, and timely for multiple purposes."

Although there are many users of forecasts for the purposes which are illustrated by the above examples, there is no way for EIA to know who all its users are. EIA serves to provide unbiased,

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objective, and independent forecasts for use by Government and the public. In this regard, EIA has the responsibility to publicize its forecasts, to make them easily available to the public, and to highlight methodological differences from past forecasts. Annually, we hold (1) an annual press conference to release the AEO followed by a briefing for industry groups; (2) a conference to discuss the analytical tools, the forecasts, and energy markets; and (3) focus groups on specific topics and industries. The forecasts are not only published in the AEO, but appear in multiple formats, including the World Wide Web, CD ROM, and in a pocket brochure. We document to rigorous standards the data, assumptions, and methodology behind our modeling constructs and encourage reviews by academia and industry experts. Until recent budget cuts, the model itself was even being distributed on diskette. My staff is open to questions and suggestions from users. However, ultimately the user must take responsibility for his or her use of the forecasts by updating the analysis as the forecasts change due to new information, energy market changes, technological improvements or breakthroughs, and/or passage of new laws and regulations.

We have not evaluated whether high energy prices have contributed to faulty investment decisions by private and public institutions nor have we calculated the associated costs. Obviously, these decisions would have benefited from having perfect information about the future, as opposed to the projections contained in the AEO. So would we. But by definition, the future is unknown. However, we believe decisionmakers are much better off with the AEO projections than without them. If nothing else, they provide a way for users to systematically develop their own forecasts by judicious replacement of the assumptions we have made in our forecasts. In fact, it is very difficult to discuss major energy issues without using these projections. It is incumbent upon responsible users performing analyses of alternative investment strategies to review the variety of forecasts available to them to insure that they use the ones most consistent with the assumptions of their analysis and to include an assessment of the risks associated with alternative choices.

Thank you very much for this opportunity to present our forecasts. I would be happy to take any questions you may have.

Chairman ROHRABACHER. We will have some questions for you later.

Mr. Schleede.

STATEMENT OF MR. GLENN R. SCHLEEDE, PRESIDENT, ENERGY MARKET AND POLICY ANALYSIS, INCORPORATED, RESTON, VIRGINIA

Mr. SCHLEEDE. Mr. Chairman and members of the Subcommittee, thank you for this opportunity to present comments this morning. My name is Glenn Schleede, and I am an energy market consultant.

But, I am appearing today as a private citizen and taxpayer, not on behalf of any other interests or clients. My comments are based on some 30 years of government and private sector experience in energy matters.

I want to commend you for holding these hearings and for entertaining views from witnesses who do not have a direct financial interest in maintaining the flow of tax dollars to their organizations via the Department of Energy. I have provided a detailed statement that I hope you will consider for the record of this hearing.

In that statement, I present views on U.S. and world energy markets and on government energy policies and programs that differ from the views that often come from DOE, its laboratories, contractors and grantees, trade associations representing contractors and grantees and other groups dependent on DOE funding, which I refer to hereafter as the DOE/Contractor Complex. I also identify issues and questions that I hope your Committee will pursue as witnesses from the DOE/Contractor Complex appear to seek authorization for their programs.

In summary, my detailed statement makes and supports the following six points.

First, U.S. and world energy markets have changed dramatically and favorably since current government energy policies and spending programs were conceived. These changes in energy markets need to be taken into account as you consider DOE's proposals to spend another $2 billion to $2.5 billion on energy supply and conservation technologies.

Second, past energy market forecasts have drastically overestimated energy prices. These high price forecasts have distorted government and private sector decisions and have resulted in billions of extra costs for consumers, taxpayers and investors.

Recently, EIA and other forecasters have substantially lowered their price forecasts. These revised forecasts dictate the need for a new look at government and private sector decisions based on previous forecasts.

Specifically, for this Committee, the lower forecasts mean that a new look should be taken at the rationale for DOE's energy technology development programs, for DOE's claimed energy savings from energy conservation and renewable energy programs and the economic analysis that DOE and its contractors use to justify their spending and regulatory programs.

If I may just mention, off my written statement, I became aware yesterday of a report put out by an organization called the American Council for Energy Efficient Economy. And, it says that we are going to save $132 billion due to appliance efficiency standards.

The report is very vague on how that number was calculated. But, it does refer back to some numbers calculated in 1993.

Since then, energy forecasts have come down dramatically. So, this number, if you ever hear it from anyone, I would urge you to question it.

It has got to be much, much, much lower based on current energy price forecasts. And, that's just one of the documents that is floating around making large claims that I believe are unsubstantiated.

My third point, we should not overreact to recent DOE officials' warnings about a looking energy crisis. There are many reasons to believe that another energy crisis is less likely today than previously.

These reasons deserve the Committee's consideration. I hope that the recent DOE officials' warnings are not merely an attempt to scare the Congress into authorizing a larger role for DOE and more tax dollars for its programs.

Fourth, we need more candor in Washington policy debates about energy matters. Specifically, we should recognize that most energy market decisions are those made—the most important energy market decisions are those made outside Washington.

We should freely admit the failures of many government energy policies and spending programs. And, there have been many.

We should recognize that the most effective Washington-based energy policy decisions are those that have reduced the federal role in energy. And, we should learn from past mistakes rather than repeat them.

Fifth, it's time to reconsider thoroughly the federal role in energy supply and technology development, demonstration and deployment activities and the spending associated with those programs. My detailed statement outlines nine specific questions that should be addressed.

Many of these nine questions have been asked before, but the answers are seldom convincing. They need to be addressed again by this Committee.

The questions deal with such issues as the appropriate role of DOE in energy technology development, demonstration and deployment as opposed to basic and applied research; the potential that DOE spending is displacing private sector investments in technology development and, perhaps, delaying the emergence of technologies that could compete in the private, competitive economy; the benefits or claimed benefits from massive spending for energy technology development by DOE and its predecessor agencies, which now apparently add up to about $100 billion; and, finally, the ability of DOE to select the right technologies for taxpayer subsidization.

The sixth point, I believe the Committee and the taxpayers deserve much more critical and objective analysis of the costs and benefits of federal energy policies and RDD&D investments than has been provided by DOE. Also, I suggest that the Committee look carefully at a potential conflict of interest within DOE that flows, on the one hand, from its responsibility to assure wise use of tax dollars and, on the other hand, from its heavy emphasis on assuring a broad role for DOE in energy matters and on assuring a steady flow of tax dollars for DOE programs.

In conclusion, my detailed statement suggests six specific actions for the Committee's consideration. In addition to my detailed statement, I have provided for the record three recent documents that deals with some of the specific questions that are outlined in the letter I received from you.

Thank you for the opportunity to appear. And, I would be glad to answer questions.

Chairman ROHRABACHER. Your entire testimony will be made part of the record, without objection. And, I am sure we will have some questions later as well.

[The prepared statement of Mr. Schleede follows:]

STATEMENT FOR THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

BY GLENN R. SCHLEEDE

MARCH 14, 1996

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to present comments this morning. My name is Glenn Schleede. I am an energy market consultant but I am appearing today as a private citizen and taxpayer, not on behalf of any other interests or clients. My comments are based on some 30 years government and private sector experience with energy matters.

I want to commend you for holding these hearings and for entertaining views from witnesses who do not have a direct financial interest in maintaining the flow of tax dollars to their organizations via Department of Energy (DOE) programs. I have provided a detailed statement that I hope you will consider for the record of this hearing. In that statement:

- I present views on U.S. and world energy markets and on government energy policies and programs that differ from views that often come from DOE, its laboratories, contractors, and grantees, trade associations representing DOE contractors and grantees, and other groups dependent on DOE spending (referred to hereafter as the "DOE/Contractor Complex"); and
- I also identify issues and questions that I hope your committee will pursue as witnesses from the DOE/Contractor Complex appear to seek authorization for their programs.

In summary, my detailed statement makes and supports the following six points:

- First, U.S. and world energy markets have changed dramatically and favorably since current government energy policies and spending programs were conceived. These changes in energy markets need to be taken into account as you consider DOE's proposals to spend another $2 to $2.5 billion on energy supply and conservation technologies.
- Second, past energy market forecasts have drastically overestimated energy prices. These high price forecasts have distorted many government and private sector decisions, and have resulted in billions of dollars of extra costs for consumers, taxpayers and investors.

Recently, ELI and other forecasters have substantially lowered their price forecasts. These revised forecasts dictate the need for a new look at government and private sector decisions based on previous forecasts. Specifically, for this Committee, the lower forecasts mean that a new look should be taken at:

- The rationale for DOE's energy technology development programs,
- DOE's claimed energy savings from energy conservation and renewable energy programs, and
- Economic analyses used by DOE and its contractors to justify proposed spending and regulatory programs.

- Third, we should not overreact to recent DOE officials' warnings about a looming "energy crisis." There are many reasons to believe that another "energy crisis" is less likely today than previously. These reasons deserve the Committee's consideration. I hope that the recent DOE officials' warnings are not merely an attempt to scare the Congress into authorizing a larger role for DOE and more tax dollars for its programs.
- Fourth, we need more candor in Washington policy debates about energy matters.

Specifically:

- We should recognize that the most important energy market decisions are those made outside Washington,
- We should freely admit the failures of many federal government energy policies and spending programs,
- We should recognize that the most effective Washington based energy policy decisions are those that have *reduced* the federal role in energy, and
- We should learn from past mistakes rather than repeat them.
- Fifth, it is also time to reconsider thoroughly the federal role in energy supply and technology development, demonstration and deployment activities and the spending associated with those programs. My detailed statement outlines nine specific questions that should be addressed. Many of these nine questions have been asked before but the answers are seldom convincing. They need to be addressed again by this Committee. The questions deal with such issues as:
- The appropriate role of DOE in energy technology development, demonstration and deployment activities—as opposed to basic and applied research.
- The potential that DOE spending is displacing private sector investments in technology development and, perhaps, delaying the emergence of technologies that could compete in the private, competitive economy.
- The benefits—or claimed benefits—from the massive spending for energy technology development by DOE and its predecessor agencies.
- The ability of DOE to select the "right" technologies for taxpayer subsidization.
- Sixth, I believe the Committee and the taxpayers deserve much more critical and objective analysis of the costs and benefits of federal energy policies and RDD&D investments than has been provided by DOE. Also, I suggest that the Committee should look carefully at a potential "conflict of interest" within DOE that flows:
- On one hand, from its responsibility to assure wise use of tax dollars, and
- On the other hand, from its heavy emphasis on assuring a broad role for DOE in energy matters and on assuring a steady flow of tax dollars for DOE programs.

In its conclusion, my detailed statement suggests six specific actions for the Committee's consideration.

Mr. Chairman, in addition to my detailed statement, I am providing for the record three recent documents[1] dealing with energy forecasts and their impact on government and private sector decisions. These documents address many of the specific questions posed in the charter for this hearing.

Thank you for the opportunity to appear before your Committee today. I would be pleased to answer questions on both the detailed statement and this brief summary of it.

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[1] My January 30, 1996 letter to the Directors of the Office of Management and Budget and the Congressional Budget Office; My February 1, 1996 paper, *Energy Price Forecasts are leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions;* and my February 14, 1996 letter to Dr. Jay Hakes, Administrator of the Energy Information Administration.

It is Time to Reconsider the Role of the Federal Government in Energy Markets and in Spending for Energy Research, Development, Demonstration and Deployment (RDD&E) Activities

A Statement for

The Subcommittee on Energy and Environment

Committee on Science

U.S. House of Representatives

by

Glenn R. Schleede*

Washington, DC

March 14, 1996

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Statement for the Subcommittee on Energy and Environment, Committee on Science
U.S. House of Representatives
by Glenn R. Schleede
March 14, 1996

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Statement for the Subcommittee on Energy and Environment, Committee on Science
U.S. House of Representatives
by Glenn R. Schleede
March 14, 1996

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to present comments this morning. My name is Glenn Schleede. I am an energy market consultant but I am appearing today as a private citizen and taxpayer, not on behalf of any other interests or clients. My comments are based on some 30 years government and private sector experience with energy matters.

I want to commend you for holding these hearings and for entertaining views from witnesses who do not have a direct financial interest in maintaining the flow of tax dollars to their organization via Department of Energy (DOE) programs. In my statement today, I will:

- Present views on U.S. and world energy markets and on government energy policies and programs that differ from views that often come from DOE, its laboratories, contractors, and grantees, associations and coalitions representing DOE contractors and grantees, and other groups dependent on DOE spending (the "DOE/Contractor Complex"); and

- Identify issues and questions that I hope your committee will pursue as witnesses from the DOE/Contractor Complex appear to seek authorization for their programs.

In summary, my detailed statement makes and supports the following six points:

- U.S. and world energy markets have changed dramatically and favorably since current government energy policies and spending programs were conceived.

- Energy market forecasts have drastically overestimated energy prices, distorted government and private sector decisions, and cost consumers, taxpayers and investors billions of dollars. Recent downward revisions in price forecasts require a new look at government and private sector decisions based on prior forecasts, including decisions on DOE energy programs.

- We should not overreact to recent DOE officials' warnings about a looming "energy crisis."

- We should recognize where truly important energy market decisions are made, admit failure when federal government energy policies and programs do not work, and to learn from -- rather than repeat -- those failures.

- It is also time to reconsider the federal role in energy research, development, demonstration and deployment (RDD&D) activities and the spending associated with those programs.

- The Committee (and the taxpayers) deserve more objective analysis of the costs and benefits of federal energy policies and RDD&D investments than it is now getting from the DOE.

DETAILED ANALYSIS AND COMMENTS

A. U.S. and world energy markets have changed dramatically and favorably since current government energy policies and spending programs were conceived.

Perhaps the best and least controversial place to start is to present data illustrating the dramatic changes that have occurred in U.S. and world energy markets since the 1970s and early 1980s when perceptions were formed about the need for a large federal role in energy matters and massive federal spending for energy supply and energy conservation RDD&D.

The following seven points are examples of many changes that have occurred in energy markets since the oil price increase shocks of 1973-74 and 1979-81. These points often seem to be ignored by those who want to maintain a 1970s-early 1980s era perception of an "energy crisis."

1. **Real energy prices have declined steadily since the early 1980s.** Attachment #1 is a chart demonstrating that U.S. average prices for various forms of energy in constant or "real" 1994$ (i.e., adjusted for inflation) have declined significantly since the high points reached in the early 1980's. Specifically, in 1995:
   - Crude oil prices were down by 71% from the high reached in 1981.
   - Natural gas wellhead prices were down by 57% from the high reached in 1983.
   - Retail gasoline prices, including taxes, were down by 45% from 1981.
   - Refinery gasoline prices (which do not include taxes) were down by 64% from 1981.
   - Residential heating oil prices were down by 56% from 1981.
   - Residential natural gas prices were down by 31% from the high reached in 1983.
   - Residential electricity prices were down by 21% from highs reached in 1984-1985.

   Increasing competition and restructuring now underway in the gas and electric industries are likely to push prices even lower.

2. **U.S. energy efficiency has improved even though energy prices have continued to decline in real terms since the early 1980s.** Attachment #2 is a graph showing U.S. energy consumption in the industrial, transportation and residential and commercial sectors from 1973 - 1995. Attachment #3 is a graph showing changes since 1973 in U.S. energy consumption and real GDP. Among the key points revealed by these two charts are that:
   - During the 22 year period from 1973 to 1995, U.S. energy consumption increased by 17.5% while Gross Domestic Product (GDP) increased by 72.8%.
   - U.S. energy consumption reached its lowest point (since 1973) in 1983.
   - From 1973 to 1983, U.S. energy consumption *decreased* 5.1% while GDP *increased* by 23.3%.
   - From 1983 to 1995, U.S. energy consumption *increased* by 23.7%, while GDP *increased* by 40.2%.

   Energy consumption per dollar of GDP has decreased from 22,730 Btus in 1973 to approximately 15,800 Btus in 1995, a drop of 30%.[1]

[1]U.S. Energy Information Administration, Monthly Energy Review, Table 1.9.

3. **Several factors have contributed to reduced energy intensity and improved energy efficiency in the U.S.** Among the key factors that have contributed to reduced energy intensity and/or improved energy efficiency are:
   - The improving average miles per gallon of fuel used by passenger cars, which has increased from 13.3 miles per gallon in 1973 to 21.5 in 1994, a 61.5% improvement.[2]
   - Very stable energy use by U.S. industry, even though the value of output has increased, in part due to more efficient energy use and in part to changes in industrial mix toward less energy intensive products.
   - Technological advances in many areas including:
     - Products targeted for improved energy efficiency such as appliances, motors, building materials, aircraft, vehicles and improved industrial processes; and
     - Products and services in areas such as electronic controls, communications, materials, and computers that provide improved energy efficiency as a by-product.

   It is important to note that reduced energy intensity and improved energy efficiency have continued and private industry continues to produce increasingly efficient products *even though real energy prices have declined.*

4. **Facts about U.S. oil imports and their relationship to U.S. exports are often ignored.** DOE officials and others who contend that the U.S. faces an "energy crisis" or a "national security threat" often point to a rise in U.S. dependence on imported oil. Clearly, dependence on oil imports has been rising and, despite the rhetoric, there is very little that can be done to change the trends in the near future. However, it should be noted that those who advance "energy crisis" perceptions tend to ignore four key facts that should be a part of an objective analysis of our oil import situation:
   - First, oil imports make up a declining share of total U.S. merchandise imports, declining from a high of 32.1% in 1980 to 7.3% in 1995. (See Attachment #4).
   - Second, a large share of the outflow of dollars for our oil imports comes back to the U.S., directly or indirectly, as payments for the merchandise and services that we export. Both sides of our trade pictures should be considered in any objective analysis, but DOE seems uninterested in the relationship of oil import dollars to our export markets.[3]
   - Third, the dollar outflow for oil -- in constant dollars -- has declined sharply since the high of $138 billion (1994$) reached in 1980 to $53 billion in 1994.[4]
   - Fourth, most alternatives to market pricing of oil that are proposed by "energy crisis" advocates would be more costly to the economy than continued reliance on imports.[5]

[2] U.S. Energy Information Administration, Monthly Energy Review, Table 1.10.

[3] Purchases of aircraft recently announced by Saudi Arabia are but one example.

[4] The outflow has remained quite stable in constant 1994$ since 1991, due in part to lower real oil prices. Specifically, the cost of imports in billions: 1991 - $55.4, 1992 - $53.8, 1993 - $52.2, 1994 - $50.8, and 1995 - $53.0.

[5] Tariffs or quotas for imported oil, for example, would push up the price of both imported and domestically produced oil. Or, for those proposing synthetic fuels, would we really be better off by paying (or subsidizing) $35 to $70 per barrel for synthetic fuels or by importing crude oil at $18, $20, or even $25 per barrel?

5. **Proved world oil and gas reserves have grown significantly.** World oil and gas consumption has continued to grow, but so too have proved oil and gas reserves.[6] Specifically:
   - World proved oil reserves have been estimated at 1 trillion barrels as of January 1, 1996, compared to 664 billion barrels as of January 1, 1973 -- an increase of 50%.
   - World proved natural gas reserves have been estimated at 4.9 trillion cubic feet as of January 1, 1996, compared to 1.9 trillion cubic feet as of January 1, 1973 -- an increase of about 160%.

6. **Non-OPEC production is growing.** Those who wish to create a perception of a forthcoming energy crisis often point to the prospects of growing world dependence on oil from OPEC and, more specifically, on oil from middle eastern nations. However, it is important to note that:
   - Not all oil from OPEC is insecure.
   - Oil production is increasing in countries that are not members of OPEC. In fact, during the past two years oil production from non-OPEC nations has grown faster than production from OPEC.
   - The late 1980s-early 1990s shifting of focus of major oil companies from exploration in the U.S. to other areas of the world where oil can be discovered more readily and recovered more cheaply has had a salutary effect on oil markets (from a consumer's point of view). Their activities undoubtedly have contributed to the growth in non-OPEC oil production.

7. **Projected growth in developing nations' energy requirements is less than certain.** Another factor often cited by those seeking to create the perception of a looming "energy crisis" is that oil demand is growing in developing nations and that this demand will "explode" in the future. We should be careful in relying on these projections since:
   - The assumptions underlying them are not always clear, and
   - It is far from clear that developing nations that are projected to increase economic growth and energy consumption rapidly:
     - Will be able to attract the capital that would be required;
     - Will make the changes in their laws, institutions, and policies that would be needed to attract foreign expertise and investment; or
     - Will have market-based economies.
   - Developing countries may be able to make use of more energy efficient capital equipment and facilities than are now in place in industrialized nations. If so, developing nations may be able to attract energy intensive industrial activities from industrialized nations, thus exerting downward pressure on total world energy demand.

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[6] *Oil and Gas Journal*, January 1996. Estimates of proved reserves have continued to grow even though producers in some regions, such as the U.S. and Canada, are no longer required or otherwise find it necessary or desirable to demonstrate *proved* reserves many, many times their annual production.

B. **Energy market forecasts have drastically overestimated energy prices, resulting in distorted government and private sector decisions, and billions in extra costs for consumers, taxpayers, and investors.**[7]

The role of energy market forecasts is particularly important to this committee because forecasts of rapidly increasing demand and prices are often used as a part of the justification for large expenditures on DOE energy technology and conservation programs. Several points about energy forecasts are important in your committee's deliberations:

1. **Forecasts play an important role in business and government decisions and actions.** Many decision makers contend that they "do not believe any energy price forecast" and this skepticism is justified. However, all decision makers should recognize that any time they use an economic analysis in evaluating a long-term contract, capital investment, or investment in RDD&D they are, in fact, relying on somebody's energy price forecast. All too often the important role played by the forecast is not recognized and its validity is not questioned.

2. **Nearly all forecasters, including EIA, have been wrong.** Energy price forecasts produced by government and commercial forecasting organizations have been wildly inaccurate -- on the high side. These high forecasts have been used as the basis for thousands of decisions by business executives, regulators, and other government officials. Many of those decisions have proven to be uneconomic and have cost consumers, taxpayers, and investors billions of dollars.

   Attachments #5 and #6 show in 1994$ EIA's reference case forecasts made each year from 1985 through 1996. The third column on these charts show that:
   - EIA had forecast in January 1985 that crude oil prices in 1995 would be $55.40 per barrel. Almost each year thereafter, EIA reduced its forecast price but always remained on the high side. EIA estimates that the actual price of crude oil in 1995 was $16.81 -- 70% below the forecast made in 1985.
   - EIA had forecast in January 1985 that wellhead natural gas prices in 1995 would be $6.99 per Mcf . EIA reduced its forecast price each year thereafter but always remained on the high side. EIA estimates that the actual price of natural gas in 1995 was $1.60 per MCF -- 77% below the forecast made in 1985.

3. **Recently, most forecasters have substantially lowered price expectations.** During the past two years forecasters have begun "catching up with" changing fundamentals in energy markets and have lowered their forecasts substantially. For example, as shown on

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[7] The problems caused by energy price forecasts that have proven to be faulty and the possibility that energy demand and price forecasts have a systematic upward bias is discussed in detail in my paper, *Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions*, 1996 Edition, February 1, 1996.

Attachment #5, the forecast issued by the Energy Information Administration (EIA) in January 1996 lowered its forecast of wellhead natural gas prices for 2010 by 38% from its January 1995 forecast (from $3.46 to $2.15 per thousand cubic feet - Mcf in 1994$).

4. **Federal program decisions (including energy technology), economic analyses, budget estimates, and efficiency standards based on previous forecasts need to be reconsidered.** Private sector and government decisions made on the basis of previous forecasts, even those made recently, should be reconsidered. The significant changes reflected in recent forecasts are likely to have a major impact on estimates of project costs and/or benefits. With the federal government, all energy programs, including energy supply and conservation technology programs, budget estimates, economic analyses, energy efficiency standards, claims of energy cost savings, valuations of oil and gas reserves and leases, and other actions that were based on past energy price forecasts need to be reconsidered.

5. **DOE energy market forecasts used to justify energy technology programs need careful scrutiny.** While not a primary interest of your committee, you should be aware that there is a need to reevaluate energy market forecasting activities and methods conducted by EIA and by other policy and program offices in DOE. I will supply additional information for the record on this matter. For your committee's purposes, it is important to note that forecasts from DOE have often overestimated energy demand and prices and underestimated energy supplies that would be available even at prices well below those forecast by DOE. Such forecasts have been used to help justify DOE's energy supply and conservation programs and spending proposals. Attachment #7 shows DOE's very high forecast of future energy demand that was used in 1991 to support the Department's proposed "National Energy Strategy" in contrast to much lower estimates of future demand in a forecast issued one month later by the EIA.

   Remaining questionable aspects of EIA's latest energy price forecasts that could affect estimates of the benefits of DOE's energy supply and conservation programs include:

   - EIA's assumption in four out of five of its cases that oil and gas prices will increase in the future. Its "low oil price" case assumes, approximately, that prices would drop in the near term but then rise to current levels in real dollars by 2015. However, EIA presents no case that allows the possibility that real prices will continue to decline.
   - The strong possibility that EIA has not adequately reflected in its latest forecast the probability that end users electricity and natural gas prices will decrease in real dollar terms as competition in the electric and gas industries increases.
   - EIA's expectation that the delivered cost of natural gas for electric generators will increase while the delivered cost of coal will decrease.

C. <u>We should not overreact to recent DOE officials' warnings about a looming "energy crisis."</u>

Unfortunately, declaring the existence of a "crisis" and then offering a government program to deal with that "crisis" has long been a standard way to gain public, media, and Congressional support for starting or expanding government-run programs. Whether the claimed "crisis" was real or not, or whether it was being resolved without federal action has been immaterial. It has been the ability to create the perception of a "crisis" that has counted.

This standard practice needs to be kept in mind as you evaluate recent statements by DOE officials that we are facing another "energy crisis." The exact nature of the DOE-expected "energy crisis" does not yet seem to be clear but, presumably, it would include some kind of energy shortage, a sharp increase in energy prices, and negative economic impacts.[8]

Additional claims of a looming "energy crisis" may be a part of the justification that DOE offers for its energy supply and conservation technology spending programs and you will be faced with the task of evaluating those claims.

Whether we do face some looming "energy crisis" cannot be known with certainty since none of us has a good record in predicting the sharp changes that have occurred in energy markets during the past 22 years. Perhaps DOE officials have some inside intelligence information that is not available to the public to support their latest "crisis" warnings.

In any case, I would like to offer several suggestions and questions that you might keep in mind as you evaluate claims and spending program justifications coming from the DOE/Contractor Complex.

1. **Many developments in U.S. and world energy markets militate against another 1970s-type energy shock.** Surely, witnesses from the DOE/Contractor Complex will present reasons why they believe we face a potential "crisis." I'd like to identify several conditions that suggest we may, instead, have relatively stable U.S. and world energy markets for the foreseeable future. (Several of these conditions were described earlier in this statement and are supported by data in attachments.)

    a. Proved world oil and gas reserves have increased.

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[8] These are conditions often attributed to "energy crises" of 1973-74 and 1979-80 when oil prices rose sharply. However, some economists have questioned why Japan, which is more dependent on imported energy than the U.S., did not suffer the same adverse economic impacts in 1973-74 as the U.S. See Bohi, Douglas, *Energy Price Shocks and Macroeconomic Performance*, Resources for the Future, 1989.

b. Large reserves of natural gas, increasingly efficient technology for using gas,[9] and the demonstrated ability to liquefy natural gas (LNG) for ocean transport has opened up very promising sources of energy for world markets (particularly electric generation).
c. Oil and gas is being found in significant quantities in heretofore unexplored areas, in part because major oil companies are now focusing on areas not previously explored that offer the potential for lower costs.
d. New technology is being developed that permits oil and gas exploration and production in deeper water (e.g., in the U.S. Gulf of Mexico).
e. New technology is bringing down the costs of oil and gas exploration and production.(e.g., 3-D seismic, horizontal drilling, improved drill bits, improved well completion technology).
f. Non-OPEC proved oil and gas reserves and production has increased, weakening the ability of the OPEC cartel to control the level of world oil production and prices.
g. Potential world oil productive capacity can be increased if Iraq once again becomes a major producer and if former Soviet Union countries develop their potential to produce and export oil.
h. Energy efficiency has improved in a wide range of production processes and products:
   - Where energy efficiency has been a goal (e.g., motors, appliances, building materials, vehicles, and aircraft), and
   - Where energy efficiency has been a byproduct (e.g., communications, information, materials, electronic controls, computers, teleconferencing).
i. Efficient futures markets are now available for oil and natural gas (and probably soon for electricity) that help consumers protect against future price risk.
j. Forecasts of rapid growth in world oil demand, heavily driven by developing nation consumption, may not occur as fast as forecasts suggest.
k. A majority of U.S. oil imports comes from relatively secure countries and regions.[10]

2. **If an oil supply interruption and price run-up were to occur, it may not last long.** Since we cannot absolutely guarantee that there will not be some energy supply interruption (perhaps some interruption of oil supplies from the Middle East) and oil price run-up, it is appropriate to ask how significant the interruption and price run-up would be and how long it will last. Those who need an "energy crisis" or the perception of one to justify their proposals may contend that it would last for a year or more. Perhaps they are right but it is useful to keep in mind that other reasons suggest an oil supply interruption and price increase may not last long. These reasons include:
   - The relatively short life of the oil price run-up that occurred when Iraq invaded Kuwait.

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[9] For example, combined-cycle electric generating units make use of gas turbine technology developed under DOD-financed aircraft engine R&D and by private sector companies. New combined-cycle units are nearly doubling the efficiency of older units (i.e., efficiency in converting Btus into kilowatt hours). See EIA's Annual Energy Outlook 1996, p. 32.

[10] During the first 11 months of 1995, U.S. gross oil imports averaged 8,855,000 barrels per day. Principal sources of these imports included Venezuela - 16.7%, Saudi Arabia - 15.2%, Canada - 14.9%, Mexico - 12.1%, North Sea (UK, Norway, Netherlands) - 7.7%, Other Western Hemisphere (Virgin Islands, Colombia, Ecuador, Trinidad & Tobago, Puerto Rico, Brazil) - 8.5%. Total for these: 75%.

- The very strong need of most oil producing and exporting countries (including most OPEC members) for oil export revenue to satisfy domestic economic needs, including the demands of their people, and their other ambitions. This need for hard currency provides a very strong incentive to restart any interrupted oil production and exports.
- Major investments made by OPEC members in downstream ventures in other countries, including refineries and service station chains.

3. **Would existing or proposed government energy spending programs really help prevent or mitigate an "energy crisis"?** When evaluating the potential for an "energy crisis" and the appropriate actions that should be taken now to deal with that potential, it is important to ask two additional questions:
   - Did government policies and programs instituted in the 1970s and early 1980s contribute significantly in dealing with the situation or, alternatively, did those policies and programs:
     - Distort markets and prolong adverse economic impacts?
     - Waste large amounts of tax dollars on RDD&D programs that produced very little in benefits?
   - Do the policies and spending programs now being advocated by those in the DOE/Contractor Complex offer more promise than those of the 1970s and early 1980s?

   These points are discussed below.

D. **We should recognize that the most important energy market decisions are not made in Washington and that federal government programs often distort energy markets.**

Often, there appears to be a strong tendency in federal agencies to avoid admitting it when federal programs fail, and to learn from -- rather than repeat -- past mistakes. On the other hand there appears to be fairly widespread agreement, at least outside Washington, that many past federal energy policies and programs were ineffective, disruptive, counterproductive, and wasteful. It is useful to explore why this might be the case.

1. **The most important energy decisions are made *outside* Washington.** First, despite perceptions to the contrary, the most important decisions about energy are not made in Washington. Instead, they are made by millions of individuals and organizations each day as they decide which car to buy, where to live, how to heat and cool their homes, whether to drill a well to explore for or produce oil or gas, whether to extend a pipeline, or which energy source should be used when a new electric generating plant is needed.

2. **The ability of DOE or any central government to understand energy markets is limited.** This is not a criticism of *individuals* in DOE or other federal agencies. It is simply the case that people in Washington are severely limited in their ability to understand, let alone control or dictate, which energy decisions are best because:
   - Energy markets are diverse and complex, involving millions of individual decisions.
   - Information on market *details* is seldom available or, when available, late.

- Federal government employees seldom have real world energy market experience.
- Many government officials underestimate the ability of people "outside the beltway" to understand market signals and to develop creative responses that are more effective and less disruptive than those developed by a centralized government.

For these reasons, energy market solutions developed in Washington often do not fit real problems. Furthermore, political considerations will often skew government "solutions" -- with the result that there is little chance that government action will solve problems rather than exacerbate them.

3. **Energy policy decisions made in Washington have often been counterproductive.** Experience since 1973 has shown that government policies have all too often exacerbated -- not prevented or mitigated -- energy problems. One only need recall:
   - Oil import fees (taxes) and quotas, particularly those that made up the protectionist-"drain America first" Mandatory Oil Import Program of 1959-1973.[11]
   - Natural gas wellhead price controls following a 1954 Supreme Court decision that severely distorted markets for gas for nearly 30 years, resulting in both wasting and under-producing gas and, probably, over reliance on oil.
   - Policies of the late 1970s and early 1980s that prohibited construction of gas-fired power plants and industrial facilities and discouraged new residential and commercial gas hookups based on the false perception that the U.S. was running out of gas.
   - The pricing provisions of the Natural Gas Policy Act that helped drive up prices for natural gas and delayed the arrival of lower, competitively determined prices.
   - The disastrous oil allocation and price controls of the 1970s that severely distorted market incentives, distorted refinery economics, misallocated oil product supplies, and contributed to gasoline shortages in some areas while creating excess supplies in others.
   - The delays by the Atomic Energy Commission (AEC) and its contractors in addressing nuclear waste issues, thus contributing to the demise of civilian nuclear power.
   - The billions in tax dollars wasted in ERDA, Synfuel Corporation, and DOE subsidies on projects that were intended to develop and demonstrate technology to produce oil from oil shale, synthetic fuels form coal, and alcohol fuels.
   - The billions in expenditures for energy technologies by DOE and its predecessor agencies that have produced little and probably have displaced private sector efforts and delayed innovation (discussed in more detail later).
   - Decisions by TVA and Bonneville Power Administration -- based on overestimated electricity demand -- that led to overbuilding of nuclear power plants. These decisions, respectively, have resulted in billions in non-performing assets now resting on the books of TVA, and the largest municipal bond default in U.S. history, in the case of Washington Public Power.

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[11] See Bohi, Douglas and Milton Russell, *Limiting Oil Imports: An Economic History and Analysis*, 1978; and Bradley, Robert L., *The Mirage of Oil Protection*, 1989.

4. **The most effective government actions dealing with energy, in terms of economic efficiency and lower energy prices for consumers, have been actions to *reduce* the government's role in energy.** There are several well known examples demonstrating that market forces and competition are superior to government actions in assuring adequate energy supplies at reasonable prices. These include:
   - Removal of oil allocation and price controls during the Ford, Carter, and Reagan Administrations permitted oil markets to perform more efficiently and helped reduce prices.
   - Removal of wellhead natural gas price regulation which first held prices artificially low during the 1950s, 1960s, and 1970s and then pushed prices to artificially high levels during the period from 1979-1985 after enactment of the Natural Gas Policy Act of 1978. Since deregulation, wellhead prices have fallen by 57% from the artificially high levels of 1983.
   - Increased competition in natural gas transportation and marketing as a result of Federal Energy Regulatory Commission actions (particularly FERC Orders 436 and 636) has resulted in lower gas transportation costs and paved the way for further changes by state PUCs that can result in reduced costs for gas users.
   - Increased competition in the electric industry as a result of the Public Utility Regulatory Policy Act of 1978, the National Energy Policy Act of 1992, and reduced regulation under consideration in FERC, state legislatures, and state public utility commissions (PUCs) virtually assures that electric rates will continue their downward trend and, most likely, stimulate further reductions in natural gas and electric rates for end users.

   Clearly, consumers have benefitted when increased competition replaced government attempts to control energy markets.

E. <u>The federal role in energy technology development, demonstration and deployment activities and the spending associated with those programs should be reconsidered.</u>

Most of us have great respect and appreciation for the contributions that science and technology have made to our national security, our standard of living, our quality of life, and our ability to compete in world markets. At the same time, we need to recognize that not all RDD&D that has been funded by the federal government has equal merit and not all of it deserves or requires federal involvement or subsidization with our tax dollars.

The issue of the appropriate federal role in research, development, demonstration, or deployment activities is controversial. Debates about government "industrial policy" have raged for years and views vary widely from one administration to another and among individuals with differing political philosophies. All the key questions deserve another thorough review. Clearly, the Committee will have to address the issue of appropriate federal role in energy RDD&D as it considers requests for authorization of spending for various DOE energy supply and conservation programs. At least the following nine key issues deserve the Committee's attention:

1. **Does proposed energy RDD&D program spending distinguish appropriately among support for basic research, applied research, development, demonstration and deployment activities?** As members of this subcommittee know, there are fundamental differences among basic research, applied research, development, demonstration, and deployment activities in terms of:
   - The objectives being pursued, and
   - The incentives, or lack thereof, that private sector firms have to pay for those activities.

   While many private sector organizations fund basic research, agreement is quite widespread that the private sector is unlikely to have an incentive to support the full level and range of basic research that is needed in the national and public interest.

   However, as work moves from the basic research end of the spectrum toward development, demonstration, and deployment, the objectives (producing a useful product or service) and the incentives for support (e.g., making a profit when producing and selling the product) changes. Furthermore, in the case of products and services intended for the private, competitive economy,[12] understanding of potential markets is critical. As indicated earlier, government officials seldom have a good understanding of private sector markets.

2. **Has spending on energy development, demonstration and deployment projects displaced funding for promising basic and applied research?** Recognizing the greater incentive for private sector funding for development, demonstration and deployment projects (as opposed to basic and applied research) that private firms find promising, the Committee should determine whether funding for DD&D projects may be displacing promising basic and applied research that is less likely to be privately funded.

3. **Are all the projects proposed by DOE really worth funding?** As federal budgets have become tighter, some observers have behaved as if all RDD&D is really high priority and worthy of subsidies. In fact, the federal government has supported RDD&D projects that were unsuccessful and were wasteful of our tax dollars. Cutting out low priority and wasteful projects will not harm the national interest even if the total dollars available for RDD&D go down. Those who favor spending of tax dollars for RDD&D activities have a responsibility to help limit funding to the best and highest priority work, and to avoid spending tax dollars for work that can be funded by the private sector.

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[12] The situation is different when the intended function is a unique government function (e.g., national defense or, until recently, space programs and weather forecasting).

4. **Can we justify the billions in tax dollars that have already been spent on energy RDD&D, let alone continued spending?** As indicated in Attachment #8, approximately $66 billion ($109 billion in 1994$) has been spent on energy RDD&D by DOE and its predecessor agencies since 1955. An additional $17 billion ($37 billion in 1994$) has been spent on "Non-defense Atomic Energy General Sciences" since 1949. Based on information provided by DOE,[13] it is hard to reach any conclusion other than that DOE-claimed successes in energy technology development, demonstration and deployment (as opposed to basic research) fall far short of what could reasonably be expected for the money spent.

5. **Do federal agencies really have the capability to carry out a cost-effective "industrial policy"?** Those who favor spending of tax dollars for the development, demonstration, and/or deployment of technologies that must compete in the private, competitive economy assume that federal government officials have the ability to select the right technologies for support. You will undoubtedly hear from witnesses who will defend this assumption or who will contend that requiring matching contributions from private sector "partners" provides the protection needed for taxpayers that the "right" technology development projects will be selected for support.

   As you hear these arguments, I suggest that the Committee keep several other points in mind as well:

   a. **Failure of previous U.S. government industrial policy experiments.** Many observers of federal government-sponsored efforts to develop economically competitive technologies have pointed out the spending on projects to produce synthetic fuels from oil shale and coal as classic examples of wasted tax dollars and the failure of federal "industrial policy" experiments.

      However, the Committee should not overlook the fact that federal government attempts to develop and promote a civilian nuclear power industry is probably the all-time largest experiment in "industrial policy." Civilian nuclear power development was inextricably related to concerns about the potential proliferation of nuclear weapons technology. Nevertheless, it would be hard to argue that attempts by the Atomic Energy Commission, its laboratories, its contractors, and the Congressional Joint Committee on Atomic Energy to promote a civilian nuclear power industry were anything but a full-blown "industrial policy" effort.

      Of course, the nation has benefitted from electricity generated from nuclear power plants and private sector firms have exported nuclear power plant equipment and technology.[14] However, we are now faced with:

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[13] References listed in Section F of this statement.

[14] Often with Export-Import Bank financing arrangements.

- The predicted demise of the civilian nuclear power industry within the next 20+ years,
- The absence of a broadly acceptable method to manage nuclear wastes from nuclear power production,
- Lingering concerns about the safety of nuclear power plants and the difficulty of safeguarding nuclear materials so that they are not turned into weapons, and
- Potentially enormous decommissioning costs when nuclear power plants are shut down.

One cannot view this situation without wondering whether the future of civilian nuclear power might look quite different if its development had been allowed to occur in the private sector without the massive government attempts to promote and speed its development and deployment. For example, would earlier, truly independent regulation of civilian nuclear power have provided greater assurance and greater public acceptance of the claims that safety concerns had been adequately addressed? Would the task of long-term management of nuclear wastes have been addressed in a more timely manner and resolved before we reached the current stage of apparent impasse? Would nuclear power, though somewhat delayed, have remained as a promising source of electricity for generations to come?

b. **Questionable ability of federal agencies to pick "winners" when the technology must compete in private, competitive markets.** There is little evidence that the government has this capability. It remains to be seen whether requirements for significant private sector sharing of costs in government supported technology development, demonstration, and deployment projects results in greater success in industrial policy efforts. Further, it appears that the magnitude of the risk accepted by the private "partner" in such cost-shared ventures may be less than is claimed when the value of tax credits, in-kind contributions to project costs, residual value of equipment and facilities retained by the private "partner," and experience and training for employees that remain with the partner are taken into account.

6. **Does DOE adequately address fundamental questions concerning the appropriate role of the government in supporting energy technology projects?** The taxpayers deserve better answers than have been provided by DOE to the following fundamental questions concerning tax dollars that have been or are proposed for energy supply and conservation technology projects:

a. **Would the technology development occur without a federal subsidy?** If the federal government is standing by with cash to support an energy technology project, it's hard to blame a private sector firm that steps forward to get a piece of the cash. However, the acceptance of tax dollars is not convincing evidence that the technology would not have been developed *without* the government subsidy. Therefore, it is quite appropriate for the Committee to ask DOE: Assuming that there are some examples of successful federal efforts to promote the development of energy technologies that are competing in the private sector, is there hard evidence that the technology would not have been developed without federal subsidies?

b. **Do federal subsidies inevitably flow to "second best" projects?** Most truly private sector firms are generally aware of the difficulties and delays, extra paperwork, contractual burdens, and administrative costs typically faced when dealing with federal agencies. The private firms may also be required to give up important information about technologies that would normally be proprietary if the project was developed without government funding. Furthermore, truly private sector firms are likely to be better equipped than a federal agency to understand potential markets, the promise of the technology, and the technical and market hurdles that would have to be overcome before a technology could be developed and sold profitably.

Recognizing these factors, a truly private sector firm seems likely to pursue *its most promising* technological opportunities without taking on the burden of dealing with the government. Is it inevitable that the technologies offered for federal support or participation are likely to be "second best" projects that a private firm finds unworthy of its independent pursuit?

c. **Do federal subsidies for energy technology projects displace potential private investment?** What really would happen to energy technology development projects proposed for federal support if the federal government was not standing by with ready cash to pay all or part of the technology development costs? The availability of federal subsidies may simply be too great a temptation for the technology developer to pass up. Is there any evidence that energy projects supported by DOE that have been successful would *not* have been developed without DOE funding or participation?

Furthermore, a truly private firm that wishes to pursue development of an energy technology would be reluctant to make the investment if there was a possibility that a *competitor* could obtain federal funds to pursue the same technology. In such circumstances, the private firm that would prefer to proceed *without* federal participation would be faced with three unsatisfactory alternatives: proceeding with only its own funds, hiring the lobbying staff needed to obtain federal funds, or stopping work on the technology.

d. **Do federal energy technologies subsidies delay, rather than speed up, the development and commercialization of technologies?** Is there a possibility that, for all the reasons identified above, federal involvement in energy development, demonstration and deployment activities results in delaying the successful development and real commercialization of energy technologies?

7. **Will DOE's capability be improved with its proposed "Portfolio" approach?** A recent letter from Acting Assistant Secretary of Energy Daniel Reicher indicates that:

> "DOE is developing a 'portfolio' approach to R&D which, among other things will not use a single resource price scenario, but rather, a set of scenarios that incorporate different levels of risk and uncertainty. This approach is under development and review, and includes participation by all parts of DOE, national laboratories and private contractors. We expect that the process will first be applied to the Fiscal 1998 budgets."

Development of this approach should not be left primarily to "DOE, national laboratories, and private contractors," since those organizations are all parties at interest in continuing the flow of tax dollars to their projects. Certainly, they should not be the ones to judge whether DOE has an adequate approach to assure wise use of tax dollars.

8. **Who in the Executive Branch is responsible for assuring that tax dollars for energy technologies are spent wisely?** As illustrated in Section F, below, it is difficult to determine whether DOE officials see their primary energy technology program responsibilities role as:
   - Guarding the public and taxpayer interests, *or*
   - Assuring the continued flow of tax dollars to the DOE/Contractor Complex.

9. **If DOE has the responsibility for guarding public and taxpayer interests, does it have the capability and will to do so?** In theory, DOE officials and staff, as employees of the federal government, probably have a greater responsibility to protect public and taxpayer interests than employees of DOE contractors. In practice, it seems doubtful that DOE officials and staff have the capability to exercise effective control over such a large, well-financed, politically astute and connected contractor complex.

F. <u>DOE's recent attempts to defend a major federal role in energy and defend its energy technology spending lack the objectivity that the Committee and the taxpayers deserve.</u>

DOE now spends about $3 billion of our tax dollars each year on energy RDD&D programs. There should be clear evidence that this money is well spent, but the evidence is unclear. During the past year, DOE has issued several documents that present its rationale for a major federal role in energy and that attempt to defend DOE's spending on energy supply and conservation development, demonstration, and deployment projects. These include:

- *Sustainable Energy Strategy, Clean and Secure Energy for a Competitive Economy*, July 1995 National Energy Policy Plan.

- Annexes to the report of the Task Force on Energy Research and Development, Secretary of Energy Advisory Board, U.S. Department of Energy, June 1995.

- Success Stories: The Energy Mission in the Marketplace, A Portfolio of Successful Investments in Applied Energy Research and Development by the U.S. Department of Energy, prepared by the Office of Policy.

- FY 1996 Congressional Budget Request, Budget Highlights, February 1995.

These documents help explain why taxpayers have a right to wonder who they can look to in the Executive Branch to protect their interests. Specifically, it's hard to read these documents without concluding that·

- They are merely a part of a rather expensive public relations program designed to keep tax dollars flowing to the DOE/Contractor Complex.

- DOE has a "conflict of interest" between its fiduciary responsibility and its effort to defend a large role for itself and continuing the flow of tax dollars.

Perhaps the best example of a document that raises doubts about DOE's role is the one titled, *Success Stories: The Energy Mission in the Marketplace.*

1. The document claims partial credit for DOE for claimed "economic successes," and "a key and enabling role in the resulting technology development" (p. 2), but is unclear -- to the point of being evasive -- concerning:
   - The specific role played by DOE.
   - The relative shares of the total cost of developing the technology borne by taxpayers via DOE and DOE's commercial "partner."
   - The likelihood that the claimed technological successes would *not* have occurred without spending tax dollars.

2. The document claims large future "savings" without any supporting evidence; e.g.:

   "Four technologies in one building technologies R&D program are expected to net more than $16 billion in economic savings to U.S. taxpayers by the year 2015." (p. 2)[15]

3. The document, on nearly every page, makes claims of "energy savings," cost reductions, and/or job creation without any documentation.

4. The document makes other claims without evidence to support them; e.g.:

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[15] For example, were EIA's older, now outdated energy price forecasts used in estimating the $16 billion?

a. "More fundamentally, the Department's record of R&D productivity has steadily improved over nearly two decades of R&D investment. Management techniques for R&D have become more sophisticated and less congressionally directed. They are squarely rooted in competition, driven by technical merit, and scientific peer review, and aligned with the needs of cost-sharing industrial partners." (p.2)

b. "The Department's programs support high-risk, precompetitive research. The Department's applied energy R&D investments are guided by a set of R&D management principles, which limits and carefully guides the use, and guards against the misuse, of public funds for R&D." (p. 3)

c. "Accordingly, a case can be made that an investment in the Department's applied energy R&D programs should not be viewed as a current operating expense on the deficit side of the Federal budget account, but rather as a high-risk portfolio of capital investments in the Nation's future, with a predictable portion resulting in significant economic paybacks that are already adding net revenue to the income side of the Federal ledger. These R&D investments not only produce public benefits, but make money for the U.S. Treasury." (p. 3)

The key question remains: Would the billions in tax dollars that have been spent by DOE and its predecessor agencies have been justified even if one accepted all the claims at face value and also gave DOE credit for the alleged "hundreds of scientifically and technically important developments" (p. 2) that DOE claims were omitted from the report?

Concluding Comments and Specific Suggestions

You have a formidable task, particularly since you and others in Congress may be the only line of defense that taxpayers have against an excessive federal role in energy and excessive spending of our tax dollars via DOE's energy technology development, demonstration, and deployment programs.

I'd like to conclude with several suggestions for specific actions that you might take:

1. Pursue the nine tough questions identified earlier in this statement concerning the appropriate role of the federal government in energy matters and the need for massive DOE spending that seeks to promote development, demonstration and deployment of technologies for the private, competitive economy. DOE probably will contend that they have been answered before. But, they should be asked again and again until convincing answers are provided.

2. Insist the DOE and its contractors present hard evidence and documentation of claims to support their requests for tax dollars -- not public relations documents. Insist on more candor and objectivity.

3. Address the fundamental question of determining who, if anyone, in the Executive Branch has the responsibility and the capability to protect taxpayer interests in the wise use of money that flows through DOE for energy technology projects.

4. Watch closely the development of the planned "portfolio approach" to energy technology that is being developed within the DOE/Contractor Complex and take steps to assure appropriate public and Congressional review of it.

5. Require that an analysis be done by an objective, non-government organization (perhaps one of the "think tanks") of the relationship between the dollars that flow out of the U.S. for oil imports and the payments that flow back to U.S., directly or indirectly, for merchandise and service exports.

6. Determine, perhaps with assistance of the GAO, the extent to which *tax dollars administered by DOE* are finding their way into lobbying efforts designed to continue the flow of tax dollars to DOE programs, including:
   - Lobbying carried out by DOE laboratories and other contractors.[16]
   - Dues payments by DOE laboratories and other contractors to coalitions, trade associations, professional societies, advisory committees, and other groups that work in support of DOE-administered programs.
   - Lobbying by officials of state energy offices that receive funds from DOE.[17]
   - DOE contributions to conferences that are used, in whole or part, to generate support for DOE programs.[18]
   - Washington offices of DOE laboratories and other contractors where the staff spend a significant portion of their time lobbying DOE staff or the Congress for funds for the laboratories and other contractor activities.
   - Payments to contractors to help DOE or DOE contractors develop statements, testimony, fact sheets, issue papers, or other documents that are used to help support DOE RDD&D programs.

* * *

Thank you for the opportunity to appear today. I would be pleased to answer your questions.

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[16] For example, a program director at the National Renewable Energy Laboratory in Colorado informed a visiting advisory committee (February 8-9, 1993) that one of the first steps that an effective program director must take is to engage a contractor who can take on the job of lobbying for funds for the program.

[17] Press reports indicate that Secretary O'Leary in a speech to the National Association of State Energy Officials on February 27, 1996 asked her audience to lobby Congress for increased funds for DOE energy efficiency and renewable programs.

[18] For example, speakers at a "White House Conference" on global climate issues, partially funded by DOE, that was held at George Washington University on April 21, 1994, exhorted attendees to help win Congressional approval for DOE's massive $1+ billion in proposed spending for renewable energy and conservation programs.

Attachment #1

Average Annual Energy Prices in Constant 1994$

1973 to 1995

3/12/96

Year	Crude Oil* $ per Bbl.	Natural Gas Wellhead** $ per Mcf	Motor Gasoline (all types)- Retail (Include taxes) $ per gallon	Refinery Price Finished Gasoline for Resale (without taxes) $ per gallon	Residential Heating Oil Retail $ per gallon	Residential Natural Gas $ per MMBtu	Residential Electricity Cts. per kWh
1973	12.09	0.65				3.82	7.4
1974	34.13	0.82				3.90	8.5
1975	34.65	1.09				4.25	8.7
1976	31.74	1.37				4.66	8.7
1977	32.20	1.75				5.21	9.1
1978	29.99	1.87	1.34	0.89	1.01	5.27	8.9
1979	41.12	2.24	1.67	1.21	1.34	5.65	8.7
1980	58.92	2.76	2.12	1.64	1.69	6.40	9.4
1981	58.97	3.15	2.15	1.69	1.90	6.83	9.9
1982	50.22	3.68	1.92	1.46	1.74	7.74	10.3
1983	42.09	3.72	1.76	1.27	1.55	8.70	10.3
1984	39.91	3.68	1.66	1.15	1.51	8.46	10.4
1985	36.11	3.36	1.60	1.12	1.41	8.19	10.4
1986	18.24	2.53	1.21	0.69	1.09	7.60	9.6
1987	22.91	2.11	1.21	.0.74	1.01	7.00	9.3
1988	17.74	2.06	1.17	0.70	0.99	6.67	9.1
1989	21.14	1.98	1.24	0.76	1.05	6.60	8.9
1990	24.41	1.92	1.37	0.88	1.19	6.51	8.8
1991	20.16	1.77	1.29	0.75	1.10	6.28	8.7
1992	19.10	1.83	1.25	0.71	0.98	6.18	8.6
1993	16.51	2.09	1.20	0.64	0.93	6.30	8.5
1994	15.51	1.88	1.17	0.60	0.88	6.41	8.4
1995 (Est.)	16.81	1.60	1.18	0.61	0.84	6.04	8.2

* Refiners acquisition cost of imported crude oil   ** Lower-48 states wellhead prices

Source: Energy Information Administration, Monthly Energy Review, Tables 9.1, 9.4, 9.6, 9.8c, 9.9, & 9.11.

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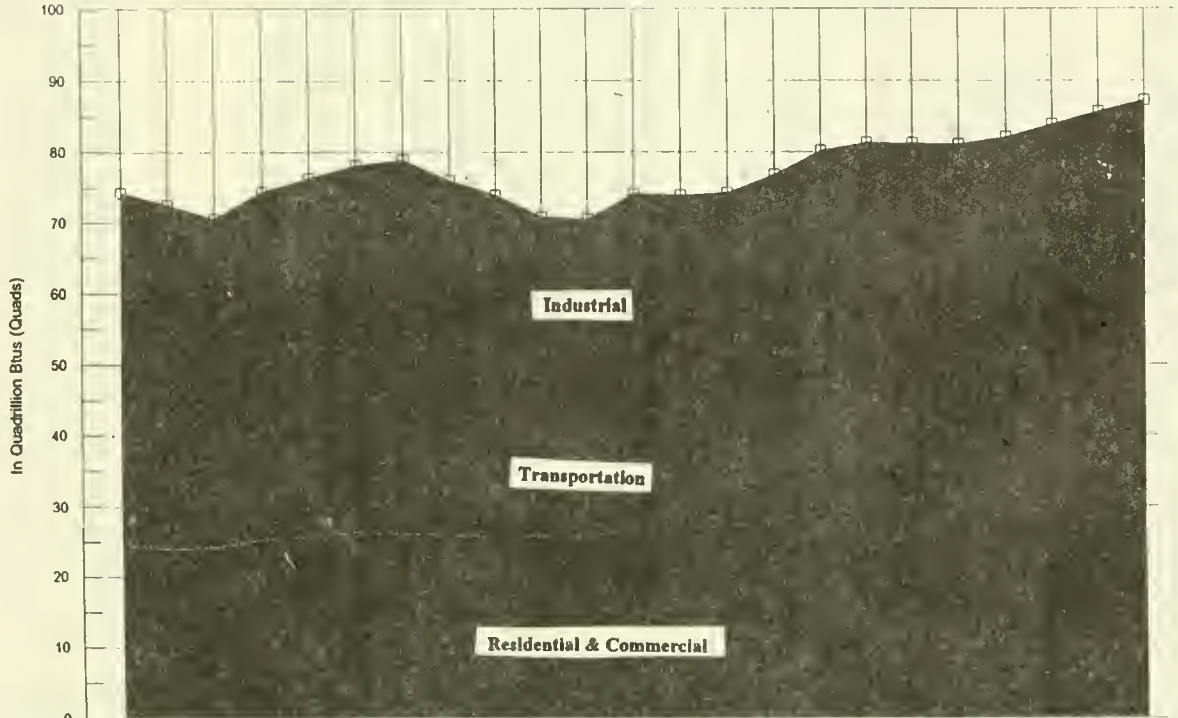
Attachment #2

U.S. Energy Consumption - by End Use Sector: 1973-1995



	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Resident & Commer.	24.1	23.7	23.9	25.0	25.4	26.1	25.8	25.7	25.2	25.6	25.6
Transportation	18.6	18.1	18.2	19.1	19.8	20.6	20.5	19.7	19.5	19.1	19.1
Industrial	31.5	30.7	28.4	30.2	31.1	31.4	32.6	30.6	29.2	26.1	25.8
□ Total	74.3	72.5	70.5	74.4	76.3	78.1	78.9	76.0	74.0	70.8	70.5

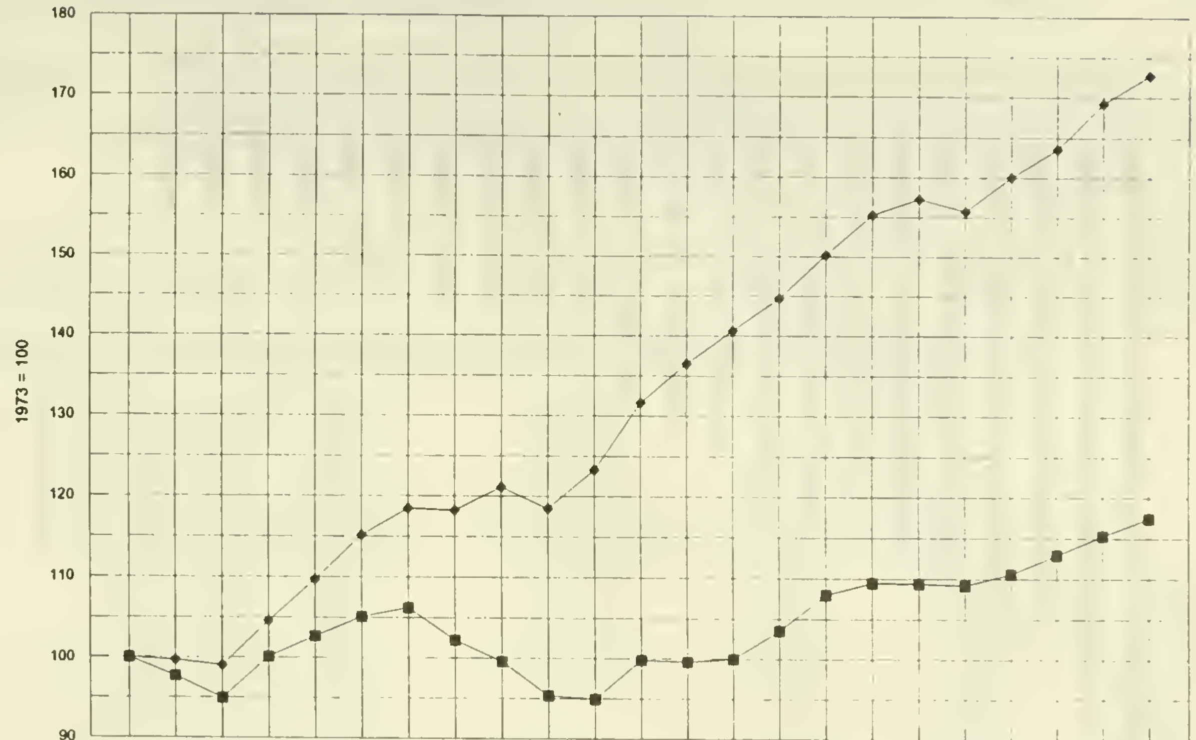
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Resident & Commer.	26.5	26.7	26.9	27.6	28.9	29.4	28.8	29.4	29.1	30.2	30.7	31.3
Transportation	19.8	20.1	20.8	21.4	22.3	22.6	22.5	22.1	22.5	22.9	23.5	23.9
Industrial	27.9	27.2	26.6	27.8	29.0	29.4	29.9	29.6	30.6	30.8	31.5	32.1
□ Total	74.1	74.0	74.3	76.9	80.2	81.3	81.3	81.1	82.1	83.9	85.6	87.3

Data source U.S. Energy Information Administration, Monthly Energy Review, January 1995, Table 2.2
1995 energy consumption estimated by EMPA based on 11 months of actual data

Attachment #3

Indices of Change from 1973 in U.S. Energy Consumption & Real GDP

1973 = 100



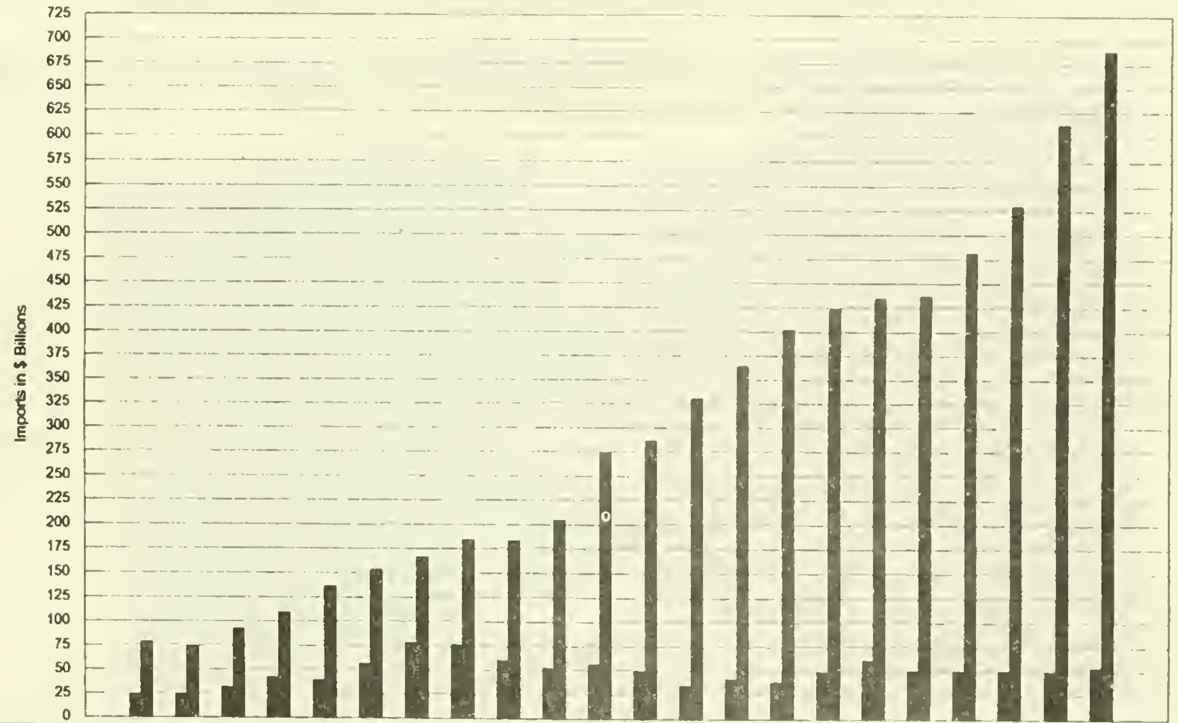
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
■ Energy Consumption	100.0	97.7	95.0	100.1	102.7	105.1	106.2	102.3	99.6	95.4	94.9	99.8	99.6	100.0	103.5	108.0	109.5	109.4	109.2	110.6	112.9	115.3	117.5
◆ Gross Dom. Product	100.0	99.6	99.0	104.6	109.7	115.2	118.5	118.2	121.1	118.5	123.3	131.7	136.6	140.7	144.7	150.2	155.3	157.3	155.8	160.0	163.6	169.2	172.8

Data Sources U.S. Energy Information Administration, Monthly Energy Review, Table 2.2, and Economic Report of the President, February 1996, Table B-2
1995 energy consumption estimated by EMPA based on 11 months of actual data

Attachment #4

Oil Imports Make up a Declining Share of Total U.S. Merchandise Imports

Petroleum and Other Merchandise Imports -- In Billions of Current or Nominal Dollars - 1974-1995



	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Petroleum Imports - $	24.7	25 2	32.2	42 4	39.5	56.7	78.6	76.7	60.5	53.2	56.9
Other Merchandise - $	78.7	74.1	92.4	109 2	136 5	153 6	166 6	184.3	183.4	204.8	273.8
Petroleum share - %	23 8%	25.4%	25.9%	28.0%	22.5%	27 0%	32.1%	29 4%	24 8%	20 6%	17.2%

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Petroleum Imports - $	50.5	35.1	42 3	38 8	49 7	61.6	51.4	51 2	51.0	50 8	54 4
Other Merchandise - $	286.1	330.3	364 0	402 2	423.5	434 5	437.1	481 4	529.6	612.4	689 0
Petroleum share - %	15.0%	9.6%	10 4%	8.8%	10.5%	12.4%	10.5%	8 6%	8 8%	7.7%	7.3%

Data Sources: U S. Department of Energy, Energy Information Administration, Monthly Energy Review, Table 1.6
U.S Dept of Commerce, U.S International Trade in Goods and Services, December 1995, Exhibits 12 & 15

Attachment #5

DOE /EIA Annual Energy Outlook Reference Case Price Forecasts: 1984-1996

(Data as shown in AEO Reports but Converted to 1994$)

Energy Product	Publication	Release Date	Price Projections shown in reports - converted to 1994$ 1995	2000	2005	2010
A. Crude oil - Average refiner acquisition cost for imported crude oil - dollars per barrel						
	AEO 1984	1/85	55.40			
	AEO 1985	2/86	40.09			
	AEO 1986	2/87	34.62	42.77		
	AEO 1987	3/88	28.24	38.79		
	AEO 1989	1/89	25.01	34.00		
	AEO 1990	1/90	23.70	32.30	38.22	42.87
	AEO 1991	3/91	26.72	28.62	34.52	38.08
	AEO 1992	1/92	23.16	29.39	33.96	37.19
	AEO 1993	1/93	21.34	24.55	27.98	31.41
	AEO 1994	1/94		21.61	25.97	29.37
	AEO 1995	1/95		19.52	21.94	24.62
	AEO 1996	1/96		19.27	21.86	23.70

What did price turn out to be? (in 1994$) 16.81

Data Source: Energy Information Administration, Annual Energy Outlook . 1984-1996, Tables A1

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Attachment #6

DOE /EIA Annual Energy Outlook- Reference Case Price Forecasts: 1984-1996

(Data as shown in AEO Reports but Converted to 1994$)

Energy Product	Publication	Release Date	Price Projections shown in reports - converted to 1994$ 1995	2000	2005	2010
B. Natural gas wellhead price - Lower 48 onshore & offshore - dollars per Mcf						
	AEO 1984	1/85	6.99			
	AEO 1985	2/86	5.38			
	AEO 1986	2/87	5.11	7.17		
	AEO 1987	3/88	3.59	5.07		
	AEO 1989	1/89	3.40	4.75		
	AEO 1990	1/90	2.61	3.75	5.07	6.54
	AEO 1991	3/91	2.36	2.91	4.55	5.61
	AEO 1992	1/92	2.25	3.03	4.12	5.18
	AEO 1993	1/93	2.19	2.74	3.65	3.95
	AEO 1994	1/94		2.52	3.01	3.62
	AEO 1995	1/95		2.18	3.08	3.46
	AEO 1996	1/96		1.89	1.99	2.15
What did price turn out to be? (in 1994$)			1.60			

Data Source: Energy Information Administration, Annual Energy Outlook . 1984-1996, Tables A1

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Attachment #7

COMPARISON OF THREE DOE ENERGY DEMAND FORECASTS

	Forecasts of Total U.S. Primary Energy Consumption (in quadrillion Btus)		
	2000	2005	2010
National Energy Strategy Current Policy Baseline* (2/91)	100.3	108.8	118.1
Annual Energy Outlook 1991 Reference Case** (3/91)	95.63	101.40	106.90
Annual Energy Outlook 1996 Reference Case*** (1/96)	95.07	100.38	104.69

* U.S. Department of Energy, *National Energy Strategy*, Technical Annex 2, February 1991, Table B-5, p.100.
** U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1991*, March 1991, Table A1, p. 43
*** U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 1996*, January 1996, Table A1, pp. 70-71

Attachment #8

3/12/96

Federal Outlays for the Conduct of Energy-Related Research, Development Demonstration, & Deployment (RDD&D) Activities

Does not include capital spending for construction and major equipment

	Outlays for the Conduct of RDD&D - In Millions of Dollars			
	Non-Defense Atomic Energy General Science		Energy RDD&D	
Fiscal Year	Current $	Constant 1994$	Current $	Constant 1994$
1949	$40	$207		
1950	49	250		
1951	50	253		
1952	60	299		
1953	63	311		
1954	64	312		
1955	73	351	$27	$130
1956	78	371	42	200
1957	91	427	77	361
1958	126	583	109	505
1959	157	719	129	591
1960	183	825	159	717
1961	214	952	173	770
1962	231	1,015	397	1,744
1963	264	1,146	462	2,006
1964	288	1,232	502	2,148
1965	309	1,297	478	2,006
1966	339	1,382	452	1,843
1967	359	1,419	478	1,890
1968	281	1,065	515	1,952
1969	385	1,394	469	1,698
1970	393	1,349	451	1,549
1971	380	1,240	454	1,482
1972	370	1,158	329	1,030
1973	372	1,102	379	1,123
1974	292	796	525	1,431
1975	310	771	933	2,321
1976	257	605	1,424	3,353
TQ	72	160	521	1,154
1977	267	592	2,197	4,868
1978	274	564	2,542	5,232
1979	305	579	3,304	6,270
1980	345	600	3,289	5,718
1981	501	797	3,681	5,858
1982	401	600	3,330	4,984
1983	464	666	2,728	3,919
1984	505	698	2,762	3,817
1985	510	682	4,249	5,685
1986	510	664	2,622	3,416
1987	576	728	2,321	2,932
1988	618	753	2,287	2,787
1989	680	795	2,454	2,870
1990	784	879	2,342	2,627
1991	834	899	2,501	2,697
1992	784	823	2,593	2,721
1993	789	807	2,517	2,575
1994	669	669	2,654	2,654
1995	700	683	2,959	2,886
1996	708	673	3,060	2,907
Totals	$17,374	$37,143	$65,877	$109,424

Data Source: Budget of the United States Government, Fiscal Year 1996, Table 9.8.; Constant $ for 1949-58 estimated.

Chairman ROHRABACHER. Mr. Romm.

STATEMENT OF MR. JOSEPH J. ROMM, ACTING DEPUTY ASSISTANT SECRETARY FOR ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY, WASHINGTON, DC

Mr. ROMM. Mr. Chairman, members of the Subcommittee, I am delighted to be here. The decisions that you make about energy research and development today will have a profound impact on the nation's security, our economy and our environment.

I do want to clear up one misconception. I don't believe the world is running out of oil or that there is an imminent world shortfall.

What I believe is that most of the world's easily recoverable oil is in one place. And, it's a very unstable place.

The issue, I think, is of importance, because our last war, the Persian Gulf war, was fought in the region that contains most of the world's oil, the reserves. And, our last recession and, indeed, our last three recessions, all followed oil price spikes.

And, the trade deficit is also of great concern to me. Most projections have it doubling to $100 billion per year just for oil in a 10 to 15 year time period.

But, I think, from the security point of view, the biggest concern is that the Persian Gulf's share of the world oil export market is projected to hit about 67 percent in 10 to 15 years. And, if prices are actually lower than EIA forecasts in their reference case, then the situation will be even worse.

And, the Persian Gulf will control three-quarters of the world market for export. And, this is far higher than their highest level ever, which was 67 percent in 1974.

At the same time, what you would see is the Persian Gulf revenues would triple from $80 billion per year today to $250 billion per year over the next 15 years. That would be more than $1 trillion of extra money flowing into one of the most unstable regions in the world.

So, it is the scenario of growing control and dominance of the world oil market by the Persian Gulf coupled with the region's inherent instability that creates, I think, a risk of a price shock and a crisis that, as responsible holders of the public trust, we need to care about. Other plausible scenarios exist, but I wouldn't want to bet America's security or economy on them.

I would like to clear up another misconception. This is not just the Department of Energy's view. Many, many experts share our concern.

Don Hodel, Reagan's Energy Secretary, said last year, "The world is on the brink of another oil shock." We are, "sleepwalking into a disaster."

Irwin Stelzer, of The American Enterprise Institute, said last year the next oil shock "will make those of the 1970's seem trivial by comparison."

And, finally, Senate Majority Leader, Robert Dole, said last March, "The second inescapable reality of the post-20th century world is that the security of the world's oil and gas supplies will remain a vital, national interest to the United States and of the other industrial powers."

So, I think the Department of Energy is in pretty good company in being concerned about energy security.

As for price, both Dan Yergin and James Schlesinger have predicted that prices will rise in the coming years, as have a number of petroleum geologists. And, a recent "Fortune" magazine cover story, "Your Last Big Play in Oil," listed several billionaires and big mutual fund managers betting heavily that oil prices would rise.

Considering that the last war we fought was in the Persian Gulf and the number of experts warning us of the dangers, as responsible holders of the public trust, who among us is prepared to answer the following question some time in the next decade. Why did you fail to take inexpensive and prudent actions when you heard the warnings and understood the dangers?

Energy R&D is clearly one of those actions. On the supply side, in the area of fossil energy R&D, we work to reduce the finding and developing costs for oil and gas.

On the demand side, we have a comprehensive strategy to develop triple efficiency cars that will use petroleum in automobiles much more efficiently and then to develop a number of alternative fuels for cost competitive use, including electricity as a transportation fuel, to advance battery research, using biofuels from crops, crop waste and municipal solid waste, gas turbine engines that would run on natural gas and light duty vehicles and, of course, fuel cells which are nearly pollution free and could run on a variety of sources.

By 2010, this diversified investment portfolio, we believe could reduce oil imports by 1.5 million barrels of oil per day, a $1 billion per year savings to the country. It would help counter the foreign threat to raise prices and would limit the economic and geopolitical impact of the Persian Gulf.

Were Congress to make the cuts that they are thinking about, it would make the oil crisis scenario more likely. If a crisis were to come, our nation's response would necessarily be more reactive and burdensome. Clearly, the private sector has been scaling back R&D in general and energy R&D in particular.

I think that, as Mr. Roemer says, it's worth pointing out that we don't just do energy R&D for one reason, such as reducing oil imports. We have a variety of other goals that we try to meet at the same time.

In particular, forecasts of low energy prices does not mean that we don't need energy R&D. Quite the reverse, as Mr. Roemer said. Energy R&D has helped keep energy costs low.

He mentioned the Sandia polycrystalline drill bit. He mentioned the electronic ballasts, the heat mirror window, which I brought.

Twenty-five million dollars in federal R&D spending in the late 1970's and early 1980's have saved American consumers and businesses $5 billion. These are well documented savings.

What I think is interesting for the Committee is that all of these technologies were developed in the late 1970's and early 1980's, a time when many were forecasting steadily rising energy prices. Yet, they have proven astonishingly cost effective, achieved significant market share, racked up their huge national savings in the past 10 years, a time of relatively low energy prices.

So, I think you see the leap-frog technologies that the Department has been investing in are worth pursuing really irrespective of price forecasts.

I think that what low prices fundamentally mean is that technological optimists were right. And, to achieve low costs in the future will require a constant stream of new, more efficient supply and demand technologies.

Let me just show one chart, if I could. This renewable energy cost curve, this comes from Royal Dutch Shell, which is the world's most profitable oil company and widely regarded for its scenario planning. And, as "The Economist" magazine noted, "The only oil company to anticipate both the 1973 oil price boom and 1986 price bust was Royal Dutch Shell."

What is interesting about this chart is that it shows that Shell believes a very plausible scenario is that photovoltaics, wind power and biomass will continue to decline in costs faster than traditional sources of energy and that even if the cost of electricity from traditional sources declines, renewable energy will out-compete it within two to three decades. And, they actually project numbers as high as a $150 billion per year annual market in sales for renewable energy within 30 to 40 years.

So, you can see, we have completely changed the program design of the Department of Energy's programs. And, we are quite well aware that energy prices could decline.

We think photovoltaics, we think that our work in fossil energy, gas is going to be price competitive even with declining prices.

I think the last point that needs to be made, again, is the multiple goal. Pollution has a very high cost to the nation.

The Department of Energy R&D is the single most cost effective way to prevent pollution. And, this fact alone would justify the investment.

Gutting these programs would mean a higher environmental cost in the future. And, I think that's a terrible burden to pass on to our children.

Thank you.

[The prepared statement of Mr. Romm follows:]

STATEMENT OF

JOSEPH ROMM

ACTING PRINCIPAL DEPUTY ASSISTANT SECRETARY
OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

UNITED STATES DEPARTMENT OF ENERGY

before the

SUBCOMMITTEE on ENERGY AND ENVIRONMENT

of the

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

MARCH 14, 1996

<u>Introduction</u>

Mr. Chairman, members of the Subcommittee, I am delighted to appear before you to discuss a subject of paramount importance to our national security, our economic well-being, and our environmental quality of life: energy research and development (R&D).

Before elaborating on the main focus of my remarks today—the possibility of an oil crisis in the next decade and its implications for energy R&D—one point deserves mention. America's growing dependence on imported oil and the world's growing dependence on Persian Gulf oil are not the only justification for our energy R&D portfolio. That is but one of many important goals of our nation's energy policy.

We are working to maximize U.S. energy productivity; that is, to keep the costs of consuming energy low for American businesses and consumers. Since this is a hearing on energy forecasting, it seems worthwhile to examine the thinking of the Royal Dutch/Shell Group, which in the past has been remarkably successful in anticipating our energy future, and which believes that continued advances in renewable energy technology will be the key to keeping the costs of using energy low in the next century.

A third goal of energy R&D is improving the national and global environment by preventing pollution. As *The Economist* magazine has noted, "Using energy in today's ways leads to more environmental damage than any other peaceful human activity." In other words, energy production and consumption imposes other costs on society beyond what people pay at the pump or in their utility bill. Energy R&D can lower environmental costs while also lowering energy bills. Supporting a clean environment means supporting energy R&D.

Finally, as with all prudent federal R&D investments, we are partnering with the private sector to maintain U.S. scientific and technical leadership and to develop advanced technologies that can serve as the engines of economic and job growth in the next century. Our energy R&D is aimed at achieving all of these goals simultaneously. Fortunately, most of the technologies DOE invests in support multiple goals and then produce multiple benefits. Efforts to achieve the first goal, keeping America secure by reducing our dependence on foreign oil, will be discussed first.

The Oil Crisis Scenario

Predictions are always risky, especially where oil is concerned, but fundamental trends in oil demand and supply underlie a growing consensus among energy experts that energy security concerns are reemerging. It is now generally agreed among forecasters that global demand, mainly from developing nations, will grow by 22-34 percent over the next 15 years. According to the DOE's independent Energy Information Administration (EIA), the world will consume another 20 million barrels of oil a day by the year 2010, up from 69 MMBD in 1995. The International Energy Agency projects even higher growth in demand, following the inexorable tide of population growth, urbanization, and industrialization. As but one example, *Fortune* magazine noted last October that if China's and India's per capita energy consumption rose to that of South Korea, and their population increased at currently projected rates, "these two countries alone will need a total of 119 million barrels of oil a day. That's almost double the world's entire demand today."

The Persian Gulf, with two-thirds of the world's oil reserves, is projected to supply more than three-fourths of the growth in world oil exports, according to the EIA. Within ten years, the Gulf's share of the world export market may surpass its highest level to date, 67%, which was attained in 1974. The EIA predicts that in the face of increased demand, oil prices will rise slowly to $24 a barrel in 2010. If, instead, they remain low, the Gulf's share of the world export market may rise to 75% in 2010.

America's growing dependence on imported oil, and the world's growing dependence on Persian Gulf oil, have several potentially serious implications for the nation's economic and national security. First, this same forecast holds that the United States will be importing nearly 60% of its oil within a decade (and, if oil prices turn out to be lower, our dependence on imports will be higher). Our trade deficit in oil is expected to double to nearly $100 billion a year by that time, a large and chronic drag on our economy.

To the extent that the Gulf's recapture of the dominant share of the global oil market makes price hikes more likely, the U.S. economy, indeed the world economy, will be at risk. Since the 1950s there have been six oil supply disruptions of two million barrels a day or more, an average of one every five to ten years, all originating in the Middle East. Although oil imports as a percent of gross domestic product have decreased significantly in the past decade, our economic vulnerability to rapid increases in the price of oil persists. Since 1970, sharp increases in the price of oil have always been followed by U.S. economic recessions. One analysis by DOE's Oak Ridge National Laboratory in Tennessee put the cost to the U.S. economy over the past 25 years of over reliance on OPEC oil, including the cost of price shocks, at $4 trillion. Oak Ridge has estimated that a price shock in 2005 could cost the U.S. economy hundreds of billions of dollars.

Second, if current energy forecasts prove out, the Persian Gulf nations' oil revenues may triple from $80 billion a year today to nearly $250 billion a year in 2010—a huge geopolitical power shift of great concern, especially since some analysts predict increasing internal and regional pressure on Saudi Arabia to alter its pro-Western stance. This could represent more than a $1 trillion increase in wealth for Persian Gulf producers over the next decade and a half. And the breakup of the Soviet Union, coupled with Russia's difficulty in earning hard currency, means that for the next decade and beyond, pressure will build to make Russia's most advanced military hardware and technical expertise available to well-heeled buyers.

The final piece in the geopolitical puzzle is that during the first oil crisis in the early 1970s, the countries that were competing with us for oil were our NATO allies, but during the next oil crisis, a new important complication will arise: the competition for oil will increasingly come from the rapidly growing countries of Asia. Indeed, in the early 1970s, East Asia consumed well under half of the oil used by the United States; by the time of the next crisis, however, East Asian nations will probably be consuming more oil than we do. These nations are already establishing stronger diplomatic ties with Persian Gulf producer countries.

Will all of these factors trigger an energy crisis? No one can say for sure, but it is clearly a plausible scenario. A report released last June on energy R&D by a Task Force of independent energy analysts, led by oil expert Dan Yergin, the Pulitzer-winning author of *The Prize*, noted several factors that are more favorable since the turmoil of the 1970s, including a "more flexible and diversified" oil supply system, including the Strategic Petroleum Reserve and the rise of futures markets, and "technological innovation that has driven down costs and brought new efficiencies to the entire spectrum of energy supply." The Yergin panel noted "energy efficiency has also had a dramatic impact. Today, the United States is 30 percent more energy efficient than in 1973—the equivalent of saving 17 million barrels per day of oil."

The Yergin Panel also discussed new challenges to our energy security, such as the rapid growth in oil and energy demand in the developing world, particularly Asia, "pointing to new competition for supply"; a tightening world oil market; declining production in the United States and Soviet Union; and "few major discoveries since the middle 1980s." I would add one more concern: while many sectors of the economy have reduced their dependence on oil, such as electric utilities, the transportation sector remains almost wholly reliant on oil use, and fuel-switching options in that sector will remain limited until we develop new technologies and infrastructure.

Thus, the threat to our security remains a serious one. This is not merely the view of the Department of Energy. Consider what a variety of energy experts from every end of the political spectrum have said recently. President Reagan's Energy Secretary Don Hodel said last year "The world is on the brink of another oil shock," and we are "sleepwalking into a disaster." He predicts a major oil crisis within a few years. The American Enterprise Institute's Irwin Stelzer says the next oil shock "will make those of the 1970s seem trivial by comparison." Oil expert Dan Yergin says, "People seem to have forgotten that oil prices, like those of all commodities, are cyclical and will go up again." James Schlesinger, President Carter's Energy Secretary has said, "by the end of this decade we are likely to see substantial price increases." Last March, Senate Majority Leader Robert Dole delivered a speech at the Nixon Center for Peace and Freedom and said:

"The second inescapable reality of the post-20th century world is that the security of the world's oil and gas supplies will remain a vital national interest of the United States and of the other industrial powers. The Persian Gulf ... is still a region of many uncertainties....

In this "*new energy order*," many of the most important geopolitical decisions—ones on which a nation's sovereignty can depend—will deal with the location and routes for oil and gas pipelines. In response, our strategy, our diplomacy and our forward military presence need readjusting."

In July testimony before Congress, Federal Reserve Chairman Alan Greenspan, not known for being an alarmist, raised concerns that the rising trade deficit in oil "tends to create questions about the security of our oil resources."

Concerns about new oil market trends have even made it into financial magazines. In an October 1995 article entitled "Your Last Big Play in Oil," *Fortune* magazine listed several billionaires and "big mutual fund managers" who were betting heavily that oil prices would rise significantly. The magazine goes on to suggest an investment portfolio of "companies that are best positioned to profit from the coming boom."

The Energy R&D Solution

Considering that the last war America fought was in the Persian Gulf a little over five years ago, and that there are a number of experts warning us of the dangers, as responsible holders of the public trust who among us is prepared to answer the following question sometime in the next decade: Why did you fail to take reasonable and prudent actions when you heard the warnings and should have understood the dangers? This is especially true since the energy R&D needed to respond to growing dependence on Persian Gulf oil achieves many other national benefits, each justification enough for the investment, including making more efficient use of energy, a reduced trade deficit, more American jobs, and an improved national and global environment.

Since the focus of the hearing is energy R&D, I will focus on the technological response to growing energy security concerns, which draws on America's traditional leadership in research and development. Here there has been tremendous progress. Given the uncertain nature of long-term high-risk R&D in leap-frog technologies, the prudent approach is to explore a number of possibilities on both the supply and demand side.

The Department has invested in exploration and development technology and related programs designed to enhance industry competitiveness by reducing the costs of finding and developing oil and gas resources within the United States. Advances in 3-D seismic exploration technology and the polycrystalline drill bit developed in DOE laboratories are two examples of this effort. We are also in the continuous process of consulting research managers from industry to ensure the Department's oil and natural gas R&D portfolio is properly focused and structured to contribute to industry's needs.

The Department has also been investing in developing cars and trucks that are highly fuel-efficient as well as ones that would run on fuels other than petroleum, including electricity, biofuels from crops, crop waste, and municipal solid waste, and natural gas.

Consider biofuels. Last year, research sponsored by the Department created a new genetically engineered organism that enhances the fermentation of cellulose, increasing the rate of conversion and yield of ethanol. This advance, described in the prestigious journal *Science*, was named as one of the 100 most technologically significant advances of the year by R&D magazine. This and other federally-supported advances have brought the projected cost of making ethanol from $3.60 per gallon 15 years ago, to about $1.00 today. If biofuels R&D continues to be funded at current levels, ethanol from fast-growing dedicated crops, crop waste, and wastepaper could be produced for as little as sixty to seventy cents a gallon by 2005.

Technologies are also being developed to make possible a superefficient hybrid vehicle that has both a small engine and an energy storage device, such as a battery or flywheel. Supporting technologies include lightweight, super-strong materials, and advanced engines. This research is part of a collaboration among several federal agencies, selected national laboratories, and the auto industry. The goal of this Partnership for a New Generation of Vehicles is to design and construct a prototype clean car by 2004 that has three times the fuel efficiency of existing cars and very low emissions, but comparable or improved performance, safety, and cost. Such a car would replace imports of oil with brainpower -- domestically produced advanced technologies.

Another direction that research is taking is toward advanced batteries for use in electric cars—among them the nickel metal-hydride battery—which promises to double the range of vehicles now using existing lead-acid batteries. In conjunction with the advances in clean power generation described below, such batteries hold out the promise of replacing imported oil with domestically produced electricity.

Along with ethanol and electricity, the Department is seeking to expand natural gas as a transportation fuel. Since 1992, the DOE has significantly increased its budget for R&D into enhancing the supply and efficient use of natural gas. We are developing gas turbine engines for light duty vehicles. In general, the DOE is seeking to encourage the wider use of a variety of alternatively-fueled vehicles and help to establish a nationwide infrastructure for fueling those vehicles.

Probably the one technology most experts would agree has the best chance over the long term of significantly reducing petroleum use in the transportation sector is fuel cells. These are compact, modular devices that generate electricity and heat with high efficiency and virtually no pollution. They run on hydrogen converted from fuels such as natural gas or methanol. NASA developed early versions of fuel cells for use on space missions. Over the past two decades the DOE has invested considerable resources to develop several types of fuel cells that will soon be used to power cars, trucks, utilities, commercial buildings, and industries. The Japanese government has been increasing its fuel cell R&D budget at 20% per year for the past five years, and Japanese companies are less than five years behind U.S. companies in this technology. The Europeans are considering significant increases in fuel cell funding. Sustained federal support might well give America the lion's share of a multi-billion dollar annual global market.

The likely outcome of all of the above mentioned programs should not be overstated: We will not achieve energy independence in the next fifteen years. Moreover, we do not need to. What this investment portfolio does offer is a chance in the coming years to counter foreign threats to raise the price of oil dramatically, and place some restraint on the economic and geopolitical impact of the increased dependence on Persian Gulf oil. At the same time, domestic jobs are created when money that would have gone overseas to purchase foreign oil goes instead to U.S. workers manufacturing technologies for highly-efficient cars and trucks, or for growing domestic biofuels.

What's more, the rapid population growth and urbanization of developing nations, coupled with the harsh pollution that characterizes most major urban centers in those nations, ensures a tremendous market for low-emission, super-efficient automotive technology. Our industrialized competitors have one inherent advantage in the race to develop the supercar: much higher gas prices of \$3 to \$4 a gallon. Fuel-efficiency matters more in their economies, and vehicles that use alternative fuels will be cost-competitive in the market sooner. The primary counterbalance to that advantage is U.S. technological leadership in most relevant areas.

Severe cuts in energy R&D budgets would bring an end to that counterbalance. The last time America ignored the warning signs of growing dependence on imported oil, the Japanese were able to seize a significant share of the U.S. auto market with fuel-efficient cars. We already spend a hundred times as much money on military forces in and around the Gulf than we do on technologies to minimize dependence on Gulf oil. Yet as the independent commission led by Daniel Yergin noted last June, "unlike the Allied Coalition in the Gulf Crisis, innovation and technological creativity cannot be summoned into service on short notice."

That our Nation's and the world's dependence on Persian Gulf oil will grow over the next decade seems inevitable. This is particularly true since most projections assume continued, significant technological progress in bringing down the cost of domestic production, in developing alternatives, and in using oil and other energy resources efficiently. Those projections have not yet factored in the possible withdrawal of the Federal government from its significant role in fostering the development and deployment of those technologies.

Keeping energy costs low

Unlike some DOE programs of the late 1970s that required oil at $80 a barrel to be competitive, current DOE energy programs are aimed at making alternatives competitive even if oil prices decline. Indeed, in addition to our efforts to improve America's energy security, another key goal of the nation's energy policy is maximizing energy productivity to help keep the costs of consuming energy low.

Some might argue that the fact that EIA projects low energy costs over the next two decades means that energy isn't a major national problem and therefore we don't need to keep investing in new technologies. I've already argued that we will be getting increasingly dependent on Persian Gulf oil in the next decade, but there is a much more important point. Low energy prices don't argue against energy R&D. Quite the reverse. Energy R&D has helped keep energy prices low, and can do so in the future.

The Yergin Task Force noted many such examples. On the supply side, for instance, Sandia National Laboratory in New Mexico solved a drill-bit problem that industry scientists had tried for two decades to solve. The resulting polycrystalline diamond drill bit lowers the cost of drilling by as much as $1 million per well, reduces lost-time accidents and fatalities, has annual sales in excess of $200 million, and has delivered a total national benefit in excess of $1 billion.

On the demand side we have had equally remarkable successes. For instance, four building technologies—fluorescent lamp electronic ballasts, advanced energy-efficient windows, analytical software for energy-efficient building design, and a high-efficiency refrigerator/freezer compressor—developed with DOE support of about twenty-five million dollars, have already saved consumers and businesses a net of more than $5 billion in lower energy bills. And, this does not even count the reduction in other costs to the nation, such as reduced pollution.

What is striking about these technologies is that they were all developed in the late 1970s and early 1980s, at a time many were forecasting steadily rising energy prices. Yet they have all proven astonishingly cost-effective, achieved significant market share, and racked up their huge national savings in the past decade, a time of relatively low energy prices. This demonstrates that the kind of leap-frog technologies the DOE invests in are worth pursuing regardless of price forecasts. Because the Department has learned from experience, our R&D portfolio is much more focused today on this kind of small-scale technologies.

Keeping the nation's costs of consuming energy low requires a constant stream of new, more efficient supply and demand technologies; otherwise, the inexorable tide of increased energy demand at home and around the world will lead to higher energy prices. Some of the energy technologies we rely on today resulted from government support, some from the private sector's natural response to high energy prices. Unfortunately, recent studies make clear that private sector R&D has been fairly flat since 1991, and U.S. companies have been shifting away from basic and applied research toward a focus on incremental product and process improvement. Increased international competition and downsizing of corporate laboratories have shortened the time horizon of most private sector R&D.

Low energy prices have further undercut private sector investment in new energy technologies. Since the mid-1980s, real private sector investment in energy R&D has dropped 35 percent.

Continued federal funding in advanced gas turbine technology, fuel cells, and other high-efficiency fossil fuel combustion technology is essential for keeping the costs of consuming energy low, as is continued funding for energy-efficient transportation, building, and industrial technologies. Most of the technologies that reduce dependence on imported oil also lower our energy costs. Federal research and development for example, has placed this Nation on the path toward electricity generating options that are twice as efficient as today's technology, up to 10 times cleaner, produce 40% less carbon dioxide and at the same time are 10-20% less expensive in terms of power generating costs.

Some of the most important investments the Department makes to ensure that future energy costs stay low are in the area of renewable energy. Consider what Chris Fay, Chairman and CEO of Shell UK Ltd recently said: "There is clearly a limit to fossil fuel. I showed how Shell analysis suggests that resources and supplies are likely to peak around 2030 before declining slowly." He said, "But what about the growing gap between demand and fossil fuel supplies? Some will obviously be filled by hydroelectric and nuclear power. Far more important will be the contribution of alternative, renewable energy supplies."

Fay presented a detailed analysis of future trends in oil supply and demand, noting that the fossil fuel peak in 2030 would occur at a usage level 50% higher than today. Shell's analysis does not rely exclusively on supply limits, but also incorporates a recognition of the tremendous technological advances that have been made in renewables over the past two decades and that are projected to be made over the next two decades.

Although these advances in renewables have been receiving very little public attention, they have been sufficient to convince Shell planners that renewables may take over the market for electricity generation in a few decades *even if electricity from fossil fuels continues to decline in costs* (See Figure 2). Shell bases its analysis in particular on the remarkable decline in costs of photovoltaics, biomass energy, and wind power, much of which stems from Department of Energy R&D funding, and anticipated future declines due to further technology improvement and economies of large-scale manufacturing. Their scenario does not assume price hikes in fossil fuels, which, as we have seen, is also a plausible hypothesis. Nor does Shell assume any attempt by governments to incorporate environmental costs into the price of energy, even though every single independent analysis has found much higher environmental costs for fossil fuel generation than for renewable energy. According to Shell's strategic-planning group, "The Energy in Transition future can claim to be a genuine 'Business as Usual' scenario, since its energy demand is a continuation of a long historical trend, and the energy is supplied in a way which continues the [historical] pattern."

In this scenario, three to four decades from now more than a third of the market for new electricity generation will be supplied by renewable resources; the renewables industry could have annual sales of $150 billion; and the fastest growing new source of power would be solar energy. Shell expects photovoltaics (along with fuel cells and small gas-fired power plants) to be key drivers of the growth of distributed power systems, which may increasingly be the power source of choice as opposed to the large, expensive, polluting power plants of the past. In developing nations, such distributed sources can obviate the need for huge power lines and other costly elements of a huge electric power grid, aside from their own environmental benefits.

Shell is worth listening to because it has perhaps been more successful than anyone else in the tricky game of anticipating our energy future. According to *The Economist* magazine, "The only oil company to anticipate both 1973's oil-price boom and 1986's bust was Royal Dutch/Shell." Anticipating the oil shocks of the 1970s helped Shell move from being the weakest of the seven largest oil companies in 1970 to one of the two strongest only ten years later. Anticipating the oil bust was apparently even more lucrative. According to *Fortune* magazine's ranking of the 500 largest corporations, Royal/Dutch Shell is not only the most profitable oil company in the world, it is also the most profitable corporation of any kind in the world. Thus Shell has succeeded both when other forecasts had projected oil prices far too low, and prices far too high.

Their Energy in Transition scenario is tantalizing not only because of Shell's reputation, but because it offers the serious possibility that the world could within a few decades begin to realize the dream of nearly pollution-free energy. Consider also that the United States, which is now the leader in most areas of renewable technology, could simultaneously reduce dependence on foreign energy supplies, turn our energy trade deficit into a surplus, and capture a large share of what promises to be perhaps the largest new job-creating sector of the international economy.

This is only a scenario, it probably won't occur exactly as described. However, our actions today can have an impact, both positive and negative. Fay notes that "new technologies cannot leap from laboratory to mass market over night. They must first be tested in niche markets, where some succeed but many fail. Costs fall as they progress down the 'learning curve' with increasing application." The long term nature of the research, and the real potential for failure, is why many options must be pursued at once and why private sector companies are reluctant to invest. Fay observes that "renewables will have to progress quickly if they are to supply a major proportion of the world's energy in the first half of the next century.... They can only emerge through the process of widespread commercial experimentation and competitive optimization."

Federal investments clearly make a difference in technology development and global market share. Consider the case of photovoltaics. In 1955, Bell Laboratories invented the first practical PV cell. Through the 1960s and 1970s, investments and purchases by NASA for space use helped sustain the PV industry and gave America leadership in world sales. In 1982, federal support for renewable energy was cut deeply, and within three years Japan became the world leader in PV sales. The Bush Administration began to increase funding for solar energy and, in 1990, launched a voluntary collaborative with the American PV industry to improve manufacturing technology; three years later, the United States regained the lead in PV sales in this rapidly growing industry. The Clinton Administration has further accelerated funding for PVs.

Sadly, however, the deep cuts of the 1980s have taken their toll: in the past decade, German and Japanese companies snapped up several major American PV companies that accounted for 63% of the PVs manufactured in the United States. Such purchases represent a huge savings for our foreign competition. They don't have to spend hundreds of millions of dollars to see which technologies succeed. They need only let the United States do the basic research and early development and then spend a few tens of millions of dollars plucking the winners when the federal government abandons funding for applied research, demonstration, and deployment. While some argue that the cuts in federal R&D will be made up for by the private sector, historically this hasn't happened. When the government pulls out of a promising long-term technology area, it sends a signal to the industrial and financial community that the area has no long-term promise and that the federal government is not a reliable partner.

Finally, while low U.S. electricity prices are a boost to us economically, they create one disadvantage. Renewable energy will be cost-effective in foreign countries before it is in America. Countries like Germany and Japan not only have far larger government financial incentives for the use and export of renewable energy, they typically pay far more for electricity: In 1991, the price for electricity in Germany's industrial sector was 8.8 cents per kilowatt-hour, whereas in the United States it was 4.8 cents per kilowatt-hour.

The primary competitive advantage the United States has had in renewables is technological leadership driven by federal research and development support. That advantage is being taken away by current and proposed Congressional budget cuts. These cuts will have two effects.

First, the transition to low-cost renewables that Shell envisions will likely be slowed, since America remains the leader in most relevant renewable technologies, and U.S. government funding remains a sizable fraction of total world R&D funding. The transition, however, even if slowed, seems inevitable at some point in the middle of the next century.

Second, when the transition occurs, the United States will miss what could be a very large new source of jobs in the next century. Using Shell's numbers, annual sales in renewable-energy technologies may hit $50 billion in 2020, and almost $400 billion in 2040. In the later year such an industry would support several million jobs.

Moreover, as noted above, the United States will be importing $100 billion worth of oil annually 10 to 15 years from now. With prudent federal investment today that might be the peak, followed by a gradual decline as U.S made technology and domestic fuels, including home-grown biomass with its implications for rural economic development, substitute for imported oil. With proposed Congressional cuts, however, we could end up only augmenting our debilitating trade deficit in oil with a dollop of oil-replacing technologies.

We cannot know today which technologies will deliver the lowest cost energy in the future, which is why the DOE pursues a variety of approaches. Indeed, a widely held view, which I share, is that diversity of supply itself minimizes overall cost. That way, the nation is protected from global shocks that only affect some of its sources of energy, such as an oil crisis, or an unanticipated national or global environmental crisis.

Low-cost Environmental Solutions

What is so remarkable about the renewable scenario is that federal energy R&D might ultimately demonstrate that the lowest cost form of power is also the one that generates the least pollution. The key national goal of improving the environment would then be an automatic byproduct of our effort to achieve a low cost, diversified, and secure energy portfolio. In this sense, renewable energy may do in the future what energy efficiency does today—cost-effectively lower the energy bills of businesses and consumers while avoiding pollution. Energy R&D reduces both the economic cost of energy and many of the societal costs too.

The environmental goal is an essential one for energy R&D because pollution and energy use are inextricably linked. Most urban air quality problems in this nation and around the world are linked to the production and consumption of energy. Some 54 million Americans live in areas that regularly violate air quality standards. The American Lung Association estimates that Americans spend $50 billion each year on health care needs that result directly from air pollution alone. As much as 80% of urban air pollution is caused by transportation energy use. Energy efficient transportation and alternative fuel technologies can substantially cut these emissions—improving local environmental quality, and cutting health care costs as well. Energy efficient technologies in homes, offices, and industry reduce emissions from power plants, further improving local and regional air quality and further cutting health care costs. And the global market potential for clean technologies in the next century is tremendous, exceeding $400 billion.

The half-dozen most energy-intensive industries in the country are responsible for the vast majority of the industrial pollution: steel, aluminum, petroleum refining, chemicals, pulp and paper products, glass, and metal casting. These industries account for about 80% of the energy consumed in U.S. manufacturing and more than 90% of U.S. manufacturing hazardous waste. They represent the biggest opportunities to increase energy and resource efficiency while reducing pollution. That's why the DOE has been forming partnerships with these industries to develop clean technologies.

Funding for pollution prevention is the best opportunity for the nation to avoid the need for costly environmental regulations. The government has a role in advancing pollution prevention for several reasons. First, pollution prevention technologies often benefit many companies only a small amount, so no one company has the incentive to spend the money by itself. Second, prevention has so many public benefits not fully captured in the marketplace: reduced resource consumption, improved environment, reduced energy consumption, and increased jobs and competitiveness. Thus the private sector will inevitably under invest in R&D on clean technologies. Third, while it is certainly possible that the 120 governments represented in the Intergovernmental Panel on Climate Change were wrong in December when they concluded, "the balance of evidence ... suggests a discernible human influence on global climate," it seems imprudent to base federal energy R&D policy on that hope. Fortunately, the same investments that prevent industrial pollution and urban air pollution while lowering the nation's energy bills, also minimize greenhouse gas emissions.

World-Class R&D

The final goal of national energy R&D policy is maintaining America's leadership in science and technology, since that is the engine of productivity and job growth essential to our economic well-being in the next century. Here the Department of Energy has demonstrated unique success by winning more R&D 100 awards (given annually to the most innovative and important technologies) than any other organization since 1963. The DOE has won 386 R&D 100 awards, more than all other federal agencies combined and more than General Electric, Westinghouse, Dow Chemical, Dupont, and Hewlett-Packard combined. In the past five years, projects supported by the Office of Energy Efficiency and Renewable Energy have won 31 R&D 100 awards representing more than 6% of the total number of awards given during that time, which is especially remarkable given that the Energy Efficiency R&D budget represents under one half of one percent of the nation's total R&D funding .

In the past two years, the Department has achieved major breakthroughs in high-efficiency lighting, super-insulating material, photovoltaic energy conversion, high-temperature superconductivity, and conversion of biomass to ethanol. As industry scales back its longer term, higher risk R&D in response to increased domestic and foreign competition and low energy prices, the federal government must redouble its efforts if we are to ensure a steady stream of technologies that enhance productivity, create jobs, avoid pollution, lower energy costs, and reduce dependence on imported oil. Such basic and applied R&D delivers so many societal benefits that it cannot in any respect whatsoever be considered "corporate welfare," a term implying a giveaway with no societal benefits.

We must invest in a spectrum of technologies because we cannot know which investments will pay off in the future. For example, when the original government-funded research was done on jet engines, who could have guessed that decades later it would lead to the turbine technology that is today generating electricity and helping to keep down electricity rates?

Conclusion

No one can predict the future with certainty. But a great many experts have examined the inexorable forces of supply and demand and concluded that while energy prices are low today, energy security is a growing concern. Fortunately, a modest investment in energy R&D--especially investments in oil and gas R&D, advanced transportation technologies, and alternative fuels--can help mitigate our vulnerability to future oil shocks.

At the same time, these and other investments in renewable energy and energy efficiency hold the key to ensuring that the costs of consuming energy are as low as possible for consumers and businesses in the coming decades. If low energy prices today, and lower energy price forecasts in the future mean anything, they mean that the technological optimists were right: energy R&D makes a difference to consumers and businesses.

These same energy investments also reduce or eliminate pollution, thereby making it possible to have an improved environmental quality while delivering the kind of low energy costs that spur U.S. economic growth. In this way, energy R&D lowers not just the direct economic cost of energy, but also its many societal costs, such as damage to the environment or public health. Stable or growing funding for energy R&D holds the prospect of dramatically reducing pollution in the lifetime of our children.

Americans today have a duty to eliminate the deficit, rooted in their obligation to future generations, but the country needs to acknowledge that public investment in R&D, far from being corporate welfare, is an investment in America's own future. As the Yergin task force wrote, Americans have an obligation to "assure for future generations that our Nation's capacity to shape the future through scientific research and technological innovation is continually being renewed."

There are credible warnings about growing dependence on Persian Gulf oil and about national and global environment problems, as well as credible scenarios explaining how we can minimize that dependence, how we can capture the huge market potential for renewable energy and other clean energy technologies, and how we can cost-effectively prevent pollution. Long after the federal budget is balanced, the nation and the world will remember if we failed to act on the warnings and if we failed to seize the opportunities.

Chairman ROHRABACHER. Thank you very much for that very aggressive, straightforward testimony. And, I'm looking forward to hearing the dialogue between Mr. Schleede and yourself.

Mr. Lynch.

STATEMENT OF MR. MICHAEL C. LYNCH, RESEARCH AFFILIATE, CENTER FOR INTERNATIONAL STUDIES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS

Mr. LYNCH. Thank you, Mr. Chairman, and members of the Subcommittee for the opportunity to speak. I have been asked to testify about long-term oil forecasting and especially DOE's, which is my primary area of expertise.

I don't think it will surprise you that someone from MIT is not going to come down and say that R&D is a bad thing, generally. [Laughter.]

Mr. LYNCH. You mentioned, Mr. Chairman, that the forecasting has been very bad. I have published a number of papers on this, and it's summarized in my written testimony.

And, it's true. It has been very bad. And, everyone, or almost everyone, was very wrong in the late 1970's and early 1980's.

But, that doesn't mean that it can't be done, because there have been very specific errors, which I think address some of the concerns of some of the members of the Committee. The first thing is that, as you can see in Exhibit 1 of my written testimony, the forecasts have always been that prices rise by a few percent a year. And, since the early 1980's, they have declined by a few percent a year.

And, the forecasters have tended to correct their forecasts by showing that the prices will rise from the current point at the new lower oil price. The mistake is the trend of prices, but the correction has been to the initial point. And, that's wrong.

Secondly, on the supply side, people have been much too pessimistic about non-OPEC and non-Middle East production. In the early 1980's, everyone said the North Sea would peak in a few years. People have been way too low on Alaskan production and so forth.

The result has been that the Persian Gulf has been predicted to recover market share really since the early 1980's. They have gained somewhat since the price collapse, but it has been quite a struggle for them.

And, it's important to realize that the arguments on behalf of the rising price forecasts and the falling oil production forecasts have seemed logical. There has been a lot of data supporting them, but that hasn't prevented them from being wrong.

There have been many experts who have been saying literally for 15 years, including a couple from MIT, I have to confess, that we are facing an imminent crisis, an imminent gap between supply and demand. And, they have been wrong.

The consensus has not proven very valuable in telling us about the validity of a forecast. It has told us more about the psychology of the forecasters.

I would also say that what people have said many times is inconceivable has actually happened. What people have said is inevitable has not happened.

So, perhaps it's a little foolish of me, as an expert, to tell you to be careful in listening to experts. But, frankly, that's just the honest truth.

[Laughter.]

Mr. LYNCH. The reality is that prices may go up in the future. And, Persian Gulf oil production and exports will rise.

However, the most likely scenario, given what we know about oil supply and demand and what we have learned about forecasting in the last 10 to 15 years, is that OPEC is going to be under continued pressure for at least the next 10 years, possibly for much longer, that they will be fighting with each other for market share. And, it's going to require some very substantial changes in the world to see prices rising.

In terms of thinking about R&D spending, that's important. It suggests that OPEC's power, the price of oil and the costs of imports are going to be lower than the official forecasts and the forecasts that a lot of people make.

But, I'm not saying there won't be an oil crisis, because an oil crisis is a short-term political event. If there were a civil war in Saudi Arabia today, we would have a big oil crisis.

But, all I'm trying to say is that the crisis is not really related to the level of U.S. oil imports or the level of world oil demand. It's related to other short term factors, including the structure of the market, including things like the SPR, which are crisis management policies.

It's not really related to R&D spending. R&D spending, I think, needs to be justified on the grounds of long-term or even medium-term scientific and economic benefits.

That's not really my area of expertise. And, I'm not going to address that.

But, I certainly think the Committee should consider those much more than it should concerns about a future oil crisis. Thank you.

[The prepared statement of Mr. Lynch follows:]

THE LONG-TERM PETROLEUM OUTLOOK
Testimony to the Subcommittee on Energy and Environment
of the Committee on Science
U.S. House of Representatives
March 14, 1996

Michael C. Lynch[1]

INTRODUCTION

Although the importance of oil prices to both the world economy and other energy prices has declined in recent years, there is renewed concern about future trends and especially rising OPEC power and U.S. vulnerability. The current debate is between the opposing viewpoints of those (like DOE) who expect rising prices and those foreseeing flat or declining prices (adjusted for inflation). The primary disagreement is over expectations for non-OPEC supply. Both groups expect that growing oil demand, especially in the Third World, will require higher production. Rising price forecasters argue that flat or lower non-Middle East oil production will necessitate a significant increase in market share for Middle East producers, as well as higher prices to cover rising capital needs. Weak price forecasters believe that new technologies will continue to lower costs and add reserves, even in the mature producing areas. They believe that this will prevent OPEC from regaining the dominance it had in the 1970s.

In previous work, I have shown that past oil market forecasts were biased towards rising prices and declining non-OPEC production.[2] Correcting for the supply pessimism leaves a forecast in which oil markets remain in surplus over the long-term, suggesting that oil prices will remain weak for the indefinite future.

THE FORECASTING RECORD: THE FAILURE OF CONSENSUS

The expert community's inability to predict oil prices in the past two decades is well documented. In Exhibit 1, a review of the Department of Energy's oil price forecasts shows the way in which their forecasts have consistently been too high.[3] In the early 1980s, ever-increasing prices were projected, typically reaching $80/barrel by 1995. (In fact, during this period almost no forecaster thought long-term prices could actually fall, even as an

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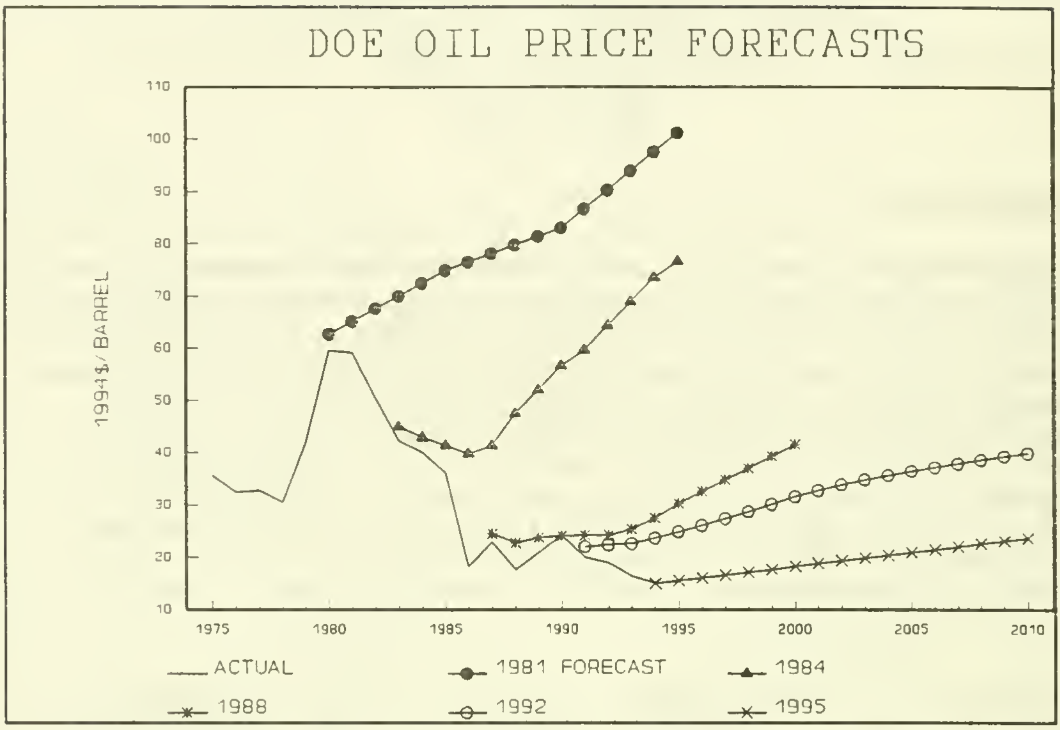
[1] Research Affiliate, Center for International Studies, Massachusetts Institute of Technology. The views expressed herein are the author's and do not reflect the opinions of any other person or organization.

[2] See "Bias and Theoretical Error in Long-Term Oil Market Forecasting," in Advances in the Economics of Energy and Natural Resources, John R. Moroney, ed., JAI Press, 1994; and "The Analysis and Forecasting of Petroleum Supply: Sources of Errors and Bias," delivered to the Eighth International Symposium on Energy Modeling, Institute of Gas Technology, Atlanta, Georgia, April 1995.

[3] Note that the great majority of oil market forecasts have, until recently, resembled those published by the Department of Energy. This consensus has led to many sheep-related metaphors.

Exhibit 1



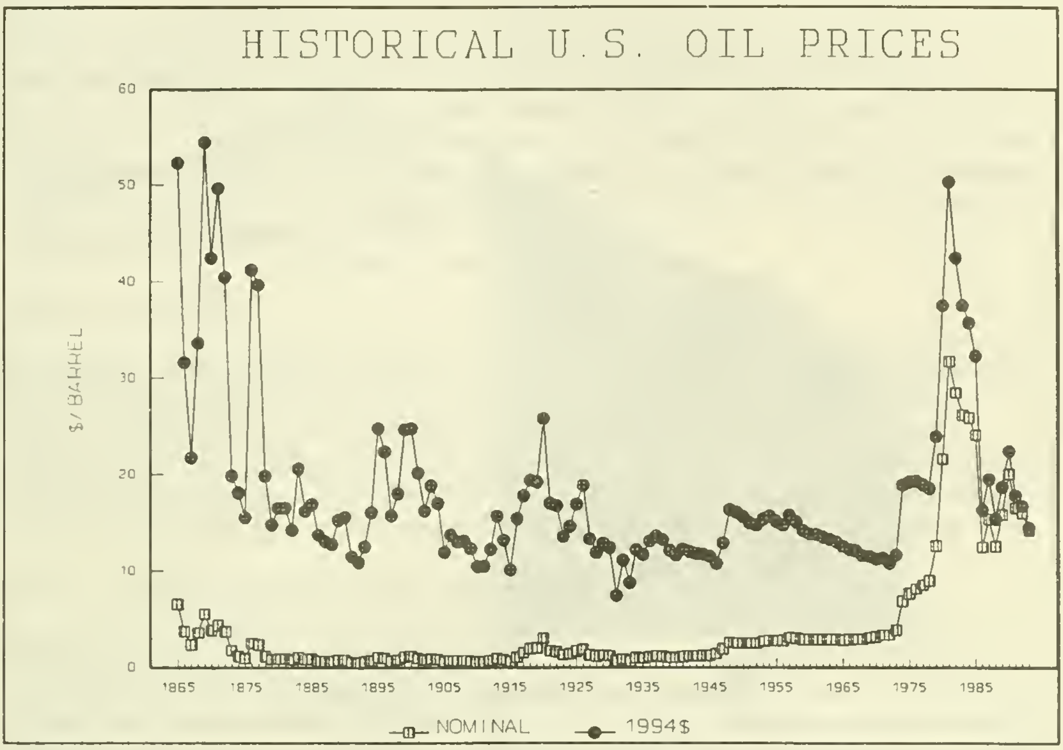
alternative scenario.) Actual market behavior has fallen far outside the consensus expectations, discrediting forecasts and forecasters.

The Nature of the Errors

One underlying error introduced into oil price forecasting in the 1970s was the belief that rising mineral prices were inevitable and could be demonstrated by economic theory. Exhibit 2 shows oil prices in both nominal and inflation-adjusted dollars. No rising trend is visible in real oil prices, which in 1970 were below those of most of the previous century. But the misconception that resource depletion would cause prices to rise several percent a year above inflation resulted in rising price expectations becoming an inherent part of most oil price forecasts for nearly two decades. Whether prices were low or high, markets weak or tight, demand rising or falling, the typical forecast called for oil prices to rise a few percent above inflation each year.

This rising trend was the primary error in the forecast, as Exhibit 1 so clearly shows. Yet the correction was typically to the initial point not the trend. As prices dropped over the past fifteen years, the forecasts like DOE's have retained the same rate of increase, only the beginning point has changed. DOE's reduction of $1/barrel in 2010 from last year's forecast

Exhibit 2

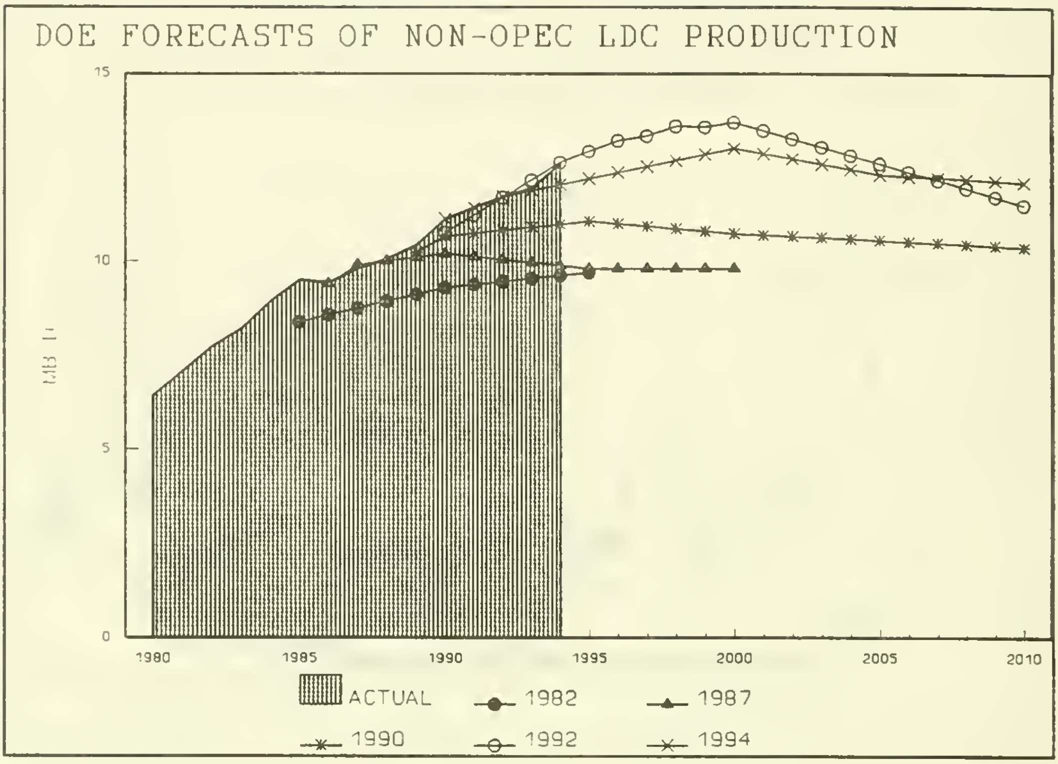


is a continuation of this practice.

Pessimism about non-OPEC oil supply has been another element behind the rising price forecasts. Prior to the mid-1970s, most organizations were optimistic about the prospects for oil supply, even in the United States. Before the second oil price shock, concerns about resource limits and geological depletion led to increasing pessimism about the outlook for non-OPEC supply. Rising costs were empirically demonstrated in the U.S., the only region with good data, but this proved to be due to inflation in costs related to the rapid increase in drilling, not geological factors. The two oil price shocks in the 1970s were cited to support arguments of resource scarcity, despite their transient nature.

This pessimism affected virtually all supply forecasts. Exhibit 3 shows the DOE forecast for non-OPEC Third World oil production, which has been consistently pessimistic and has been repeatedly raised. The continued forecast of an imminent peak which has had to be regularly corrected demonstrates an underlying bias, inasmuch as the Third World's petroleum basins are far less mature than any other region of the world. Other producing regions, such as the North Sea, Alaska, and the smaller OPEC countries were similarly viewed by forecasters as mature producers facing imminent decline, and forecasts of their production have also been consistently too low.

Exhibit 3



The oil market forecasting errors appear to be the result of mistaken assumptions and theories, and correcting them should improve forecast accuracy. Conservative but less pessimistic non-OPEC production forecasts should generate a more reliable estimate of OPEC's market position in the long-term and allow an unbiased assessment of prices.

GENERAL FORECASTING LESSONS

Many lessons can be drawn from this review, some generally applicable to forecasting, others of which are more specific to the oil industry. Those most relevant to this discussion are listed below.

Consensus is not equated with validity

First, the consensus appears to tell us nothing about the accuracy of the experts' beliefs. Instead, it seems to demonstrate the political, bureaucratic and psychological difficulties that many forecasters have in disagreeing with the consensus. Indeed, on a complex issue with many uncertainties, the existence of consensus should be viewed skeptically.

The inconceivable is quite possible

Many of the actual market occurrences of the past two decades, whether price spikes or crashes, the sharp drop in demand of the late 1970s, or the continually increasing non-OPEC oil supply of the 1980s and 1990s, have been repeatedly described by forecasters as "inconceivable".[4] The corollary to this rule is that the supposedly inevitable has often failed to come to pass, including the "inevitable" price increase and various "inevitable" production declines. Again, usage of terms like inconceivable and inevitable seems primarily suggestive of the mindset of the analyst.

Confusing type of effect

The tendency to misunderstand the nature of effects has left observers frequently confused. Examples include mistaking economic effects for geological ones, policy decisions for economic constraints, and transient events for long-term trends. In oil production, for example, the increase in factor prices in the U.S. due to the drilling boom of the early 1980s was interpreted as a sign of resource depletion and extrapolated indefinitely, and the effects of wellhead price regulations on oil and gas were said to demonstrate resource scarcity.

Analysts are heavily influenced by prevailing moods

A number of previous works have referred to the "zeitgeist," "vintages of consensus," or, more academically, "intellectual regimes" to describe how prevailing moods can influence projections and decision-making. Those moods, in turn, can be affected by short-term or transient effects. In effect, when there is consensus about finite resources inexorably driving prices upwards, it becomes difficult for an individual to produce a differing view and all but impossible for a large organization to do so.

SPECIFIC LESSONS FOR PETROLEUM FORECASTING

Beyond the lessons which are generally applicable to research and forecasting, there are certain points specific to oil market forecasting which should be considered when judging a forecast.

Prices forecasts are too high, the error is in the trend

Oil price forecasters have consistently been not just too high, but unable to even foresee the trend in prices. Actual prices are about 20% of where they were widely predicted to be a little over a decade ago. Since the late 1970s, the consensus price forecasts have been for a 3% real price increase, even while prices have fallen steadily.

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[4] My own 1989 forecast of declining long-run oil prices was described as heretical by the Petroleum Economist (9/89), but has proved fairly accurate.

Demand forecasting suffers from exogenous effects, but also misspecification

Although demand forecasting has hardly been perfect, it appears to have primarily suffered from an inability to predict prices and economic growth rates. However, most analysts seem to have been too conservative in their beliefs about the potential price response of demand. Very substantial improvements in energy efficiency have taken place, far beyond what most experts, even the most ardent conservationist, anticipated. Oil turns out to be very much like other commodities.

Supply is misspecified

One of the most glaring errors in petroleum forecasting has been the post-1980 need to revise supply upward while lowering price projections. The fact that lower price expectations have resulted in higher demand expectations is logical and consistent with basic economic theory. But lower prices and higher production are not normally consistent with basic economic theory, and are a strong indication that the underlying premises are incorrect.

Malthusian Bias

One of the primary problems which has permeated oil market forecasting for the past two decades has been the tendency towards a Malthusian bias.[5] It might be posited that this reflects the natural tendencies of environmentalists advocating conservation, oil companies or OPEC requesting special treatment, but the bias has seemed to permeate all forecasts for nearly a decade and a half.

This is significant because one of the most important elements of past forecasting error has been the problem of bias. In any complex system, and especially in the social sciences, there remain significant uncertainties or areas where detailed analysis has not been, or cannot be, done. As a result, the influence of uncertainties and assumptions means that every forecaster must make many choices. In theory, an economic forecast will be unbiased, meaning that the errors average out, or the aggregate of all forecasts is unbiased, meaning that the community of forecasters is, on the whole, unbiased.

Such has not been the case for oil price forecasting, as is demonstrated by examining the forecasts of the 1990 price of oil submitted to the IEW survey in Vienna. (Exhibit 4) From 1981 to 1985, only one of 84 forecasts was too low. It was not until 1988 that the average forecast was approximately correct and the 1990 Gulf War may have contributed to that.

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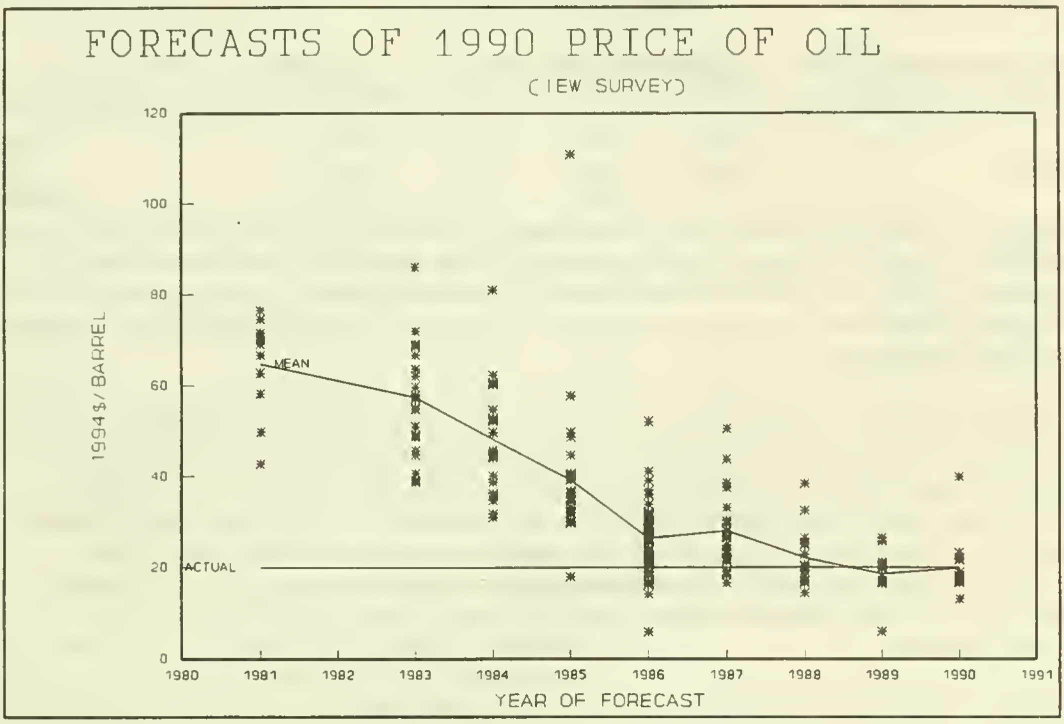
[5] Malthus was the political economist in the 19th century who extrapolated from rather sparse data to conclude that the world's agricultural productivity could not keep up with population growth. Fears of limited resources predate him by millennia, but he formalized the theory.

Exhibit 4



Conclusion: Forecasting is an Art, not a Science

The lessons above are not intended to suggest that forecasting cannot be done. But it is important to recognize the many difficulties and uncertainties, rather than implying precision.

THE LONG-TERM OIL MARKET OUTLOOK

What *might* happen in the oil market includes a broad range of possibilities. Prices *could* collapse to $5 per barrel and stay there for two decades. They *could* begin to rise more or less continuously. However, these are relatively unlikely events, and if we correct for the errors and biases described above, the result is a much more accurate picture of the long-term market.

Demand

If low oil prices prevail as anticipated, then demand forecasts should be increased relative to those containing rising price forecasts. The OECD nations have reversed their demand trend since the 1986 oil price collapse, from a 1.4% per year decline from 1973 to 1985 to a growth rate of 1.6% from 1985 to 1994. Recent strong economic growth in Asia and Latin

America should result in high growth in oil demand in the Third World overall, even though the same cannot be said for the Middle East and Africa.

Thus, the expectations that oil demand will rise rapidly are not misplaced, and this forecast anticipates particularly high levels of demand. But demand alone will not determine prices.

Supply

Evidence of resource abundance and low costs support optimistic interpretations of future non-OPEC oil supply. The density of wells drilled in the non-OPEC Third World is 2% of the density in the U.S. in 1970, the year lower-48 production peaked. Average per-well production outside North America and the FSU is approximately 320 barrels per day, versus 12 in the United States.

Anticipated production peaks have been repeatedly overcome throughout the world, with only the United States experiencing a decline as the result of geological maturity. Most areas are seeing increased investment and production, with the non-OPEC Third World growing by 4.8% per year over the past decade and the North Sea adding 1.2 mb/d in the past two years alone. The Former Soviet Union (FSU) has numerous undeveloped fields over 1 billion barrels in size which are likely to be developed upon resolution of legal and fiscal questions. Heavy oil from Canada and Venezuela could add several million barrels per day over the next two decades.

These facts suggest that the surplus of oil which has plagued OPEC for the past dozen years is likely to continue for many years, as smaller producers continue to expand, complementing the larger producers such as Russia, the North Sea, Venezuela, Iraq, and Mexico, all of which are likely to add significant volumes beyond today's level.

The Supply/Demand Balance

My most recent forecast (Exhibit 5) projects a 56 mb/d increase in oil demand over the next quarter-century. This may appear daunting, but only reflects a 2.2% per year increase, far below pre-1973 growth rates. With the projected production increase from the Third World, the North Sea and the FSU, the growth in supply needed from OPEC only amounts to about 2.5 percent per year. The large OPEC producers, Abu Dhabi, Iraq, Iran, Venezuela, Kuwait and Saudi Arabia have all indicated a desire to increase production much more rapidly.

Price-Setting

Prices in the oil market are influenced, but not determined, by the balance of supply and demand and the long-run marginal cost of production. The OPEC oil cartel maintains prices above long-run marginal costs and its ability to do so is the primary influence on long-term price trends. Policy-makers in most OPEC countries recognize that the prices of the late

Exhibit 5

LONG-TERM OIL MARKET BALANCE
TB/D

	1992	2000	2010	2020	Average Annual Increase
DEMAND					
OECD	37,500	41,500	46,700	49,600	1.0%
LDC	20,200	29,510	44,050	62,960	4.1%
FSU/ECE	7,800	6,100	7,500	9,200	0.6%
WORLD	65,500	77,110	98,250	121,760	2.2%
SUPPLY					
OECD	19,195	22,173	23,663	24,946	0.9%
LDC	11,320	13,465	18,530	24,363	2.8%
FSU	6,500	9,000	11,000	13,400	2.6%
UNCONVENTIONAL	300	750	1,250	2,500	7.9%
TOTAL NON-OPEC	37,315	45,388	54,443	65,209	2.0%
DEMAND FOR OPEC OIL	28,185	31,722	43,807	56,551	2.5%

NOTE: OECD INCLUDES MEXICO, LDC INCLUDES CHINA.
Source: Lynch, Michael C., International Petroleum Price, Supply and Demand: Projections Through 2020, GRI, 1996.

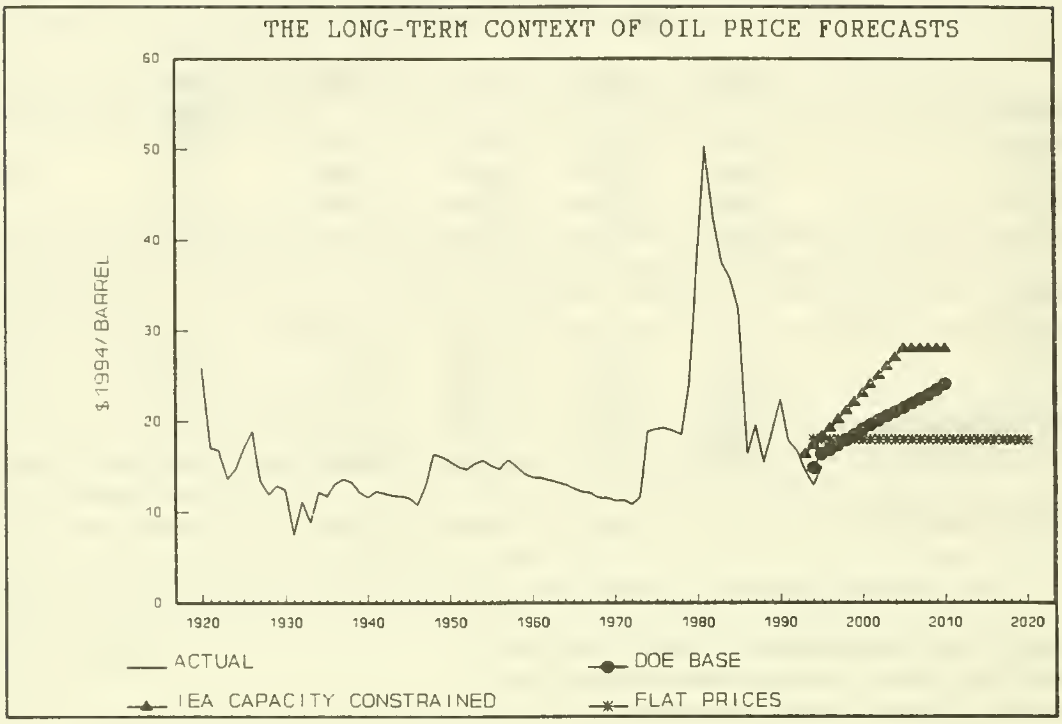
1970s were unsustainably high, implying that even a recovery in their market power will not necessarily result in higher prices. In the forecasts of DOE and the IEA, neither OPEC's market share or its oil revenues recover to the level of the mid-1970s until 2010. Even should the cartel decide to raise real oil prices in the future, their power to do so will remain limited. Forecasts of rising prices beginning in the late 1990s thus appear to be too optimistic.

Conclusions: Prices are much more likely to be weak than strong

The world oil market will most likely continue to experience excess supplies, as smaller oil producers add reserves and capacity, and the medium-sized producers like Venezuela, Mexico, and the Former Soviet Union absorb a large share of the increase in oil demand. The major Middle Eastern OPEC producers will see rising demand for their oil, but at such a low growth rate that they will have no difficulty adding capacity to meet it.

The factors which drove oil prices higher in the 1970s were transient in nature, but the effort necessary to overcome them created an underlying pessimism about the industry's ability to provide oil at reasonable prices. However, the ongoing technological revolution in the

Exhibit 6



industry, combined with managerial improvements and a more friendly fiscal environment in oil exporting countries, will keep real oil prices flat for the next two decades. As Exhibit 6 shows, a flat oil price forecast appears to be much more consistent with historical behavior than the rising price forecasts of DOE and the IEA. A declining price, or flat at a lower level, would hardly be unrealistic.

POLICY RECOMMENDATIONS

This more benign forecast should not be interpreted to mean that there will be no problems in the future. Specifically, the argument that rising OPEC market share will lead to an oil crisis is a fallacy, as is the inverse: weak oil markets and pressure on OPEC does not preclude oil crises. Neither does optimism about oil supply and prices directly lead to an argument in favor of lower R&D spending.

Oil Crises[6]

Oil crises are not a function of resource scarcity and are largely unrelated to long-term market trends. They reflect short-term disruptions of supply, which are hardly abnormal events. A crisis is not a function of the level of world oil demand, OPEC oil production, or U.S. oil imports, but rather reflects: a) the size of disrupted supply; b) the availability of replacement supplies; c) the organization of the oil market; and d) the response of consumer governments, particularly in releasing strategic inventories.

The economic impact of an oil crisis is a function of the change in prices and the level of imports and consumption in consuming nations. Reducing oil consumption or developing alternative supplies has a very minor impact on the possibility that an oil supply disruption will lead to higher prices. Certainly, lower imports will reduce the impact of crisis-induced higher prices on the domestic economy, but, the cost of reducing oil imports by 10% over a long period is probably much higher than say, the impact of a 50% price increase for one year.

R&D Spending

Presumably, no one will be surprised to hear an M.I.T. researcher speak in support of research. An increase in knowledge is, all else being equal, something to be sought after. New technologies have been one of the major factors in the development of American economic strength. Although basic research has only vague, long-term payoffs, the benefits should not be ignored.

But it is always better to maximize accuracy, whether in forecasting or providing a rationale for R&D expenditures. Clean coal technology, fusion power, or photovoltaics will not prevent another oil crisis from occurring, and are likely to provide only a slight moderating effect on the crises which do occur. This is not to say that R&D in these areas should not go forward, just that they need to be justified in some other way.

Questions about the optimal level of R&D spending, the balance between basic and applied research, and the appropriate split between private and public sector research are important ones. However, the answers are beyond my area of expertise and I would not presume to provide them here. My only recommendation is that the Congress consider all arguments (both pro and con) with a healthy dose of skepticism and recognize the value of a balanced strategy.

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[6] For a discussion of the nature of oil crises, see Michael Lynch, "Fighting the Last War: Preparations for the Next Oil Crisis," MIT Energy Laboratory Working Paper MIT-EL 86-009WP, October 1986.

Chairman ROHRABACHER. Thank you very much, Mr. Lynch. Ms. Cubin will have to be leaving shortly, so we are going to pay her the courtesy of being the first one to offer her questions to the panel.

Ms. CUBIN. Thank you very much, Mr. Chairman. I will be brief.

But, it occurs to me that—and I would like Dr. Hakes and Mr. Romm to respond to this. I live in Wyoming, and if I were to read in the newspaper about a plant closure or a partial closure of an automobile plant in, you know, Ohio and 10,000 jobs are gone, you know, that's a big concern for the country and in a lot of ways for the economy, the people involved plus the ramifications to all of us.

Well, there have been 500,000 jobs, good paying jobs, lost in the oil and gas industry because, I believe, of government policy and other reasons obviously.

Has the Department of Energy done anything at all to try to help, other than R&D to try to help, the domestic oil industry?

We have plenty of oil right now all over the oil producing states. They are closing in marginal wells if they can't get some sort of tax incentive or if there isn't some reason that they want to spend the extra money for tertiary production.

And, I haven't seen anything out of the Department of Energy. But, I would like you to respond to that.

Dr. HAKES. I can answer the data side of it. In looking at jobs, I think it's important to analyze what are the factors involved. And, in fact, I think there's a multitude of reasons.

But, if you look at the coal industry, for instance, there has been a lot of loss of jobs in the coal industry. It's largely because of automation.

Basically, mining is done much more mechanically than it has been done——

Ms. CUBIN. I'm talking just about oil and gas. Wyoming is the largest energy producer in the country.

We have hydro power. We have uranium. We have solar. We have wind. We have oil. We have gas. We are the largest coal producer.

I am talking about oil and gas.

Dr. HAKES. Yes. And, the other point I would make is that some of the technologies that have been developed in the private sector and the public sector are creating a somewhat more optimistic look for oil—domestic oil production.

We are showing later in the forecast period that domestic production will actually rise over some period. And, that's a different scenario than has been in the past.

And, that's largely driven by technology, basically things like 3-D seismology, the ability to drill deeper, the ability to do horizontal drilling. Those things are all creating a more optimistic view for domestic oil.

Ms. CUBIN. But, is all you do predict? You don't do anything active?

I'm——

Dr. HAKES. I'm from the data part of the Department. Joe is best prepared to deal with the policy side.

Ms. CUBIN. Okay, Joe.

Mr. ROMM. Yeah. I would say on the non-R&D side, among the things the Administration is doing is supporting legislation to lower industry costs by reforming the Oil Pollution Act of 1990. We are changing regulations to allow reduced royalties on declining production.

The Department of Interior has granted most of the royalty relief requested on stripper wells on federal land and is in the process of reforming its procedures for calculating the royalty payments due for natural gas. And, we are now close to agreement on the Royalty Fairness Act pending before the Congress.

And, I would be happy to get you more information, because my area is a bit more energy efficiency than fossil energy. But, I—we can——

Ms. CUBIN. Well, I am on the Resources Committee where we are doing the Royalty Fairness Act. And, while we thought we had an agreement with the Administration, we don't, because after we had agreed to the bill and brought the bill forward the Administration said, "Uh-oh, the bill has a fatal flaw, and that's delegation to the states."

So, I just have to say that whatever things you are doing are minuscule in helping the industry as compared to, number one, the money we spend on the Department of Energy and, number two, the need out there.

And, why wouldn't it be a policy of the Department of Energy, why wouldn't it be part of the reason you exist to help the domestic industries instead of allowing us to become reliable to the point that it could cause a national security interest, supposedly, under certain scenarios?

I don't understand—I don't understand why you are there, I guess.

[The following information was received for the record:]

INSERT FOR THE RECORD

The Administration and the Department of Energy have a number of successes that will help the domestic oil industry. These successes have been documented in recent testimony by C. Kyle Simpson, Associate Deputy Secretary for Energy Programs, before the House Resources Committee, Subcommittee on Energy and Mineral Resources, on March 21, 1996. The following highlights the accomplishments contained in the full statement:

ALASKA NORTH SLOPE EXPORTS: Based on a study undertaken by the Department of Energy, the Congress passed and the President signed legislation that will permit the export of Alaska North Slope crude oil. The prohibition on these exports has been in place for more than 23 years. The Department's study indicated that domestic oil production will increase by about 100,000 barrels per day due to increased wellhead revenues; American jobs will increase by about 25,000 primarily in California and Alaska; and domestic reserves will increase.

ROYALTY RELIEF: The Administration worked tirelessly to support royalty relief legislation that will bring more of our domestic resources within economic reach in the deep water of the Central and Western Gulf of Mexico. Legislation signed by the President in November of last year will provide royalty relief over the next five years for all new lease sales in the Central and Western Gulf in water depths of 200 meters or more. We have estimated that this relief will add up to 15 billion barrels of oil equivalent to our domestic reserves; will provide as many as 160,000 new American jobs, especially in the Gulf Coast states, and will provide increased revenues to the industry and the federal government. In addition, the law provides the opportunity for royalty relief on existing leases where development has not taken place without the economic incentive provided by royalty relief. Onshore, the Administration has provided royalty relief to stripper wells and heavy oil wells producing on federal lands.

OIL POLLUTION ACT OF 1990 FINANCIAL RESPONSIBILITY: The Department of Energy and the Administration have worked closely with the Congress to implement the Oil Pollution Act (OPA 90) requirements for financial responsibility for offshore facilities in a manner that protects the environment while reducing the financial burden on operators. The Secretary of Energy commissioned a study by the National Petroleum Council and has acted on its recommendations by supporting the efforts of the industry and the Department of the Interior to develop a rational, risk-based approach to financial responsibility requirements for OCS facilities. While this effort has been slowed due to the inability of the Congress to work out differences between the House and Senate, the Administration is hopeful of a positive resolution to the situation.

BUREAU OF LAND MANAGEMENT NATIONAL PERFORMANCE REVIEW: The Department of Energy has worked closely with the BLM on the Bureau's Onshore Oil and Gas Performance Review in order to make its regulatory structure more efficient and responsive to oil and gas operations on public lands. Regulatory streamlining is ongoing and will result in improved access to public lands as well as reduced regulatory burden on those areas already under lease.

ROYALTY FAIRNESS: The Administration is working with the Congress on proposals to improve the fairness of the royalty collection process for onshore and offshore oil and gas production. The process has grown increasingly complex and contentious as changes arise in how these commodities are marketed. The Administration and the Congress have made progress, and we will continue to work with the Congress in an attempt to resolve these issues.

ACCESS TO PUBLIC LANDS:

- *Lease Sales in the Outer Continental Shelf and Five Year Plan:* The Department of Energy supports the work of the Department of the Interior and its Minerals Management Service (MMS) as they promote the orderly, environmentally responsible development of the natural gas and oil resources of the Outer Continental Shelf (OCS). The success of the latest lease sale on the OCS is an example of how government and industry can work together to ensure the timely development of the Nation's offshore resources. In addition, we support the size, timing and location of leasing as described in MMS' *Proposed Leasing Program (1997-2002).*
- *Green River Basin Initiative:* The Department of Energy is providing its technical and analytical expertise as an ex-officio committee member to the Bureau of Land Management's Green River Basin Advisory Committee. This committee will make recommendations to the Secretary of the Interior as to how to develop the oil and gas resources in the Green River Basin of Wyoming and Colorado without compromising the environment.

These are the most important of the non-R&D initiatives under way in the Department of Energy to provide assistance to the domestic oil and gas industry. In addition, there are many international initiatives that will assist our domestic companies and provide jobs for American workers. For example, we have been working with U.S. firms and our counterparts in the Caspian Region's private and public sectors on ways to develop Caspian Region oil and gas resources and acceptable methods of transporting the products to world markets. Finally, there are many R&D-related initiatives that will assist in lowering the cost of production for domestic oil and gas companies, making it possible for them to operate in the present market environment.

Mr. ROMM. Well, I think I'm here mainly—let me, let's get back to you as much information on what the Department is doing outside of energy R&D. Energy R&D is mainly what I can speak to.

I think the Department is working pretty hard to develop technologies that would lower the finding costs and would help particularly small producers do a better job of finding oil cheaply and then getting it out as much as possible, such as the advanced seismic and advanced computing——

Ms. CUBIN. I'm sorry, my time is up. And, I'm sorry to interrupt.

But, the greater harm that you are doing, while I agree that there have been some areas where the royalty—there have been tax breaks by the Federal Government on federal land for tertiary production, but the biggest problem is the lack of permitting—the time that it takes, by the time someone decides they want to permit, and all of the hoops that someone has to jump through in order to be able to drill that are set up by the Federal Government, it is so expensive because of the Federal Government's action—and I don't know how much of this action comes from the DOE. I know it comes from the Forest Service, the Park Service, the Endangered Species Act. And, that's all outside of you.

But, the benefits to the domestic industry from the Department of Energy, I don't see them out there. And, I've been involved in this business for 14 years.

So, I would hope that somewhere someone would want to do something about the domestic energy. Five hundred thousand jobs have been lost.

Thank you, Mr. Chairman.

Chairman ROHRABACHER. Thank you, Ms. Cubin. And, I think I will proceed at this point and then go to Mr. Roemer.

Dr. Hakes, I would just like to have a better understanding of—I mean, you admit in your testimony that your forecasts have been off. And, I would say they have been off by not just a small amount but they have been off the chart.

What's the missing part of the equation? How come? How come your predictions have been so far off?

Dr. HAKES. It's the price side where there has been the greatest error in areas like predicted demand and consumption and things like that. I think the forecasts have been in the ball park.

I think basically a lack of understanding of the impacts of decontrol of the market and the beneficial impacts that that would have. Most of the—most erroneous forecasts were in the late 1970's and early 1980's when that transition was going on.

In the area of gas, there continues to be deregulation. During the 1980's, that was very beneficial to the gas industry and to the customer.

Second, I think a lot of people, including us, underestimated the impact of technologies. A lot of the good news on the price side is technology-driven.

Many countries in the world still haven't applied this modern technology. But, they are being applied in the United States and it has made a big difference.

Chairman ROHRABACHER. Let me be presumptuous here when you say that and just suggest that what you are really saying is that it's very difficult for the people within perhaps a government agency making predictions to understand how the market will react to higher prices and that development of new technologies and new approaches will become available as a result of high prices. And, that isn't part of your equation.

Dr. HAKES. Well, it is part. Now, we've, I think, developed our skills considerably over the years.

We now have a number of years dealing with a less controlled market. And, you know, this is not something that has been done for decades and decades, so I would feel much more comfortable defending the types of methodologies and the sensitivity to the market, the sensitivity to technology in our current forecasts than I certainly would of forecasts that were made 10 years ago.

Chairman ROHRABACHER. Okay. Well——

Dr. HAKES. I think the market has confidence in a lot of the EIA data and, at least, a short-term confidence in the short-term forecasts because they tend to move the market. And, the market reacts to this kind of information.

Chairman ROHRABACHER. Well, Mr. Romm, for example, was stating about the political instability and some of the things that we, you know, have to worry about in terms of the Middle East. But, let me give you an example.

I mean, here we have Iraq, who is a major producer, who is outside now, who has been kept outside the world market. Why wouldn't your forecasts suggest that there is going to be a dramatic reduction in the price of oil in the long run because Iraq eventually is expected to become part of the world market again?

Dr. HAKES. Well, it does. I mean, we—some of our scenarios are assuming—particularly the low-price scenario assumes that Iraq is back on the market.

To some extent, the market has already incorporated some expectation that Iraq will be coming back on the market in the next few years. So, what—the impact it has on prices is its relative impact to what the expectations were of what that would do.

Certainly, that's a factor in the way oil is priced today and the way we do our projections. But, we do—you have identified what is a sensitivity in our forecasts.

And, that's why they have to be looked at in conjunction with other factors. And, that is, we do assume current policy in our reference case. We don't try to guess what the Congress is going to do or what the United Nations is going to do.

And, therefore—and that's clearly explained to the reader.

Chairman ROHRABACHER. But, it sounds like also you aren't figuring out what new technologies will do.

Dr. HAKES. No, we do that.

Chairman ROHRABACHER. If it becomes profitable for new technologies to come on market or come on line, I mean, it would be—it seems to me that when you are making—I don't know how many people suggested that the automobiles would be—maybe that was part of your predictions. Was that part of your predictions that automobiles, after a certain number of years, were to become so much more fuel efficient?

Dr. HAKES. Right, because it was required by law. So, that was easy to predict.

Chairman ROHRABACHER. All right.

Dr. HAKES. But, the—we do a lot of work on technology. And, this is, I think, an enhancement of the last couple of years.

We do, for instance, high- and low-technology penetration cases. And, we can show that if, for instance, technology in the natural gas industry improves faster than we anticipate that would show lower prices and more supply.

And, I think the industry and others that we consult with on issues like this are pretty comfortable with how we have treated a lot of those technology issues. But, again, as you've pointed out, particularly in our early forecasts, we did not do as good a job with those issues. I think we do a much better job today.

Chairman ROHRABACHER. Okay. Mr. Schleede, what's the cost of this?

I mean, when we have predictions that are off by a significant amount, how does that really impact the rest of us? What is the cost of those bad predictions?

Mr. SCHLEEDE. I don't have a total number. But, I can give you a few examples.

These high forecasts find their way into many, many decisions. For example, electric utilities are required to buy power from non-utility generators as a result of the Public Utility Regulatory Policy Act of 1978.

In order to determine the price that had to be paid for that power, utility commissions and utilities calculate what they call avoided costs, basically how much would it have cost the utility to produce this power if they were not buying it from the non-utility generator. When those calculations were being made, they were using forecasts such as EIA's and those produced by commercial forecasters.

They were using estimates—I heard President Fessler of the California Public Utility Commission just last week say that California was using an oil price of $118 per barrel. Those numbers found their way into the prices that the utilities were required to pay.

As a result, consumers and electric utilities are now stuck with these long-term contracts. In some cases, they built power plants that weren't needed, expensive nuclear power plants.

Consumers and the utilities are now stuck with these huge costs. I've heard an estimate from Southern Cal Edison of $2 billion per year as the extra costs that their customers——

Chairman ROHRABACHER. Was this from Southern California Edison?

Mr. SCHLEEDE. I've heard that number.

Chairman ROHRABACHER. Two billion dollars a year?

Mr. SCHLEEDE. I've heard that number. I can't verify it. I can give you the papers that I got it from.

Now, as we move towards less regulation of electric utilities——

Chairman ROHRABACHER. Well, before you move on, let me just ask. And, you think that's possibly an accurate figure?

I mean, even if it's $1 billion a year for one company, I mean, that is an amazing figure.

Mr. SCHLEEDE. It is a huge number, I will admit. But, I would have to go back and look at it. And, I suspect there's good information available on this from the California Public Utility Commission.

Chairman ROHRABACHER. So, you are suggesting that the actual cost of this to our society, if this is one company, is in the tens of billions of dollars that we are paying that is basically needless?

Mr. SCHLEEDE. Yes. Estimates that have been made of how much stranded costs—you've heard the phrase "stranded costs" associated with the changes that are underway in the electric utility industry, these stranded costs or stranded assets. That means investments that have been made, contract commitments that have been made, may not be recoverable as the market becomes more competitive.

Estimates of that stranded cost run to $200 billion, 10 times the stranded costs that occurred when the natural gas pipeline industry was deregulated. No one knows exactly what that number will be, because it makes an assumption about the market price of electricity.

If the market price of electricity goes down, as I suspect will happen, that cost could even be larger. But, a lot of those stranded investments are directly due to using these very high-priced forecasts and making long-term capital investments and long-term contract commitments based on that.

Chairman ROHRABACHER. Well, I would like to get Mr. Romm in on this, because one of the points he made was actually that there were some benefits, some side benefits, here that the society was actually enjoying because some of these technologies that you've mentioned would not have been developed had not these forecasts believed that we were going to actually have higher prices. And, now with lower prices, we are still enjoying the benefit of those technologies.

What about this? Is it conceivable that these things are giving us $100 billion or $200 billion a year worth of benefit, meaning to offset the cost that Mr. Schleede just mentioned is a burden that we are bearing?

Mr. ROMM. Well, I wouldn't want to compare apples and oranges. I wouldn't want to compare——

Chairman ROHRABACHER. Well, if you have to carry apples and oranges on your shoulder, still that's a burden that somebody—who cares if one's a different color or not if it happens to be the same burden?

Mr. ROMM. I just wouldn't want to compare the costs to the nation of incorrect forecasts, most of which were made by the private sector, with the benefits of government R&D.

The last nuclear plant ordered in this country was 1973. The last central power plant ordered in California, I believe, was 1975. So, this was long before EIA came into existence and could have confused the—you know, could have led to misperceptions on what the future trends were.

I think it's also worth saying that I personally think it's a mistake to only go back 16 years and say future forecasts have consistently been too high. If you go back to the late 1960's and early, very early, 1970's, many people were predicting that prices wouldn't be so high, which is why they predicted the huge demand growth that led them to buy all the power plants to produce power that ultimately wasn't needed because price went up and demand came down.

So, my point is just that people have been wrong in both directions. I think it's important to not bet the future economy and security of the country on someone saying, "I know which way the price is going to be. I know what the future is going to be."

The question is: what is a plausible scenario for the future? And, I think that a growing dependence on Persian Gulf leading to security and trade deficit concerns is a very plausible scenario.

Chairman ROHRABACHER. Well, Mr. Romm, let me ask you about that growing dependency. And, I have friends who are independent oil producers, and they are always telling me about how horrible it is that we are more dependent on foreign oil.

If the price of oil is expected to go up in the future, isn't this the time that we should be using more foreign oil rather than depleting our own domestic resources?

Mr. ROMM. Right. And, my scenario—using inexpensive oil is good for the economy.

Having the world become very dependent on one of the most unstable regions in the world is a great risk to the nation's security. And, that's what we are trying to avoid.

We are not trying to avoid people using inexpensive oil. We believe that the Department's R&D programs have helped keep the cost of using energy overall low.

I think the issue is just the geopolitics of increased dependence on the Persian Gulf.

Chairman ROHRABACHER. Mr. Schleede, do you have a comment? You seem like you are ready to jump on that.

Mr. SCHLEEDE. I think it would be useful to just look back a little bit in history and figure out why we are so dependent upon foreign oil. We had an energy policy in this country for a long time that, in effect, led to the draining of America first. It was a protectionist policy of the 1920's and 1930's and particularly in the mandatory oil import quarter, which provided tariffs and other incentives to make sure we drained America first.

We ignored the possibility of using lower-cost foreign oil. Now, we've got ourselves in a situation where the lowest-cost oil available is elsewhere.

And, it has been government policy that got us into this mess, not that has gotten us out of it.

Chairman ROHRABACHER. Mr. Lynch, are you comfortable now that some of the predictions that we are going to get are going to be more accurate than the predictions we've had in the past?

Mr. LYNCH. You mean, from EIA?

Chairman ROHRABACHER. EIA and generally.

Mr. LYNCH. Mr. Romm quoted a number of experts who have recently sort of backtracked on their earlier lower forecasts. I have noticed sort of a cycle of a couple of years where people see there's too much oil and they get embarrassed about their high price forecasts and they sort of backtrack and then somebody writes an article and says, you know, "Oh, there really is a problem in a few years."

T. Boone Pickens is now pretty much bankrupt, because he believed that U.S. gas prices would go very high. I doubt if he was, you know, buying into the EIA forecast.

So, I think what you are seeing—for instance, The World Bank has recently come out with a low price forecast—the U.N. and others.

I think the EIA is moving in the right direction. But, especially in the oil price forecast, it should be substantially lower, more flat rather than rising in the long run.

Chairman ROHRABACHER. You know, I am going to ask you to repeat that last sentence, because I am having a little trouble, after this message is done here.

Mr. Lynch, could you repeat what you said in those last couple of sentences?

Mr. LYNCH. I think the EIA forecasts, they still are tending to show an oil price increase of a couple percent a year, whereas most of the experts—certainly the oil industry has come to a flat or even declining price forecast. And, I would like to see them do that.

I don't know how much that influences, you know, utilities and so forth.

Chairman ROHRABACHER. All right. Mr. Roemer, would you like to proceed?

Mr. ROEMER. Thank you, Mr. Chairman. You know, I couldn't help but think, Dr. Hakes and Mr. Romm, as we talk about these models and how easy they are to criticize and critique what a tough job you have.

I was looking in the back of the room as we were talking about how far off some of these models have been in the past by saying that oil was going to disappear in the next few decades and then now how we are going to have sufficient access to energy prices. And, I was looking in the back of the room and I saw somebody reading the sports page.

Wouldn't it be nice if we had a model to accurately predict our NCAA pools and then bring our witnesses up here and say, "Gee, you were way off. You were really way off."

For the stock market, to bring T. Rowe Price and Vanguard and Fidelity up here and say, "You didn't predict that the market was going to be at 5600 right now. You said 4800."

I wish we had an accurate model that could tell us the effect of Iran and Iraq and Mexico and a host of different foreign countries and how that's going to affect our price of oil in this country. It is a very difficult job to do.

And, you know, with all due respect, Mr. Schleede, I wish you had a better model. I wish anybody had a model that could tell us with accuracy to the year 2015 or 2020 what precisely are going to be the key variables.

Now, I think this model helps us illustrate the forces at work. I think it helps us illuminate what we need to consider.

But, how do we improve that? How do we get a better model when there is so much volatility?

And, certainly, I think, one of the lessons that we learn is one of the things that we've heard from the Republican side and the Democratic side is let's try to cut some of the regulatory burdens on some industry. Let's try to make efficiency one of the key words, but let's not say, based upon a model in the 1970's or the 1990's that says oil is going to be high or low, that we cut R&D monies for valuable efforts in solar and renewable and fusion and nuclear and other things that really could determine our security when we are getting anywhere from 48 to projections of 70 percent of our oil from the very, very volatile Middle Eastern region. I think that's very difficult.

Mr. Schleede, do you have a model that you can present to the Committee——

Chairman ROHRABACHER. Before Mr. Schleede moves forward with his answer, I have a—there is a markup in International Relations that I'm also a member of, and I am going to have to leave for a few moments.

And, Mr. Wamp will be chairing while I'm gone. And——

Mr. ROEMER. I was going to say, Mr. Chairman, I would be happy to——

[Laughter.]

Chairman ROHRABACHER. But, I also would like to acknowledge the presence of former Chairman Brown.

Mr. BROWN. I thought you were going to invite me to be chair.

[Laughter.]

Chairman ROHRABACHER. All right. And, Mr. Brown will be recognized after Mr. Roemer.

Thank you very much. I will be back as soon as I can. Thank you.

Mr. ROEMER. Thank you, Mr. Chairman. Mr. Schleede, do you have an accurate model that could give us more precise and definitive information projecting into the year 2015 or 2020?

Mr. SCHLEEDE. Clearly, I don't have a model nor do I have the $60 million that EIA has to spend on the Energy Information Administration. But, what I would suggest you look for in the model—and here I think Mr. Romm's comments illustrate the problem pretty clearly. And, I separate his comments from Dr. Hakes.

I think EIA has done a lot better in recent years. Particularly this last forecast is a step forward. There are still things that I think are real problems with the model that I would be happy to talk about.

But, what I am looking for and what I suggest the taxpayers deserve and the consumers deserve from the Department of Energy is greater objectivity in the analysis. We listened to Mr. Romm sit here and tick off all sorts of "Chicken Little" kind of scenarios that we should worry about in order to support DOE R&D programs.

As a taxpayer, I would like to see the folks in DOE be a little more objective and recognize that there are reasons why this perceived energy crisis may not occur and to present some balanced arguments rather than emphasizing all the time that the sky is about to fall. We need some objectivity from——

Mr. ROEMER. So, I guess what you are advocating in terms of objectivity is that we, as decision-makers in Congress, have a host of hearings on these matters so that we can best ascertain and judge what should be funded and what shouldn't be and whether legitimate "Chicken Little" theories and what aren't and that this Committee should have extensive hearings on these kinds of matters?

Mr. SCHLEEDE. I would hope so.

Mr. ROEMER. And not just one or two hearings.

Mr. SCHLEEDE. There are good reasons to suspect that there are systematic, upward biases that have affected price forecasts for the last few years. I've got a detailed paper to put in the record that helps explain some of those.

But, there are a lot of good reasons to worry about that systematic, upward bias on commercial forecasts and on the older EIA forecasts. Again, EIA's latest forecast is better than what they have done before. But, there are still problems with it, I believe.

But, your idea of getting viewpoints from both sides and getting some objectivity back into this and getting the folks at DOE to stop acting like their only mission in the world is to get more authority for DOE and more money for its programs would help.

Mr. ROEMER. Mr. Romm, how would you respond to some of those suggestions that Mr. Schleede made?

Mr. ROMM. Yeah. I will try to repeat that I'm not predicting the sky is falling. I am predicting that we've seen what happens in the past when there are crises in the Middle East and don't—and we haven't prepared for them.

We had a war five years ago. We've had three recessions in 20 years; all followed price spikes.

It is possible to hope that the future is going to be great. It's not the job of people who work for the government. Our job is to take an insurance policy, as you would say.

What is a plausible scenario for the future? It is possible and I hope the prices remain—you know, that we don't have a price problem and that we don't have a problem with a growing dependence on Persian Gulf oil.

I wouldn't want to bet the future of the country on this.

Mr. ROEMER. Can you just repeat, Mr. Romm, what were the variations in terms of our imports from the Middle East Persian Gulf area based upon the different projections?

They went anywhere from 45 percent to 75 percent. Is that accurate?

Mr. ROMM. Yes.

Mr. ROEMER. With that kind of volatility in where we are getting our oil, I'm not sure how you can't say—one of the models might say, you know, there could be another recession based upon energy prices. And, for you guys to outline that possibility is certainly not a "Chicken Little" theory but something that would warn us that we need to have alternative energy sources.

Mr. ROMM. Right. I mean, I would make two points, one of which is that we see, in these projections, that the world's dependence on Persian Gulf oil could exceed its highest level ever. And, this would be accompanied by a subsequent huge amount of influx of dollars into that region.

And, I would just, you know, point out that this is a very unstable region. I would—you know, let me read from a recent "Congressional Research Service" report: "This is an area with a history of wars, illegal occupations, coups, revolutions, sabotage, terrorism and oil embargoes. To these possibilities may be added growing Islamic movements with variance grievances against the west and particularly the United States."

So, we——

Mr. ROEMER. So, "Chicken Little" wouldn't necessarily be moving to 75 percent. "Chicken Little" might be, to the American people, in Indiana or Tennessee or Oklahoma, that we are currently 50 percent. And, that is somewhat dangerous to be relying on 50 percent.

And, we should continue to have an insurance policy and many options and many alternatives.

Mr. ROMM. Indeed. And, I would say that I'm not here asking—the Department isn't here asking for huge increases in energy R&D spending.

The nation spends so little on energy R&D. The nation's energy bill is $500 billion a year. Energy R&D is two-tenths of 1 percent of our entire energy bill.

I'm here before a Committee that is contemplating a 50 percent cut in advanced transportation, efficiency technologies and advanced alternatives, you know, fuels, advanced renewable technology. So, I'm pleading.

This is an important program for both national security as well as other goals. Again, we've been focusing on oil.

The sole goal of the Department is not just to reduce dependence on Persian Gulf oil. We are concerned about reducing the environmental impacts of energy.

We want to keep energy costs low. And, we want to maintain U.S. scientific and technological leadership.

We can do all those simultaneously while keeping dependence low.

Mr. ROEMER. For two-tenths of 1 percent?

Mr. ROMM. For two-tenths of 1 percent of what the nation spends on energy. It's a very small amount of money.

Mr. ROEMER. Thank you, Mr. Romm.

Mr. WAMP. The Chair recognizes the distinguished Ranking Member of the Full Science Committee, Mr. Brown of California.

Mr. BROWN. Thank you very much for giving me the opportunity to ask a few questions.

I am concerned that we don't get into a hysterical mode over the fact that oil forecasts and oil price forecasts are not very accurate. I think of other forecasting that is in the same category, going back to Malthus, for example, forecasting the supply of food and decided the whole world would starve to death within a fairly short time. Fortunately, he was proven to be wrong.

But, the same tendencies, the same effort to evaluate long-term trends persist today with very dynamic and unstable systems. And, I think that's at the root of most of our forecasting errors.

And, I would like to point out also that the Department of Energy isn't the only agency that tries to justify its budget by even a small amount of crisis thinking. You know, I can't help but go back to the Intelligence Agency and the Defense Department who made such a miserable job of forecasting the threat potential of the Soviet Union for so many years. And, that is acknowledged today.

But, forecasting a huge threat there is very healthy for your budget if you are in the intelligence business or the military business. So, what I would like to see—and I think it's developing here—is a more restrained approach to this.

We don't want to be crisis-driven. We want to continue to improve the system, but I don't think that you need to depend upon the threat of a crisis if you have a stronger underlying motivation, which is the total quality improvement of the American economic system.

If you are driven by that—and I don't know anybody who disagrees with the need to continue to focus on that if we are to survive as a great economic power—then you will try to improve energy efficiency, you will invest in energy R&D. You will try to do everything possible to achieve the kind of economies and savings that we are trying to achieve. And, it's part of our goal here in this Committee.

Now, the question is. Does anybody disagree with that? That's a very self-serving question.

[Laughter.]

Mr. BROWN. No? All right. Where do I go from here, then?

I think I will yield back the balance of my time.

Mr. WAMP. Thank you, Mr. Chairman. In the order of those that appeared, not including those in higher authority like Mr. Brown, I'm next. So, if I might, I want to make a statement and lead to a question.

This morning, I had breakfast with Secretary of the Army, Togo West, talking about the military budget. And, the word is out on the President's request for 1997 for the military, including the Army. And, it's a reduction.

And, there are many folks on the Republican side of the aisle that think that just because we are at peace and the Cold War is over that we shouldn't reduce those budgets too rapidly and that we should be careful about these reductions. And, to me, this issue, if we are consistent, is somewhat similar.

I have friends on all three sides of this issue. And, Mr. Schleede, you stated earlier in your testimony—and I looked for it in the written testimony, but I think you just said it in your testimony earlier—and I'm paraphrasing, that you hoped that the threat of a future oil crisis would not cause a call for a larger role for DOE.

But, as Mr. Romm pointed out—I asked my staff to go get the numbers. And, from the 1995 budget to the 1996 budget to the 1997 budget, these numbers continue to come down, continue to come down dramatically.

I don't think that even the Secretary of Energy herself is calling for increasing these funding areas. I think she's calling for decreases internally.

Now, the President's request continues to tick up. But, he is, in fact, requesting less last year than the previous year's budget.

So, he's recognizing, too, in his request—and I think it's traditional for the President to always request more than he expects so that when he gets what he gets, it's still not quite as bad as they thought it would be. And, you all know how that works.

So, my question is—and I think Mr. Brown's right. We need to be reasonable.

I think Mr. Roemer is right. We might need to have more hearings before any of these votes come on these significant reductions in these energy R&D accounts, which I'm certainly very reluctant to support.

But, I would like to know how much is enough? From each of your perspectives, what is a reasonable reduction?

And, think as if it is a national security issue, as if I were sitting with Secretary West at breakfast this morning about exactly what we can do.

Since we have missed some of our estimates and predictions and since clearly there is an abundance of foreign oil right now, how much is a legitimate reduction over the next two or three years? I personally believe that no reductions is not enough and the reductions that our Chairman proposes are way too much.

So, what should we come together at?

Mr. SCHLEEDE. Would you like a response?

Mr. WAMP. Yes, from each of you, please.

Mr. SCHLEEDE. In my past history in different places in government and in the private sector, I've had some budget responsibilities. So, my bias usually is to start with zero and then see how much rather than see how much we spent last year and see whether we should increase or decrease from that. I like the zero-based approach to evaluating any budget proposal.

A couple of points. How much of this R&D that we are talking about is really being—how much of the money is really being spent productively and how much of it is being wasted?

Each week in the mail, I get piles of papers. And, here's one called, "The Directory of United States Coal Technology and Export Resources," paid for out of the Clean Coal program, not one of your committees but another one.

This, presumably, is paid for out of an R&D budget. It is a collection of, in effect, advertisements for anyone involved in coal or coal technology, paid for by the taxpayers, mailed out at the expense of the taxpayers and information on individual companies that some private company out there could have just as well put together and probably made some money on it.

Instead, that is paid for out of an energy R&D budget at taxpayer expense. So, one question I would like to suggest you focus on is how much of this money that is being spent for R&D is really for advancement of technology—or advancement of knowledge and in the creation of new products that compete in the private economy; or, how much of it is for overhead and sheer waste like I think this is?

A couple of years ago, I didn't get just one of these, I got three of them, followed by a letter from DOE saying, "Would you like to advertise in this, because we have a huge circulation of this document?" If it's free and it's mailed out in multiple copies to a lot of people, I can understand why they have a huge circulation for it.

But, that's one point.

Mr. WAMP. Thank you, Mr. Schleede. Let me add one antidote that I think supports the notion that we've got to be very careful here.

In Oak Ridge, Tennessee, which I represent, the research and development that was brought out of these transportation programs actually led to the development of the technology in east Tennessee to build electric buses. There is now a company in Chattanooga, where I live, in east Tennessee that builds electric buses. It is called "Advance Vehicle Systems."

That technology came from the embryonic stage in our region through the Department of Energy through the national laboratory system into applied technology, on the streets. It's now creating jobs, building a lot of buses.

And, it has led to a lot of good things in our part of the world. That is kind of from cradle to grave, the way this can work.

And, a zero around energy R&D programs won't allow that life cycle. And, I would just suggest that we look at, as we have these hearings, situations where it has actually borne the fruits of its original investment and not just talk about go to zero and start over.

You can't go to zero and start over when you are talking about programs that have advanced. They are not efficient. They need to improve.

I wholeheartedly agree that we've got to do more with less, but let's not throw the whole thing out the window.

Mr. ROMM. If I could comment on that? I think that's a very important point.

The nature of R&D is that you have some losers and some—you know, some technologies don't pan out and some do. The question is. Are your successes so successful that they justify the entire investment?

In the case of Oak Ridge, just one example, which is advanced refrigerator/freezer compressors, a $1 million investment in Oak Ridge has saved the U.S. economy $5 billion in the 1980's. And, this is very well documented.

I think the question is—most people think that R&D is one of the most important investments the country can make. The energy efficiency in the energy renewable program has already taken last year a 30 percent cut. That is deeper than the cut in domestic discretionary funding that most people think is needed to get to a balanced budget.

This Administration thinks that we can increase the budget and still balance the overall federal budget in seven years, because it recognizes the importance of R&D to the future of this country. The reason to cut costs in the Federal Government is because of our obligation to future generations, that we don't burden them with terrible deficit costs.

We have another obligation to future generations, and that is to keep energy costs low and to improve the environment. That's what R&D does.

And, that's why I don't think we need further cuts in these programs at all. And, I think one would be hard pressed to find many technologies that--and many investments that have such a high rate of return.

One last number, which I give in my testimony, and that is that the nation spends 100 times as much money on military forces in and around the Persian Gulf as it does on R&D to prevent the next oil crisis. So, it's really, again, a drop in the bucket.

Mr. WAMP. Mr. Schleede.

Mr. SCHLEEDE. You hit on the critical question, evaluating government spending in R&D. And, that's when you can point to some successes; they sound very good.

One question you need to focus on—and it's a very difficult question to answer and perhaps not answerable—and that's. Would that technology have been developed had it not been for the tax dollars that went into the Oak Ridge program?

And, I submit it's very difficult to argue either way on that. But, I'm not sure that technology would not have been developed. Perhaps if that money had not gone into Oak Ridge, those scientists and engineers involved in it would have been out in the private sector and would have developed it earlier.

But, even if you take all these success stories that can be claimed—and here's a document that DOE put out last year that chronicles the success stories, "Energy Mission in the Marketplace." And, it goes back over the last, I don't know how many years, 20, 30 or 40 years of energy R&D spending.

Now, is that worth $100 billion that's in there, that has been poured into energy R&D?

And, I think there is a reasonable basis for questioning whether all the money that is focused—that's funneled in through government programs is producing that. And, I think it's difficult to argue that the successful technologies would not have been developed by the private sector if the government had not gotten in the way.

Mr. WAMP. This is very beneficial. And, I commend the Chairman for allowing these alternative views to appear at the same time.

Before I yield to Mr. Ehlers, as one parting shot here for the Department of Energy, I don't think you do the overall energy options and portfolio justice to turn your back from nuclear energy. And, I say that everywhere I go.

I think that our fear of waste is so exaggerated that it does not serve this country well for us to withdraw from the nuclear capabilities that we have for energy production.

And, the Chair yields to Mr. Ehlers.

Chairman ROHRABACHER. I know that Zach is going to be here permanently one day, so——

[Laughter.]

Chairman ROHRABACHER. Mr. Ehlers, go right ahead.

Mr. EHLERS. I think someone else might be in there for a little while before him, however.

[Laughter.]

Mr. EHLERS. I don't want to make you feel insecure in your chair, Mr. Chairman.

[Laughter.]

Mr. EHLERS. Thank you, Mr. Chairman. I appreciate the opportunity to respond to this panel.

This is an area I've had an interest in for a very long time. And, I regard energy supply as one of the most important issues before our nation, let alone this Committee.

I was reminded, in listening to the arguments about the forecasts, of a comment made by Neils Bohr, who is a famous physicist and developer of the first reasonable theory of the atom. And, he had a unique way of using language.

And, I remember his comment once in a discussion. He said, "It's awfully difficult to make predictions, especially about the future."

[Laughter.]

Mr. EHLERS. And, I think he went down in history with that comment.

Mr. OLVER. Would the gentleman yield?

Mr. EHLERS. Yes.

Mr. OLVER. Were you present at that time?

[Laughter.]

Mr. EHLERS. Well, I hate to reveal my age, but—actually, I don't. I'm in my 60's, as you know.

But, no, I have had personal conversations with Neils Bohr. And, he does have a unique way of using language.

In any event, just one side comment before we get into my full comments. Mr. Schleede, I find those directories very useful. Or, when I did research in this field, I found them very useful.

I would be delighted if they were produced by the private sector. And, perhaps we have to put a price on them from the DOE.

But, I hesitate to castigate government agencies for producing information that is useful for those in the field. And, this is an ongoing problem—what should we do and what should the private sector do.

But, I don't totally agree with your condemnation of the production of that. I just wanted to get that on the record.

The real issue, however, to my mind—and most of this discussion has been about energy prices and predictions of that, whereas the Hearing Charter says to focus on energy supply, demand and prices. And, I am particularly concerned about energy supply long-term.

And, that is where I believe the government has a role. And, that's where most of my questions will go.

It seems to me that the most important issue facing this nation in regards to energy is to maximize the efficient use of energy. And, it has always been a surprise to me that many in industry don't pay enough attention to that, because we worry a great deal about efficient use of manpower or womanpower.

That's a big issue. How can we increase productivity? How can we operate more efficiently?

But, I found, in my experiences, that American commerce and industry has not paid enough attention to maximizing efficient use of energy.

I would even give a little indictment of the DOE of its not having done enough in this area. And, I think the indictment that I've mentioned on the DOE is that one of the most effective program, the Green Lights program—and, in fact, was originated by the EPA rather than the Department of Energy and it should have been, I believe, originated by the Department of Energy. They should have been concerned about that long before the EPA was.

The question is. How can we maximize efficient use of energy? And, that's through some R&D to find out better ways of using energy, to improve the efficiency and getting the word out.

I think we do a reasonably good job in the R&D. I don't think we do a very good job on getting the word out to the manufacturers, to the users, so that they can make intelligent decisions.

I happen to be a strong supporter of energy appliance, not necessarily standards but information, so that the consumer knows when they buy an appliance what the energy efficiency is. I think that's a governmental function, in my mind, to let the consumer know in a very objective fashion what the energy costs of their particular appliances are so they can make wise consumer decisions.

The real issue though, I believe, is what is the long-term energy supply. And, perhaps the most useful chart here is the Shell Oil chart.

I hope it's accurate in their projections, because I'm not worried about 2015 as yet. I'm worried about 2025, 2035, 2045 and what's going to happen then.

And, my questions are directed to anyone at the table. I'm sure you are all familiar with M. King Hubbard's curves. I'm certainly familiar with them.

I'm not familiar with what is happening in that field now. One of the disadvantages of being a congressman is that you don't even have time to think, let alone read. So, I am a little out of touch with the field.

But, I'm curious what each of the members of the panel think about when is the bell-shaped curve or approximate bell-shaped curve of M. King Hubbard going to peak, because it seems to me that also has a very important bearing on prices. The difference between an energy glut and an energy crisis is only 2 percent.

If you have 1-percent extra oil, you have a glut, or at least the papers call it a glut, which I find a strange term. If you have 1-percent shortage and you get the lines at the gas station, they call it an energy crisis.

And, I can assure you, when we start reaching the peak of the Hubbard curves with respect to the fossil fuels, we are—the public is going to regard that as a crisis. It's also clear to me, based on the last 20 years of history, that when we have had these energy shortages, which people call crises, it does have a dramatic effect on the economy.

That one graph shown—although it may relate, Mr. Chairman, with the tax hike as well, they could have had it together. But, it's clear when you look at the last three so-called crises we've had, which were just temporary shortages, but they all had a dramatic effect on the economy.

Energy is frequently not understood in terms of its role in the economy. But, I think it's very important.

So, the question, then, based on those comments and that discussion is. When are we likely to reach the peaks of the Hubbard curves? Or, if you have some other model other than the Hubbard model, that's fine.

When does it become a real problem? When do the prices really start to escalate rapidly?

And, what are the likely replacement scenarios? And, I think that's the real function of DOE, to try and look out long term where the industry may not have the resources, may not be able to dedicate a lot of resources because it's not profitable.

I would like to know where each of you are personally in this. And, I also would appreciate your comments on what is likely to happen to energy prices when we start peaking out on the Hubbard curves.

And, we will just go down the line.

Chairman ROHRABACHER. If I could ask each of you to be concise, because Mr. Ehlers has used his five minutes a few minutes ago.

Dr. HAKES. I would like to be able to answer that question, but our analysis that we do at the Energy Information Administration is confined to the year 2015. And, we've not gone beyond that area. So, I don't really feel very equipped to answer that question.

Mr. EHLERS. That's unfortunate, because that's where the real problems are. I would rather have you spend your time on that than forecasting prices between now and then, because we have people like Mr. Schleede, who can do the forecasting and get paid for it by other people.

Mr. Schleede.

Mr. SCHLEEDE. I'm not getting paid for this part of it, I will tell you.

[Laughter.]

Mr. EHLERS. That's okay. I'm sure you make enough elsewhere.

[Laughter.]

Mr. EHLERS. We appreciate your presence.

Mr. SCHLEEDE. As far as King Hubbard's bell curve, if you look back, we've been getting predictions that we are at the top of that curve now, dating back into the 20s. And, where it is, where that top of the curve really is, I don't know. And, I'm not sure anyone does know.

It was only a few years back that government policy assumed that we were running out of natural gas. And, we now know that we've got more natural gas than we know what to do with and world proved reserves of gas are up threefold from what they were 15 or 20 years ago.

But, I think the thing that we have to keep in mind is that technology keeps developing that change the world a great deal. And, not all that technology is developed by the government.

But, technology does keep changing our outlook and making new things available that none of us in the forecasting business or other business have been able to see. And, that's the case with energy right now.

Energy efficiency has improved tremendously over the last few years. And, not all of it has been price induced.

A lot of the energy efficiency improvements that are occurring are byproducts from other technology developments—electronics, communications, electronic controls, better materials, all of which have energy efficiency as a byproduct and which are helping us. But, to try to predict out 50 years or 40 years, I think, is very difficult and perhaps impossible to do.

I certainly don't have any confidence in any predictions out there. What I do worry about is when people do make these predictions is that they are based not on the best information available but on the desire to show a particular bias conclusion that benefits them.

And, that's what I think this Committee ought to worry about.

Mr. EHLERS. If I may, I agree totally. And, it always bothers me that people let ideology creep into these things on both sides.

Mr. Romm, quickly.

Mr. ROMM. I'm not a forecaster. I'm a physicist, like yourself. And, I just go by reading the literature as much as possible, because the government is not in the job of betting on one future or another.

I would say that apparently the Congressional Research Service has an expert on earth sciences who is very knowledgeable in this matter. I have an August 18th report that he did.

He has a line in here, "Discounting the reserves that may be exaggerated and utilizing only that portion of the resources that may be produced in actual practice could reduce the ultimately recoverable oil remaining in the world to a level where the midpoint of world oil depletion would occur at the turn of the century followed by a production decline of nearly 3 percent per year." And, he makes clear that that's a worst case scenario.

But, another view—and this is something I am more familiar with—is Royal Dutch Shell. And, I had one chart up there.

Last year, the Chairman and CEO of Royal Dutch Shell UK, a man named Chris Fay, gave a speech in which he outlined what Shell thought. And, Shell is the most profitable oil company. It's the most profitable, according to "Fortune" magazine the most profitable corporation in the world.

He said, "There is clearly a limit to fossil fuel. I showed how Shell's analysis suggests that resources and supplies are likely to peak around 2030 before declining slowly."

"And, about the growing gap between demand and fossil fuel supplies, some will obviously be filled by hydroelectric and nuclear power. Far more important will be the contribution of alternative renewable energy supplies."

And, that's why Shell has bought two photovoltaic companies and they invest in biomass in Brazil. And, clearly, if Shell predicts renewable energy may be the dominant source of power by the middle of the next century then, indeed, this is an area where the Federal Government is crucially needed, because this is long term, high risk R&D.

We have been very successful in bringing the cost of photovoltaics and wind energy down, which is one of the things that has convinced Shell that renewables are going to make deep market penetration. And, I would just comment that the Japanese outspend us just on photovoltaics by over two to one.

So, the other countries of the world have caught on to what Shell understands, which is that renewables may, indeed, a plausible scenario, be very dominant in the next century. And, if the United States is going to participate in what may be one of the world's largest international markets, we had better have high levels of R&D in that area.

Mr. EHLERS. Mr. Lynch, very quickly.

Mr. LYNCH. Yes, thank you. Actually, I have a paper on this subject of supply modeling, including the Hubbard approach, coming out next week.

I would mention Shell also has a large synthetic fuels plant in Malaysia, which would be profitable if the price of oil was where they had forecasted. But, they are losing money on it now.

The short answer to the Hubbard question is. Hubbard got lucky. If you read his earlier statements, you will see he really didn't have a very clear methodology, but he happened by chance to come close to predicting the U.S. oil production peak.

The main error is that he's using a curve. The area under the curve is supposed to be total resources. That amount, in theory, is fixed because it's the total resource. But, the estimates of that have increased over time since his original work and even recently.

So, you really can't see a peak, because the peak keeps moving out further and further into the future. And, people who do this kind of work are always sort of explaining that the previous peak was wrong but now they have a new peak and it's the real peak.

So, I wouldn't give too much credence to that. I can forward to your staff my paper, if you would like.

Mr. EHLERS. I would like to see it. And, let me just comment——

Chairman ROHRABACHER. Thank you, Mr. Ehlers. You know, you have had about three times as long as anyone else.

Mr. EHLERS. Thank you. I appreciate your tolerance. I will be very, very quick.

I just want to point out——

[Laughter.]

Mr. EHLERS. (continuing) the key point is that there is a peak. And, my personal opinion on the oil, it's likely to be about 2020 or 2025.

The last item——

Chairman ROHRABACHER. Thank you, Mr. Ehlers.

Mr. EHLERS. (continuing) energy is the only non-recyclable resource. Everyone should remember that.

Chairman ROHRABACHER. What's the only non-recyclable resource?

Mr. EHLERS. Energy. It's the only resource that cannot be recycled. It's a non-material resource.

Chairman ROHRABACHER. I think there is a university lecture behind that last statement.

[Laughter.]

Mr. EHLERS. But—no, I would be happy to extend that.

[Laughter.]

Mr. EHLERS. Thank you, Mr. Chairman.

Chairman ROHRABACHER. That's the second round. Mr. Doyle.

Mr. DOYLE. Thank you, Mr. Chairman. Following Mr. Ehlers' lead, I will try to be brief.

[Laughter.]

Mr. DOYLE. Let me start by saying, you know, in the political forecasting business, there is a saying that the only thing that is certain is that nothing is certain. But, I would note for Mr. Roemer's benefit that one thing that is certain about the NCAA tournament is that Penn State is in it and Notre Dame isn't.

[Laughter.]

Mr. ROEMER. Would the gentleman yield?

Mr. DOYLE. Yes. Yes, I will yield to the gentleman.

Mr. ROEMER. Now, we are really talking about some serious issues here.

[Laughter.]

Mr. ROEMER. I would note to the gentleman that both Indiana and Perdue are in the tournament and that we still have the most successful high school basketball tournament in the country.

Thank you.

[Laughter.]

Mr. DOYLE. And, I wish them all the luck in the world.

[Laughter.]

Mr. DOYLE. I guess, looking at these models and talking about, you know, the uncertainty of things, clearly looking at models that predict energy prices into the future are clearly uncertain, at best. But, I think one thing that maybe we can all agree upon is that energy research and development has contributed to keeping energy prices low.

And, it's also my understanding that in these models, we take into account constant technology gains so that if we were to drop off the research and development efforts that clearly would have an effect on these models also. And, I guess it just gets down to a question of since we can't, you know, decide what the pace of our nation's energy research and development should be by looking at the facts, because it seems that the facts are clearly uncertain at best, it comes down, in my mind, on which side do we make a mistake.

Do we err on the side of not keeping pace with other countries? Japan, for instance, spends many, many times more money on research and development than this country does.

Do we put our country in the position that if we guess wrong and we don't continue to make these investments in research and development, I think we find ourselves in a much more serious situation than if we continue these efforts. And, I think it's also important to note that the amount of monies we are talking about have fallen dramatically since 1980.

I mean, we are now spending roughly 20—or there has been roughly a 20-percent cut from what we spent in 1980 in applied research investment. So, we are not sitting here talking about an ever increasing dollar amount going into research and development in energy here in this country; we are looking at decreases.

And, I just think that it doesn't make much sense to this member, who certainly is in no position to guess what the future holds in the year 2015 or beyond, that if we are going to make a mistake—and, clearly we seem to make lots of mistakes when it comes to predicting these things—I would hope that we err on the side of keeping this country competitive and continuing to make investments as other countries and competitors are doing in research and development.

And, with that, Mr. Chairman, I will yield back the balance of my time.

Chairman ROHRABACHER. Well, I think we should have the panel comment on that. Go right ahead, Dr. Hakes.

Dr. HAKES. Well, I think that relates to a policy question. And, so I would defer to the other members of the panel.

Chairman ROHRABACHER. Mr. Schleede.

Mr. SCHLEEDE. I don't think there is anyone that questions that R&D has produced benefits. The question is. Which R&D has produced benefits?

Is it the DOE-funded R&D programs or is it R&D that is primarily coming from the private sector? And, I submit that question is not always clear.

And, even when you take DOE's claims of the things it has been involved in, this document, for example, is noticeably weak in identifying what the DOE role really was in these developments. It's impossible to tell by reading it whether DOE had a significant influence or whether it provided a few dollars and then took credit for the results.

But, the question, undoubtedly, gets back to how much insurance can we afford. How much should we spend?

And, we could throw money at lots of things and say it's insurance and that we ought to err on the side of safety. But, we can't afford it.

Chairman ROHRABACHER. Do you have a comment?

Mr. ROMM. I think it's clear. I think there's a great concurrence that energy R&D is of great value to the nation.

I think the document on energy success stories that Mr. Schleede refers to is something that we have a lot of supporting material for, including very detailed discussions of what the role of the Department is. And, I think it's important not to overstate what the Department does.

I think it's important, however, to understand that the country has, in some sense, got a looming, you know, R&D problem, which is that the private sector R&D has been flat in the last five years. A lot of this is due to corporate downsizing, international competition.

Energy R&D, because of low prices, since 1985 in the private sector is down 35 percent. So, we have this situation where everyone says energy R&D is important, the private sector has begun to pull out because of competitiveness and low energy prices, and, the one body that is charged with looking long term is also seeing cuts in energy R&D.

So, I would just say that this is a time when we should be thinking of how do we increase federal R&D spending, how should we particularly increase energy R&D spending. And, I don't think the notion that we should be cutting the budget in half makes much sense, given the tremendous consensus on the value of energy R&D.

Mr. DOYLE. And, Mr. Chairman, I would like to correct a statement I made, too. When I said that since 1980 there was a 20-percent reduction, I actually had it wrong.

Since 1980, we now spend 20 percent of what we spent in 1980. We have actually reduced Department of Energy R&D funding 80 percent. We now spend 20 percent.

In our total budget—I mean, here's a graph that shows what our total U.S. energy's expenditures are. And, this little pencil line you see down here is what the federal energy R&D efforts are.

Chairman ROHRABACHER. That's right. That's right. Mr. Doyle, I——

Mr. DOYLE. So, I just want to reiterate that.

Chairman ROHRABACHER. I remember those corporate boondoggles that we cut out.

Mr. Lynch.

Mr. LYNCH. Thank you, Mr. Chairman. I just want to say that I'm a little concerned at the suggestion that maybe there's some magic number of correct research spending.

I think one thing you do want to consider is why are you spending the money on particular projects and just think that, you know, you don't want to build a Clinch River breeder reactor just because it's located where, I believe, the Senate Minority Leader was from. You don't want boondoggles, whether they are DOE boondoggles or congressional boondoggles, with all due respect.

Chairman ROHRABACHER. Point well taken, Mr. Lynch.

[Laughter.]

Chairman ROHRABACHER. We now have Mr. Davis from Virginia.

Mr. DAVIS. Thank you, Mr. Chairman. Let me ask the Department of Energy representative, do you have any information that leads you to really fear the instability situation in the Gulf at this point in terms of an energy crisis?

Mr. ROMM. Well, I think if you read the newspapers, every major Gulf exporter has had some turmoil, terrorist event or war within the last one year or two years alone. I think the people—the security analysts who look at this—are very concerned about it.

And, I think obviously we've had classified briefings. And, we would be delighted that any member who really wants to get at this issue, how stable are the Persian Gulf suppliers today and what is the likely prospect in the future, we would be delighted to set up some security briefings.

But, as I say, it is——

Mr. DAVIS. I guess my question was maybe that would be a good thought for this Committee, is if you are relying on some confidential information or classified information, maybe we ought to know that.

I would just ask, Mr. Schleede, you don't seem as concerned obviously as the DOE people in terms of a future energy crisis. Now, if one comes upon us, you are not going to be held accountable, understand.

But, I just wonder if you could kind of speak to that?

Mr. SCHLEEDE. Well, I think there are many reasons to be less concerned about another energy shock, crisis, or whatever, than there have been previously. And, in my detailed statement, I list a dozen or so of those reasons.

But, I would come back to a point that what I would hope the DOE would start doing is paying attention to arguments and points on both sides and not do what Mr. Romm has done this morning, and that's just emphasize all the reasons why we might have to be concerned. I mean, as taxpayers, we ought to be able to look to people in the government to present objective information. And, I submit that what we are getting out of the DOE R&D folks is nothing but scare arguments to justify their programs and not getting an objective, balanced look at what the future energy situation is like.

I can tick off some of the reasons why I think we should be less concerned, if you would like. But, they are detailed in my statement.

Mr. DAVIS. Okay. Thank you.

Mr. ROMM. If I could just interject here, I keep hearing that it's the Department that is not being objective. I've tried to be very objective here.

I think if you compare my testimony to Mr. Schleede's, you will find that his testimony presents only the reasons why we should worry less today about a crisis. And, there are, indeed, such reasons, including the strategic petroleum reserve, including the fact that the world oil markets are much more—there's a futures market.

There are a number of factors which would mitigate against the kind of crisis that we had in the 1970's. I list them in my testimony.

However, to only list the ones that would mitigate against a crisis, as Mr. Schleede does, I would argue that's not objective. I try to argue in my testimony some of the reasons why we should still be concerned about an oil crisis in the future.

And, I would just mention two of those, one of which is that in the 1970's we were—the competition for oil was between us and our NATO allies. That's who was competing for oil.

If there were a crisis early in the next century, what you would find is that the competition for oil would have an additional element. And, that is the tremendous growth in east Asian supply—in east Asian demand.

So, you would have a completely different geopolitical picture, whereas nations that have not been our traditional allies would be competing for us with oil as opposed to what happened in the 1970's.

Does that completely weigh against the other factors? I think that's for the members to decide.

I think a second factor, which is worth mentioning, is that the sectors of the U.S. economy that could easily reduce their dependence on oil have done so. The utility sector has dramatically reduced its dependence on oil. The industrial sector has worked to reduce its dependence on oil.

The transportation sector, however, remains 96 percent dependent on oil. In order for the transportation sector to have other options, we need new technologies and new infrastructure. And, that's something that the Department works on.

I am not saying that the factors that make a crisis more likely outweigh the ones that make it less likely. I am not predicting a crisis. I want to make that very clear.

I'm saying it's a plausible scenario. I'm saying that people like Don Hodel of The American Enterprise Institute and Bob Dole have raised similar scenarios.

It's the government's job to worry about plausible, worst case scenarios and find appropriate funding.

Mr. DOYLE. Okay. Thank you. I yield back my time.

Mr. EHLERS. Dr. Hakes, a final comment?

Dr. HAKES. I would also like to say that I question Mr. Schleede's throwing around the term "non-objective," because when we work on these forecasts every year, we invite experts of every persuasion. And, I would ask. Don't we even invite you every year to come talk? And, don't we invite Professor Lynch to come talk?

And, we have participation from almost all elements of the energy industry, energy experts. And, those are calculated before these projections are made.

If there was some attempt here to push things in one direction, why would we invite you to our meeting?

Mr. DAVIS. Let me just ask Mr. Schleede, if he could, to have the last word on my time, since he's a constituent of mine. Do you want to respond to that, Mr. Schleede?

[Laughter.]

Mr. SCHLEEDE. Thank you. I should have repeated a comment I made earlier.

I am making a distinction between EIA and the rest of DOE. I do consider EIA much more objective than I do the part of the Department that is out constantly seeking more tax dollars for its programs.

Mr. EHLERS. Thank you very much. I would just comment that since I've arrived in Washington, I've noticed a great paucity of objectivity in this particular part of the world, something we all share in.

Next, Mr. Olver from Massachusetts.

Mr. OLVER. Thank you, Mr. Chairman. I was going to ask—in fact, maybe now with you in the Chair is an appropriate time to ask for equal time with your comments earlier.

But, actually I have to leave here very shortly. So, I think I am going to make an attempt to stay somewhere close to the allotted time.

I wanted just to explore a little bit a couple of things that two of the former—two of my colleagues had spoken about with the panel. And, first, from the gentleman from Michigan, who is chairing now the hearing, you had made a comment that you were very strong—it was kind of—it started out in a different way, but then came down that you were strongly in favor of making certain that we had the information so consumers could make the correct decisions.

And, I think that that's something that we can all agree on, that people should have that information. But, unfortunately, once you get finished creating the information, then the problem is that the consumers are not—do not have an equal right in this society, as we are, to actually—to make the correct decisions because of the economics of the situation. It's not a free decision for them to do.

So, life-cycle costs, which ought to make them reach one decision, may not be open. Whatever may give them the lowest life-cycle costs may not be open as a thing for them to take because of their circumstances.

And, so it seems to me that if you are developing an energy efficiency over a continuum and you've got products which on a continuum use less or a greater amount of energy and people—you get that information out there, that it is one—and since the decision is not exactly free because of the economics to families that it is then an appropriate goal, an appropriate purpose, for government to try to move this continuum toward energy conservation, toward something which is less abusive, usive [sic] and abusive, of what you, Mr. Chairman, had pointed out, is the only non-recyclable input.

And, you would ask for just a brief comment. Am I on base or off base on that, in your view?

Is it appropriate for government to use its R&D and its policy to set goals for what ought to be the standards of energy efficiency and move that continuum toward an energy efficient position? Briefly, because I have another one that I want to talk about from another member.

Mr. EHLERS. Are you asking Mr. Schleede?

Mr. OLVER. No. I'm asking anybody. Is the analysis that I gave basically correct?

Or, is it—do you generally agree or generally disagree?

Mr. EHLERS. Mr. Schleede.

Mr. SCHLEEDE. If you are talking about balancing benefits and costs and doing it honestly, I think clearly that makes a lot of sense. However, in the appliance efficiency standards, which deals directly with the point you are talking about, we have a situation where appliance efficiency standards have been evaluated, the economics have been evaluated, on the basis of price forecasts that are much higher than current forecasts.

And, as a result, the economics justifying those forecasts need reevaluation. Now, whether DOE is——

Mr. OLVER. But, for the people that do not have a free decision in this, it's not, in the process of what you are saying, whether the forecast is off by 20 percent or not, their position is still going to be exactly the same. They don't have a free decision in the economics.

Mr. ROMM. If I could interject——

Mr. SCHLEEDE. As far as the customer is concerned, that's correct. But, whether DOE, in setting these appliance efficiency standards which are then—the costs of which are then imposed on consumers, whether they are using the best information available and using up-to-date price forecasts in their economic evaluation is a separate question.

And, it needs attention.

Mr. ROMM. If I could just interject, Mr. Schleede is just factually incorrect that the appliance efficiency standards are based on forecasts that are way off. The fact of the matter is that most of the appliance efficiency standards deal with saving electricity.

Electricity price forecasts, they just haven't gone up and down very much. That's A.

B, the standards—typically you issue a standard. The product has to be manufactured in a few years. We shoot for paybacks of three to four years. So, we are only talking about what is going to happen in the next several years that matter.

To give a couple of examples, just so we can stop being abstract about this and get very factual, we issue detailed analysis of what the cost of conserved electricity from our standards is. Typically, the cost of conserved electricity is two cents a kilowatt hour, three cents a kilowatt hour.

The proposed—one of the refrigerator standards that we are considering would have a cost of conserved electricity of 2.9 cents a kilowatt hour and a payback to the consumer of 3.7 years. Most consumers are paying eight and a half cents per kilowatt hour.

So, it really doesn't matter whether the price of electricity is forecast to go up 10 percent, to go down 10 percent. These standards are remarkably cost effective.

Mr. OLVER. You gentlemen are extremely good, at least the two already, at answering some other question. But, I really am not quite sure what the question is that you are answering.

Anyway, I want to go on to a different thing. At——

Mr. EHLERS. Just a moment, Mr. Olver. I just want to mention that we have a vote on the Floor.

We have—Ms. Rivers, do you have a question to ask?

Ms. RIVERS. Yes.

Mr. EHLERS. And, Mrs. Cubin wishes to ask a second question. We would like to wrap this up before we take the vote, if at all possible.

Mr. OLVER. Well, let me ask just——

Mr. EHLERS. You have just a few seconds left on our clock. But, go ahead and ask your question.

Mr. EHLERS. The gentleman from Tennessee made a comment, which was that he felt it was—this is—perhaps, to paraphrase, it was tragic that we had withdrawn from nuclear energy as a source of energy because of fear, grossly exaggerated fear, of waste. Now, could I get quickly from this group, do you generally agree with that position that he has put forward or do you generally disagree?

Quickly. Just disagree or agree generally.

Dr. HAKES. The factor is the cost, the investors' unwillingness to put forward the capital costs.

Mr. OLVER. Can I get you to say generally disagree or generally agree?

Dr. HAKES. That is one factor.

Mr. OLVER. Pardon?

Dr. HAKES. The factor is one waste—waste is one factor. But, there are other factors as well.

Mr. OLVER. All right. I see it's not going to be possible for me even to get that out so that I can then ask the other question, which was the—the meat of that question was going to be what did each of you think were the key things that would get us—if you generally agreed with the position—back to nuclear energy being properly a part of the mix that we ought to be considering for the future.

And, that, I thought, might get us something interesting as to how we ought to function here. But, I don't have time.

Mr. EHLERS. Thank you, Mr. Olver. Ms. Rivers. And, Mrs. Cubin has volunteered to submit her question in writing.

So, Ms. Rivers will be the last.

Ms. RIVERS. Thank you, Mr. Chairman. I address this question, first, to Dr. Schleede but then others I would like to hear from.

We agree, in that Congress has the responsibility to review the effectiveness of these programs. But, what I am hearing from you—or, actually what I read from you, because I was not here earlier and I apologize for that, is that you feel like the Yergin Task Force and the Energy Advisory Board are really hopelessly compromised in terms of being able to provide objective advice.

So, it sounds like what we are talking about is that the decisions on these issues are going to have to be made in the political arena. If I accept that, do you think two hours of hearings are enough to make that kind of decision?

Mr. SCHLEEDE. I really don't want to make the——

Ms. RIVERS. Well, it's an easy question.

Mr. SCHLEEDE. (continuing) Committee's judgment on that. But, just to clarify, I have more confidence in the Yergin report than I do in the information coming directly out of DOE which seems to me to be terribly biased in favor of conclusions that they need more money.

Ms. RIVERS. Okay. To follow up on that, then, in saying that we are concerned about the information that we are getting from our agencies and we are going to have to make the decisions politically, I would ask you. Given the level of attendance and the depth of understanding on this issue, how long do you think it should take this Committee to understand these issues to the point that they could make major decisions on forecasting and funding?

Mr. SCHLEEDE. Given the collective intellectual capacity of this Committee, I shouldn't think it would take very long at all.

Ms. RIVERS. Oh, okay.

[Laughter.]

Ms. RIVERS. Do others have a comment on that?

Mr. LYNCH. I thought the Yergin report was fairly well. But, yes, I think you need a lot more time and effort.

The Office of Technology Assessment perhaps had a role in that in the past. We have a lot of additional information that we would be glad to provide.

Ms. RIVERS. Okay. And, how long do you think it would take us to take all that in, to understand it and do some good policy-making?

Mr. LYNCH. I think that's up to—you know, we have a lot of material. That's up to you all to decide.

Ms. RIVERS. Okay.

Mr. ROMM. If I could just——

Mr. ROEMER. Would the gentlelady yield?

Ms. RIVERS. I would just like to hear from Mr. Romm.

Mr. ROEMER. Okay.

Ms. RIVERS. And, then, yes.

Mr. ROMM. If I could just say, I'm glad there has been a uniform endorsement of the Yergin report, which was headed by one of the world's foremost authorities on oil. The Yergin report clearly spelled out great concern about the world oil situation, the world energy situation, called on more of the—the government to do more in energy R&D.

I would like to read the last paragraph. "But unlike the allied coalition in the Gulf crisis, innovation and technological creativity cannot be summoned into service on short notice. Energy R&D is the long term investment, a modest investment by comparison to the cost of disruption, that is made to assure a more secure and productive future."

Chairman ROHRABACHER. Thank you very much, Ms. Rivers. I am going to give Mr. Roemer the last word, but I would like to close this hearing. We are going to be adjourning after that.

Let me just say that I thank you very much for coming here with your testimony. I am sorry I had to go back and forth.

We are on the edge of a major military engagement in the Taiwan Straits. I'm on the International Relations Committee.

Let me just say that we have not cut—apart from anything you have heard from the community, we have not cut research and development in energy. What we have cut—at least in this last year, what we cut were things that were labeled research and development.

As Mr. Schleede has pointed out, catalogs, promotions, commercialization, utilization, now that may be a useful function for the government but it's not basic research and development. And, that was one of the priorities we had.

Every member of this Committee had a chance to substitute the cuts that we had for other priorities. That was something that we did in this Committee, is that any suggestion you have that you want to make, if you want to cut something else, we will cut something else if you make that or put an alternative there for us in terms of the spending reductions.

So, with that said, I believe some of the reductions in the early 1980's, as pointed out by Mr. Doyle, I was around. I was a reporter during those time periods.

And, I know that during the Carter years, yeah, we spent a lot of money on research and development. And, a lot of them were hyper-boondoggles that benefited huge corporations and they made money on these "research" projects.

And, they weren't worth it in the long run. And, they were all based on the projections of high energy costs.

And, so, in the end, if we don't have the right projections as to what energy is going to cost, we will make decisions that cost this country hundreds of billions of dollars. And, I can agree with Mr. Romm that we need some long term investment in research and development, but it has got to be based on good figures.

So, with that, I am going to leave the last word to Mr. Roemer, who can refute everything I just said——

Mr. ROEMER. Mr. Chairman, let me just say in 30 seconds that——

Chairman ROHRABACHER. All right.

Mr. ROEMER. I think much of what we are talking about here in terms of R&D is investment in the safety and the national security of this country. It's investment in jobs—good, high paying jobs—for the people of this country.

And, we are talking about two-tenths of 1 percent of the budget. Now, if we can stay out of a war like the Persian Gulf for two-tenths of 1 percent of the budget when we cannot rely on Iraq and Iran and Syria and a host of other countries in the Middle East for 50 percent, let alone 78 percent of our oil, I think that this is something that we should have more hearings on, that we should understand in a very, very intelligent and expertise way.

And, I think that, with all due respect, Mr. Chairman, I think that this is worth the taxpayers' money.

Chairman ROHRABACHER. All right. Mr. Roemer, thank you.

This hearing is adjourned.

[Whereupon, the hearing was adjourned at 11:53 a.m.,

[The following material was received for the record:]

APPENDIX:

FOLLOW-UP QUESTIONS AND ADDITIONAL MATERIAL FOR THE RECORD

Dr. Jay E. Hakes
Administrator
Energy Information Administration
U.S. Department of Energy

Answers to Followup Questions

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q1. EIA's latest forecast (Annual Energy Outlook 1996) includes five cases: (1) Reference; (2) Low Economic Growth, High Economic Growth, Low World Oil Price, and High World Oil Price. In all five cases, EIA projects that world oil prices in 2005, 2010 and 2015 will be higher in real dollar terms than they were in 1994.

- For its Low World Oil Price case, EIA projects that real world oil prices will be only a few cents higher than they were in 1994.
- For its Reference case, EIA projects that real prices will increase by nearly 64% from 1994 to 2015.
- For its High World Oil Price case, EIA projects that the 1994 price will more than double by 2005 and then continue upward.

a. Is there zero probability that real world oil prices will be lower in 2005, 2010, or 2015 than they were in 1994?

b. If the probability is not zero, what probability would you estimate? If at or near zero, are you, in effect, telling all decision makers that there is virtually no possibility that real world oil prices will be lower after 2000?

A1. a. The first Administrator of the Energy Information Administration was fond of reminding us that "there are no facts about the future." This caution is particularly applicable to world oil prices. It is possible that real world oil prices in any year through 2015 could fall outside the indicated range, including a drop below the 1994 price. Based on current information, trends, and policies, however, we think it is unlikely that prices will fall substantially below the 1994 price (or above the high price scenario) and remain there for a sustained period of time. There are many reasons for this assessment, including anticipated growth in world demand for oil at rates far surpassing those seen in recent decades.

World oil prices are particularly difficult to project as the world oil market is not a competitive market and prices are determined in part by decisions made by major oil producing countries rather than strictly by market forces. Specifically, some of the larger producing nations in the Organization of Petroleum Exporting Countries (OPEC) produce less oil than they are capable of producing in order to keep prices at a higher level than they might otherwise be. Some oil market analysts have expressed the opinion that if the world oil market was fully competitive, prices could be under $10 per barrel, closer to the marginal costs of extraction and transportation from the Persian Gulf. Consequently, the announced or discerned intentions of OPEC nations must be factored into any forecast of oil prices. Since these intentions could change, or political events could change the circumstances in which decisions are made, any price forecast is based on the best current assessments, and should not be considered a certainty.

It is also possible that changes in policy could affect the world price of oil. For instance, some actions (such as carbon mitigation policies that tax oil consumption or mandate world-wide efficiency standards) to lower world demand for oil would likely lead to lower world crude oil prices than those projected in the AEO. It should be noted that, depending upon the years selected, the Low Oil Price case does show flat prices. The 2000 price in the Low Oil Price case is lower than the 1994 price ($14.66 per barrel in 2000 vs. $15.52 per barrel in 1994, in 1994 dollars). In fact, the entire Low World Oil Price path is lower than the actual 1995 price of $16.78 per barrel.

The cases in the AEO are not meant to bound the possibilities of future oil prices, but rather to provide a range based on world oil market conditions and reasonable assumptions about future demand and supply, as they are now understood. Thus, to assert that there is zero probability for any particular level of future prices would go far beyond EIA's ability or claim to foresee future energy market behavior.

b. We have no basis for assigning probabilities to the price paths in the different AEO cases. Some of the important determinants of prices, as discussed above, are not market driven and are not amenable to analysis of probability. The low price case has prices near constant 1994 prices in real terms. We believe that this case is a real possibility, although we cannot state a probability that it will occur. Likewise, we cannot say that there is virtually no possibility that real world oil prices will be lower than the 1994 price after 2000.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q2. The EIA Annual Energy Outlook 1996 assumes that 37 gigawatts of nuclear capacity, accounting for about 40 percent of the Nation's current nuclear generation capacity, will be retired by 2015. What are the reasons for this pessimistic assessment of nuclear power?

A2. The operating assumption in the Annual Energy Outlook 1996 (AEO96) is that each nuclear power unit retires when its operating license expires. A nuclear power plant is licensed to operate for 40 years, a limit imposed by the Atomic Energy Act of 1954. An amendment to the act allows for a renewal of the license for an additional 20 years, contingent upon approval by the Nuclear Regulatory Commission. Although a rule is in place for license renewal, it has not yet been tested and no utility has applied to renew the license of a nuclear reactor. For the six nuclear units that have been retired over the last ten years, the average number of years of operation at retirement was 20 years, with the oldest operating for 28 years. As of 1994, 50 percent of all operating nuclear power plants have total operating costs of over 3 cents per kwh and 25 percent of them have costs of over 4 cents per kwh. (Included in these costs are fuel, operating and maintenance, post operational capital expenditures, and the relevant overhead costs.) Additionally, as the older plants age, many of them will need aging-related repairs/replacements of components. The total levelized cost of new steam coal plants and advanced combined cycle plants are estimated to range between 3.6 and 5.1 cents (1994 dollars) per kwh, depending on the technology and year of operation. Given these data and the statistics, an assumption that all existing units operate for 40 years is not pessimistic. Furthermore, as new advanced combined cycle plants become available after 2010 at a cost of 3.6 cents per kwh, many of these nuclear units will be uneconomic. It should be noted that this assumption has been adopted because of the difficulty of determining precisely which nuclear generating units will renew their licenses, and which will be retired early. Because of the likelihood that there will be some of each, we have made the assumption that, on average, all units will simply retire after 40 years.

No new nuclear orders are expected to be initiated over the forecast horizon, due to nuclear waste and economic concerns. The total levelized cost of a conventional nuclear plant beginning operation in 2000 is projected to be about 6.3 cents per kwh (1994 dollars), compared to 5.1 cents per kwh for a coal-steam plant and 3.9 cents per kwh for an advanced combined cycle plant. For plants beginning operation in 2015, the corresponding costs are expected to be 6.3 cents per kwh for conventional nuclear, 4.4 cents per kwh for coal steam, and 3.6 cents per kwh for advanced combined cycle. The levelized costs for an advanced nuclear technology, which is expected to be available for commercial operation during the forecast horizon, is projected to be about 5.8 cents per kwh in 2015. Thus, the nuclear technology has higher average levelized costs than competing fossil fuel technologies. Note that these costs refer to utility-operated plants only.

The Office of Civilian and Radioactive Waste Management projects that 80 reactors will run out of space for spent fuel by 2010 if no permanent waste storage facility is available. The Department of Energy does not expect to have a high level waste storage facility completed before 2010. Existing nuclear plants will have to purchase onsite storage containers, thereby increasing the cost of operating nuclear power. EIA believes that it is highly unlikely that new nuclear power units would be built without guaranteed storage availability for the waste. Also, new nuclear orders will be of a new design, adding risk and uncertainty to the cost and performance of future nuclear power units. Potential investors are likely to wait until the technology is proven and the costs are well defined, perhaps through the experience of building units overseas. Also, as the electric power industry moves towards deregulation, nuclear may be perceived as a riskier investment than other technologies with shorter lead times for construction. With competition, cost recovery will be determined by the marketplace rather than by cost-of-service regulation. Therefore, cost recovery for long-leadtime, capital-intensive technologies such as nuclear will be characterized by greater uncertainty.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q3. To what extent does the latest EIA forecast address the likely restructuring of the electricity industry, which should lead to increased competition and, in the view of many analysts, to lower electricity prices in the future?

A3. Because the AEO96 assumes current laws and regulations, the full impacts of electricity restructuring are not incorporated in the reference case. As stated in the AEO, many questions remain about the evolving market structure, and it is likely that the answers will involve both legislative changes and the development of new market institutions.

However, some of the assumptions used in the AEO96 were modified because of the likely market impacts arising from the anticipation of further competition in the electricity industry. Improvements in the costs and performance of new fossil and renewable generating technologies over time have been incorporated in the AEO96, partially as a result of market deregulation. For example, the cost and performance characteristics for new gas-burning advanced combined-cycle plants have improved dramatically in recent years and they are expected to continue for some time. It is true that this trend toward lower costs and higher efficiency may have occurred without market deregulation; however, the move towards competition has certainly accelerated it. In fact, the two trends, the movement towards a competitive market and the improvement in generating technology cost and performance are reinforcing one another. As the cost of generating power from new technologies continues to fall, the pressure on policy makers to deregulate grows. And, in turn, as the market becomes more competitive, the pressure on generating technology vendors to lower costs and improve performance also grows.

In addition, the AEO includes a two page box discussing the potential impact of electricity market restructuring. Figures showing the sensitivities of electricity prices and capacity expansion plans are included and discussed (pages 30 and 31). In addition, EIA is currently analyzing the factors that will drive the competitive price of electricity and the impact of historical market regulation on the efficiency of operation of fossil steam plants. The results of these efforts will be published in separate analysis reports.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q4. On page 1 of your prepared testimony you state that EIA has "made significant efforts to assure that users of our material are made fully aware of their limitations and the unavoidable uncertainties that underlie energy forecasting, as well as alternatives to our projections (such as those made by private forecasters, or committed long-term contracts that assume price risks."

What are the "significant efforts" that EIA made?

A4. The significant efforts that EIA has undertaken to make users aware of the limitations and uncertainties that underlie energy forecasting include:

- The verbal statements in virtually all major presentations made by the Administrator and his chief forecasting representatives that considerable uncertainties underlie every energy forecast, including EIA's;

- the inclusion of such a statement prominently in the Preface of the AEO96 and previous AEOs;

- a discussion of uncertainties in the AEO forecast in the Administrator's message in the AEO;

- inclusion of special highlighted key areas of uncertainties as in, for example, the discussion of electricity restructuring (pages 50-51 in AEO96) and a section in each major area that discusses the challenges for the future;

- a summary of the most recently available alternative forecasts with an illustration of how these compare with EIA's in selected key variables, and

- publication of alternative integrated cases which explore uncertainties that relate to macroeconomic growth and world oil prices as well as special sectoral analysis which explore the impacts of alternative technological penetration assumptions.

In addition, we have cooperated with the U.S. Department of Energy Policy Office and the Federal Energy Management Program (FEMP) of the Office of Energy Efficiency and Renewables to develop more timely updates and dissemination of our forecasts for use in federal energy purchasing programs. At the same time, we have advocated that our forecasts be only one of several options identified for the Federal manager in making energy-related decisions, including the futures market, specific contract offerings and other forecasts. As a result of our cooperative effort, users of the FEMP software that provides life-cycle energy costs are allowed several options in addition to the AEO reference case in choosing projections for life-cycle costs.

In addition, our documentation includes a section on uncertainties and sensitivity analysis on the key variables we believe to be the most important. To stress the fact that we recognize uncertainties in any energy forecasting, we hold regular working group meetings with Department of Energy and other Government users of our forecasts to solicit advice and information from knowledgeable experts, and we hold an annual conference following publication of each year's AEO where uncertainties are a key topic of discussion. We also hold numerous meetings throughout the year with stakeholders both within and outside of the Department. Recent examples include meetings to address cost and performance issues for residential, commercial, and electricity technologies in April 1995; a meeting held in May 1995 to solicit the views of outside experts on model scenarios that should be pursued; and an all-day workshop held in August 1995 to address natural gas resource issues. Almost all of our models have been reviewed by outside experts through the ongoing Independent Expert Review Program, which provides for outside academic and industry experts to critique the models and their results. Finally, we continuously publicize the caveats and limitations of our forecasts through full documentation of our assumptions in the AEO Supplement (available on the Internet and the EIA CD-ROM); and our complete set of National Energy Modeling

System (NEMS) model documentation reports (available through EIA's National Energy Information Center, as well as on the Internet and the EIA CD-ROM).

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q5. How can decisionmakers protect themselves from making uneconomic decisions because energy price forecasts may turn out to be inaccurate?

A5. The risks inherent in making uneconomic investment decisions in energy are not very different from the risks in making any large investment in other areas, and the same means of protection are available to energy decisionmakers as they are elsewhere. The actions that can minimize the risk in making uneconomic decisions include the ability of the decisionmaker to develop an appropriate small set of scenarios that include the plausible set of circumstances that can occur on the upside and on the downside of investment decisions. These scenarios plus a "baseline scenario" should be used to evaluate possible investment actions being considered. Investment tools have been developed and are available to the investment community and financial markets and these should be considered. In the final analysis, however, model forecasts are an adjunct to, rather than a substitute for, good business judgment.

As stated before, EIA forecasts are only one of a number of sources available to users. Others include the futures market, committed long-term contracts, and alternative forecasts from the private sector. Judicious analysis of all of these sources, including EIA's, is necessary for users to minimize the risk associated with reliance upon a single forecast. However, it is unlikely that risk can be completely removed from investment decisions, and it would be imprudent for EIA to suggest that there is a way to do so.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q6. Mr. Schleede has suggested that even though EIA is an independent agency within the DOE, its continued [location] within the Department raises questions about EIA's real independence. He has further suggested that consideration be given to removing EIA from DOE and making it part of an independent statistical agency.

Would you please comment?

A6. EIA has steadfastly honored its impartial role within the DOE mandated by the Congress in its authorizing legislation. The preservation of that independence is ingrained in EIA's culture. We employ internal peer review processes to assure that EIA's forecasts and analysis are supported by factual information and that assumptions that may be subject to differing views are documented and transparent to users. While EIA does perform alternative policy analysis, we do not take policy positions and thus maintain our position of objectivity. EIA has long recognized that our independence is a principal factor that gives our work credibility and value and distinguishes EIA from other forecasting organizations.

EIA's independent role has worked well at the Department of Energy for close to two decades. The Professional Audit Review Team, which has evaluated EIA annually since its beginning, has constantly found no reason to question EIA's independence from DOE's energy policy function. So there is no reason to make a change. We believe this view is shared by the vast majority of customers in the Administrations, Congress and the public that have used EIA's work throughout its existence.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q7. To what extent does EIA use external peer review prior to issuing its forecasts?

A7. In EIA, we exercise an open and proactive process for developing current information about industry, technology, and international developments and trends relevant to our outlook. The principal forums for receiving such information with respect to the mid-term forecasts appearing in the AEO include:

- technical working groups for government experts within and outside of the Department which meet monthly,
- an annual NEMS/AEO conference following publication of the AEO,
- special all-day meetings which bring in outside industry, academic and government experts to exchange technical information as we did, for example, in April 1995 to address cost and performance issues for residential, commercial, and electricity technologies; in May 1995 to solicit the views of outside experts on model scenarios that should be pursued; and in August 1995 to address natural gas resource issues,
- an annual press briefing on the day of the AEO's release,
- special briefings for industry analysts, both on the day of the AEO's release and throughout the year (such as special briefings provided earlier this year to the American Gas Association, the Natural Gas Supply Association, the Gas Research Institute, and the Interstate Natural Gas Association of America), to gather industry's reactions, comments and feedback which would be considered for the next forecast,
- regular participation in meetings of energy organizations such as the Edison Electric Institute, the National Mining Association, the Gas Research Institute, and the Energy Modeling Forum, as well as ongoing consultation with the Electric Power Research Institute concerning its information on cost and performance of electricity technologies, and
- an ongoing Independent Expert Review Program, which provides for outside academic and industry experts to critique the models and their results, and whose recommendations are incorporated where time and resources permit.

Because it is important to maintain not only the reality of technical independence but also the perception, we require a significant level of research to ensure that a particular suggestion is well-grounded both theoretically and empirically before we will adopt changes to the model suggested by others. It is our belief that NEMS and the AEO forecasts have benefited from the external peer review that the model and analyses have undergone.

QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q8. To what extent are EIA's assumptions used in its forecasts consistent with the assumptions used by other Government agencies, such as OMB, the Council on Economic Advisors or the Department of Treasury?

A8. Most of the projections and primary assumptions of the other government agencies cited in your question focus on macroeconomic issues. As such, their methodology does not incorporate a detailed representation of the energy sector and fuel prices. Consequently, we can answer the question primarily in terms of economic assumptions. We have limited our response to those forecasts of which we are aware that have been released during the last year.

EIA independently develops its assumptions and forecasts for the U.S. energy-economic system using its technical judgment and modeling systems. Consequently, EIA assumptions and outlooks have been significantly different in the past compared with the economic assumptions and outlooks developed by other Government agencies such as OMB, CEA, and the Department of the Treasury. However, the 1996 EIA forecasts of economic growth are very comparable to the forecasts of other Federal government agencies that have been released over the last 12 months. To compare them one must take into account the different time periods covered. For the period 1994 through 2000, EIA forecasts real Gross Domestic Product (GDP) growth at 2.45 percent annually. For the same time period, the official Council of Economic Advisers (CEA) forecast contained in the February 1995 Economic Report of the President was 2.5 percent. CEA does not release a longer term forecast. The Bureau of Labor Statistics released a set of forecasts in November of 1995 containing a projection of real GDP growth between 1994 and 2005 of 2.27 percent annually. The EIA growth rate covering this same period is 2.35 percent. In its Fiscal Year 1997 Budget, released in January of 1996, the Office of Management and Budget (OMB) assumed that GDP growth from 1994 through 2002 would be 2.28 percent annually, compared to EIA's assumption over the same period of 2.41 percent. The GDP forecast used by the Congressional Budget Office in its December 1995 forecast is essentially identical to that used by OMB. Underlying the GDP forecasts are population growth projections for which EIA uses the Census Bureau middle-growth forecast. It should be noted that many of the differences among the economic assumptions used by government agencies are small, and are related as much to the timing of the release as anything else. The OMB forecast, for example, included data for the fourth quarter of 1995, which had lower GDP growth due to abnormal weather and the effects of government furloughs. EIA's projections were made prior to the fourth quarter, and thus did not include its impacts. Other than that, the GDP forecasts made over the past year were essentially identical.

OMB and the CEA do not publish energy price projections. In developing the economic forecast that is used in the budget formulation process, a set of energy price projections is developed by OMB, Treasury, and the CEA. No formal model is used. Instead, recent energy prices, the futures market, and general inflation projections are used to develop a judgmental energy price forecast.

The Environmental Protection Agency often uses energy price projections from EIA for reference case purposes. Rather than relying exclusively on one forecast, they may use projections from private forecasters such as DRI and WEFA, consulting firms such as ICF, Inc, and energy industry-supported groups such as GRI to provide a range of energy price estimates for scenario purposes. Appendix F of the Annual Energy Outlook 1996 contains a series of tables that compare the EIA projections with those of other forecasting groups. For example, Table F2 indicates that although the world oil price for 2010 ($23.70 per barrel) in the AEO96 reference case is somewhat higher than the other forecasts, the Low World Oil Case ($16.02 per barrel) falls below the lowest forecast. The AEO96 wellhead gas price for 2010 ($2.15 per mcf) is lower than all the other forecasts. Delivered coal prices to utilities ($25.88 per ton) in 2010 are in the mid-range when compared to other forecasts.

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QUESTION FROM THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT, HOUSE COMMITTEE ON SCIENCE

Q9. Mr. Schieede has criticized the EIA Reference case forecast that the average price of natural gas delivered to electric generators will climb sharply after 2005 compared to the price of coal delivered to electric generators, so that by 2015 the average delivered price of natural gas will be 230% the price of coal as compared to the 1994 actual relationship of 161%.

How would you respond to that criticism?

A9. Changes in the relative prices of fuels for a particular end-use sector can occur for a variety of reasons related to both demand and supply. There is no a priori reason to believe that price ratios should be constant. Indeed, in a competitive market, prices are constantly changing in response to such factors as regulatory policy, demographic changes, technological progress, and even the weather. Just over the last five years, for example, the relationship between the average delivered prices of natural gas and coal to electric utilities has varied significantly. The price of natural gas delivered to electric utilities was 149 percent that of coal in 1991 and 185 percent of coal in 1993 (see Figure 1). While this variation largely reflects the recent volatility of natural gas prices, it is also in part related to the coal market, which has undergone significant changes due to the Clean Air Act Amendments of 1990 (CAAA90), a miners' strike in 1993, and a decline in overseas demand for U.S. coal. Price data from 1973 to 1994 show significant changes in relative prices of fuels delivered to electric utilities. Relative to coal, natural gas was most competitive in 1974 when its price was about 68 percent that of coal, while by 1984 its price had reached 216 percent of the price of coal delivered to electric utilities. The price ratio in AEO96 is stable at current levels (ranging from about 1.5 to about 1.8) before starting to increase around 2008. After 2010, natural gas is expected to see further price pressure due to increased demand from the electric generating sector as the nation's nuclear capacity begins to retire while the demand for electricity continues to increase (see Question 3 for a discussion of the assumptions concerning the retirement of nuclear generating capacity).

Natural gas is an attractive fuel for the electric generating sector because technologies fueled by natural gas have lower capital and non-fuel operating costs and higher thermal efficiency than other fuels, which offset the higher fuel costs of natural gas technologies. The choice of a technology is largely driven by the levelized (that is, over the life of the unit) delivered cost per kilowatt-hour at the plant, including capital, operating, and fuel costs, as well as the costs of environmental and other regulatory constraints. The AEO96 projects that in 2000, for a typical baseload-serving facility, the levelized cost of electricity from a new natural gas combined-cycle plant will be 22 percent lower than the cost of electricity from a pulverized coal unit. Although the gap narrows by 2015, the cost of the natural gas plant will still be 18 percent lower than that of the coal plant. Over the forecast period, technological progress reduces capital costs and improves thermal conversion efficiency for both coal and natural gas generation technologies. Improvements in thermal conversion efficiency for natural gas-fired technologies are projected to exceed that of coal (17 percent improvement for coal between 2000 and 2015 vs. 22 percent improvement for natural gas). Because of this improvement, increases in the price of natural gas can exceed those of coal without significantly reducing the cost advantage of natural gas-fired technology (see Figure 2).

Another factor affecting the increase in natural gas prices is the change in the regional mix of demand, resulting in higher average transportation costs. In 2015, for example, the reference case projects that the regional market shares of the West South Central (the "gas patch," close to most domestic production of natural gas) and Pacific regions will be almost halved from their 1994 shares, to 25 percent and 13 percent, respectively, of total U.S. natural gas consumption in the electric generation sector. In comparison, gas used for electric power generation in the South Atlantic, Middle Atlantic, and East North Central regions is projected to increase significantly, from 18 percent in 1994 to 49 percent by 2015. Because these plants are further from the source of natural gas supply, the average cost of gas transportation to electric generators is expected to increase. From 2005 to 2015, approximately 20 percent of the increase in the delivered price of natural gas is directly attributable to the increase in the transportation costs caused by the change in regional consumption patterns.

Natural gas resources in the United States are abundant; however, some of the resources are in geologic formations that are less accessible and more costly than others to explore and develop. As more of the economic areas are exploited, the returns (in terms of new discoveries) per drilling effort are likely to decline due to the reduced availability of larger fields for exploration and development at the same depths. This is especially true for the more mature areas of the onshore lower 48 states, the source of most U.S. natural gas production. Technological progress tends to reduce drilling and finding costs and enlarge the resources that are economically recoverable. The resultant increases in costs per discovery may be partially or fully offset by technological progress, depending on the type of the specific resource. For frontier areas such as the deep offshore, technological progress could fully offset the early depletion affects while for mature onshore fields, the cost offsets by technological progress may only be partial. The net result, however, is likely to be an increasing cost function for investment in new reserves, which would translate into an upward sloping supply curve for natural gas.

Finally, the price of coal to electric utilities is projected to remain virtually flat from 1994 through 2015. Factors influencing this projection are assumed flat miners' wages, productivity improvements of about four percent annually, unit transportation rates from the mine to electricity producers that are essentially unchanged on a national basis (but somewhat lower for Western coal), and a gradual shift to lower-cost Western coal production due in part to the requirements of the CAAA90. Between 2000 and 2015, delivered coal prices are projected to increase by less than 2 percent, as the price pressures that are associated with increasing demand for low-sulfur coal begin to offset moderating gains in labor productivity.

Figure 1.

Ratio of Natural Gas to Coal Prices
Delivered to Electricity Generators

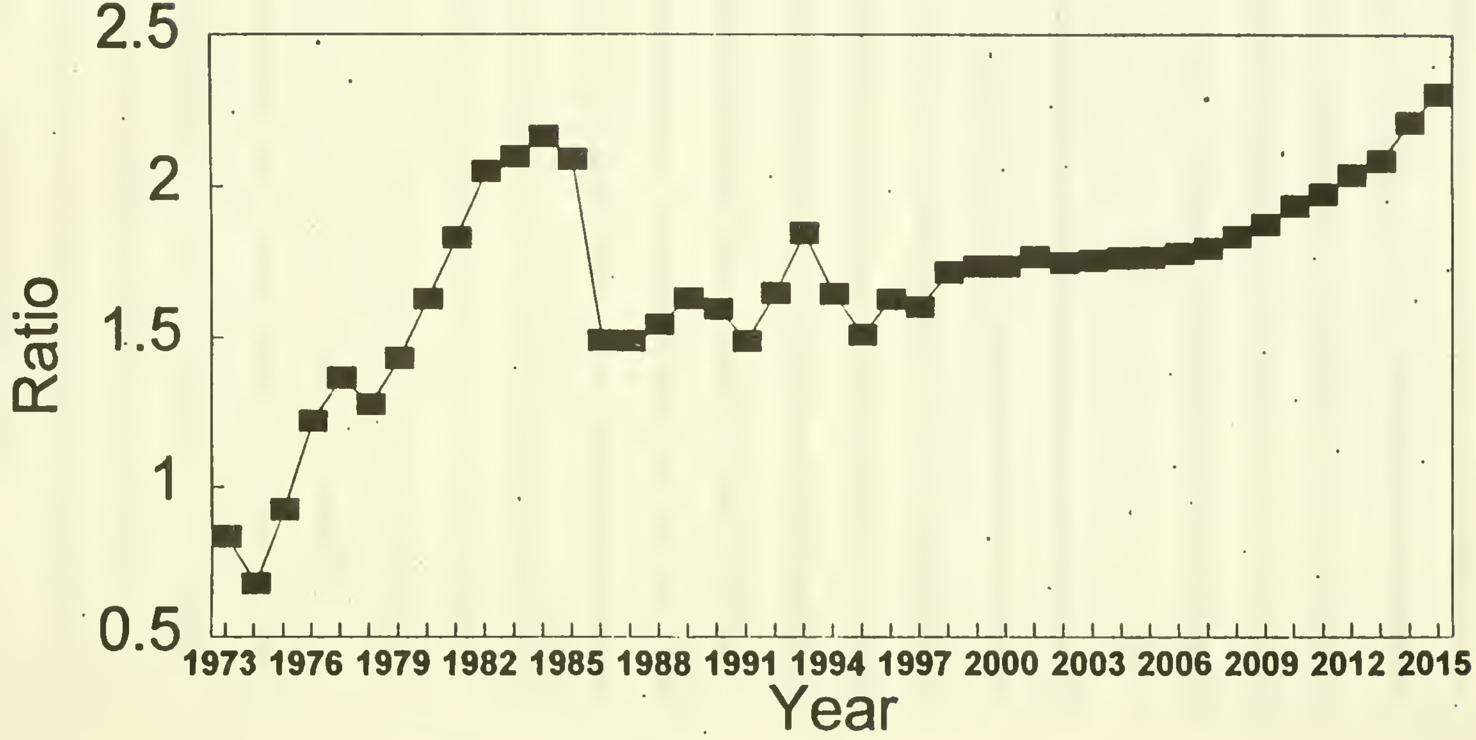
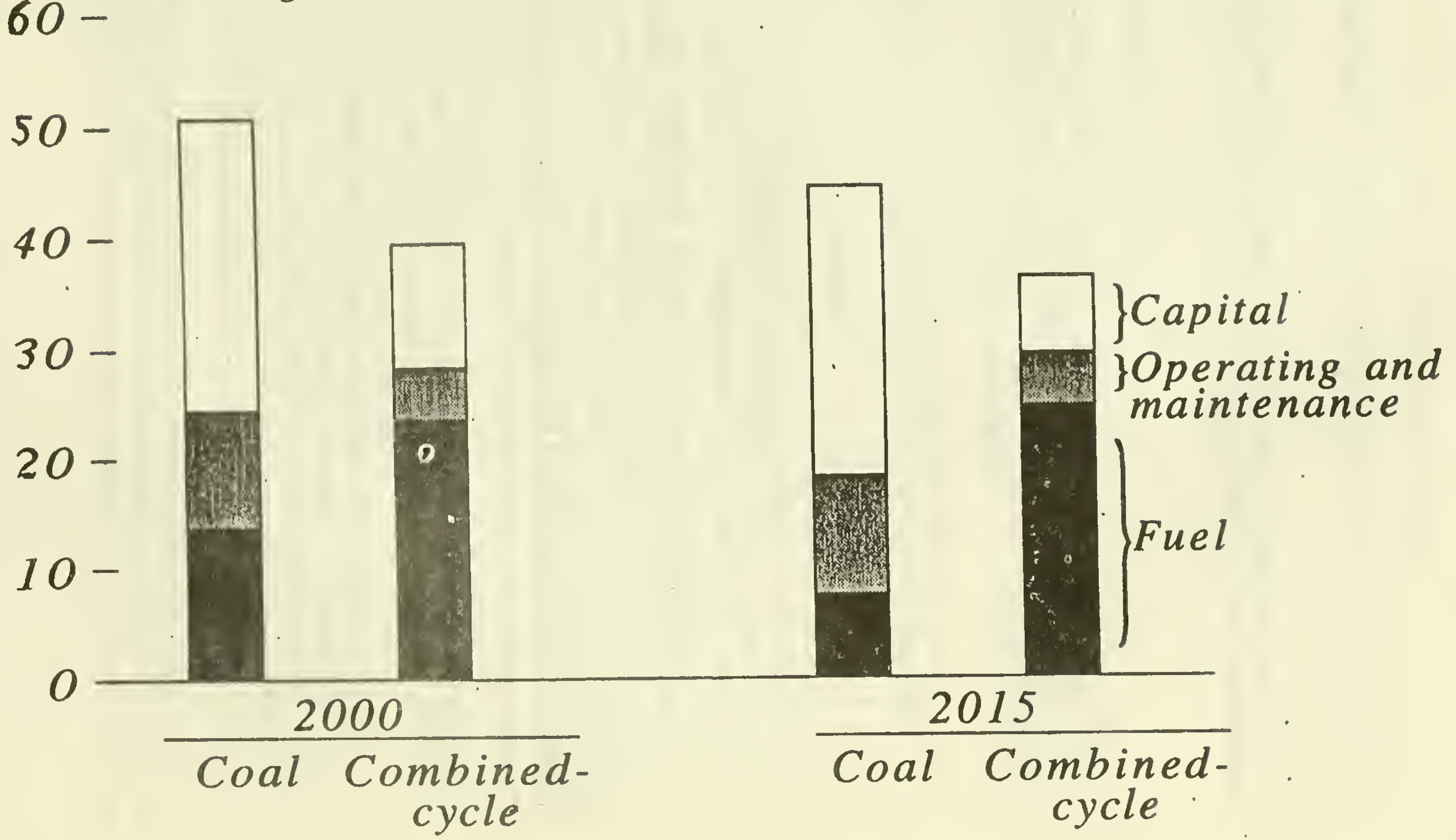


Figure 2.

Electricity Generation Costs for Conventional and Advanced Technologies, 2000 and 2015 (1994 mills per kilowatthour)



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Answers to Followup Questions and Additional Material

Glenn R. Schleede response to Follow up Questions

March 14, 1996 hearing on U.S. Energy Outlook and Implications for Energy R&D

1. **Question: Now that EIA and other forecasters have lowered their outyear price projections, is the faulty forecast problem something that we don't have to worry about anymore?**

   Answer to Question 1:

   The answer to this question is clearly "No." EIA's latest forecast (Annual Energy Outlook 1996) is a step forward in catching up with major changes that have occurred in energy markets, but more improvements are needed and the faulty forecast problem deserves continuing attention by your committee and others in the Congress. For example:

   a. **More changes are needed in EIA forecasts** to reflect changes that are occurring in energy markets. Among the remaining problems with EIA's forecasts are the following:

      1) EIA's forecasts are based, essentially, on one basic "scenario" or set of assumptions about U.S. and world energy markets. The *assumptions* that EIA has made lead, inevitably, to the conclusion that the world will be increasingly dependent on oil from Persian Gulf nations. *Other equally plausible assumptions would result in much less future dependence on Persian Gulf oil than is suggested by EIA's assumptions.*

         These *other* plausible assumptions and scenarios deserve equal attention. The Congress should consider *requiring* EIA to present several plausible scenarios -- rather than just one scenario -- in its annual energy forecasts. This would help assure greater objectivity, more thorough analysis, and better public, Congressional and media understanding of potential future energy markets. EIA should develop forecasts based on *each* scenario. At least one of the several scenarios should, for example, reflect the very real possibility that:
         - Oil and gas production (and proved oil and gas reserves) and exports from former Soviet Union, Eastern European nations, and other Non-OPEC nations will increase more rapidly than assumed by EIA.
         - OPEC nations, including those in the Persian Gulf region, will find it in their interests to increase productive capacity when world oil demand grows.
         - Other energy demand and supply factors will turn out to be more favorable than EIA has assumed -- in terms of continuing improvements in technology, slower growth in demand, lower prices, and faster growth in supply even at lower prices.

         To EIA's credit, the agency's leaders held a public conference on March 25, 1996 in Arlington, Virginia and invited several energy experts who presented information that heretofore has not been adequately taken into account in EIA forecasts, including information about the outlook for world oil markets. Hopefully, this information will be reflected in future EIA forecasts.

2) EIA's Annual Energy Outlook 1996 price forecasts assume, in all five cases, that real oil prices will be higher in 2015 than they were in 1994. In effect, EIA is telling all those who use the Annual Energy Outlook that there is no chance that real prices will be lower in 2015 than in 1994. This is an unwise signal that could lead to additional faulty decisions in the future. In fact, future real oil prices could be lower than 1994 and decision makers should take this possibility into account.

3) EIA's Annual Energy Outlook 1996 forecasts of electricity prices reflect level or, in some cases, slight downward adjustments. *The changes now underway in the electric industry are virtually certain to result in significant downward adjustments in electricity prices during the next 10 years.* Those who rely on EIA's latest forecasts for electricity prices are likely to make unwise decisions. Furthermore, the downward adjustment in electricity prices is likely to force additional downward adjustments in natural gas prices for end users.

4) EIA's Annual Energy Outlook 1996 forecasts that natural gas prices will increase significantly after 2005 and that the gap will grow significantly between the delivered price of coal and natural gas to electric generating companies. Interfuel competition in energy markets is unlikely to permit the growth in price differentials that EIA forecasts.

b. **Decisions based on past forecasts need to be reconsidered.** Thousands of government and private sector decisions have been made during the past few years on the basis of high energy price forecasts (by *EIA and other forecasters)* that have proven to be faulty. These faulty forecasts have already resulted in huge costs for consumers, taxpayers and investors. In some cases, it may be possible to reduce the future cost burden if decisions are reconsidered. Therefore, all possible decisions based on high price forecasts should be reconsidered in light of the new, lower forecasts that have been issued by EIA and other organizations. Within the government, these decisions include:

- Justification for spending on energy supply and conservation technology projects.
- Estimates of savings from energy efficiency and conservation projects.
- Estimates of savings from existing and proposed appliance efficiency standards.
- Estimates of the value of oil and gas leases, including ANWR and the Naval Petroleum Reserves.
- Estimates of revenue that will be received from lease bonuses and royalties.

In addition, your committee should look very closely at the economic justification for any proposed spending on energy conservation and renewable energy programs, and the fusion energy program that has been justified by past energy price forecasts.

2. **Question: In your statement, you indicate strong appreciation for science and technology but still seem to favor cutting back on energy development, demonstration and deployment projects. Meanwhile, the American Association for the Advancement of Science (AAAS) has recently warned that the U.S. is running serious risks because R&D spending is being cut. How would you answer the AAAS concern?**

Answer to Question 2:

I have great appreciation for the contributions of science and technology. However, I believe the Congress must stop assuming that everything that is labeled "R&D" or "science and technology" is inherently worth support from tax dollars and that all proposals are of equal merit. As the competition for tax dollars grows, clearly the *Congress will need to sharpen its ability to distinguish among those R&D efforts that deserve funding and those that do not.* DOE energy technology programs are a good place to start.

I haven't reviewed the AAAS document, but I believe that emphasis by any organization on a reduction in the total dollars spent for R&D is fallacious. If this is what the AAAS has done, it's unfortunate. Any fair appraisal of taxpayer-financed R&D spending should consider:

1. What the dollars are actually being spent for?
2. Whether the results being achieved are worth the dollars spent?
3. Whether priorities being given to competing R&D needs are in the nation's best interests?

On the first question (What is money actually being spent for?), I submit that too much of the money being spent by DOE under the label of "R&D" does little or nothing to advance scientific knowledge or produce new technologies. Much of the money seems to be spent for questionable studies, promotional documents, Washington offices for DOE contractors, lobbying efforts (including efforts paid for under DOE contracts and grants), and other overhead.

On the second question (What results are being achieved?), the DOE's best efforts to date to explain what has been achieved by the $100 billion that has been spent on energy R&D do not provide a convincing story. In addition, it is very clear that much of the money that has been spent on energy R&D ("synfuels" is one example) has been wasted.

On the third question (Are priorities correct?), I suspect that we probably are not wasting a lot of money on basic research. However, the chances of waste grow rapidly as federal agencies provide funds for efforts that include development, demonstration or deployment of technologies. Further, as spending is used for projects other than basic research, the likelihood grows that private sector funds are being displaced. The private sector is far better than government agencies in understanding and assessing markets and in producing needed technologies *when they are needed* -- without help or interference from the government.

If AAAS has not already done so, perhaps the organization should focus its attention on the outputs from our investments in R&D -- not on the inputs (i.e., the number of dollars spent).

I have reviewed papers issued in the past by various special interest groups that decry "cuts in R&D." These papers all too often use statistical gimmicks, misleading comparisons, and incomplete analyses. For example:

a. They often start from some high point in R&D spending and assume that the high point was the correct level of spending.
b. They ignore the fact that much past spending that they characterize as "R&D" has been wasted on demonstration and commercialization projects that were funded only because of faulty market forecasts, powerful political constituencies, or blatant porkbarreling.
c. They do not distinguish adequately between basic research, applied research, development, demonstration and commercialization activities. The rhetoric then incorrectly asserts that private industry has little or no incentive to engage in any of these activities.
d. They make highly selective and misleading comparisons in their attempts to show that R&D efforts are not getting enough tax money. (For years, it was the "Soviets are spending more than the U.S. Now it's "The Japanese are spending more.")
e. They ignore the fact that government spending on R&D sometimes displaces work that would be undertaken by private industry on a timely basis.
f. They ignore the fact that government spending ties up resources (dollars and people) that might make more important additions to our knowledge base if those resources were used elsewhere. They ignore the fact that government contractors and grantees, often operating under cost-type contracts and grants, have bid up salaries of scientists and engineers to the point where universities, colleges and high schools have been unable to compete and are, therefore, less able to educate the next generations of scientists and engineers.

As "entitlement programs" and interest on the national debt command a growing share of available tax dollars, competition for remaining funds will become more rigorous. To help taxpayers get the highest value for the tax dollars that are available for R&D, ideally AAAS and other scientific and engineering organizations would:

- Participate constructively in identifying and eliminating low priority and/or wasteful R&D, rather than merely complaining about "cuts" and crying out for "more R&D spending."
- Help in weeding out those activities paid for from R&D accounts that contribute little or nothing to the advancement of scientific knowledge (e.g., useless studies, directories, public relations materials and events, unnecessary travel, "Washington Offices," lobbying, payments by contractors and grantees to associations, coalitions and other dues to lobbying organizations).

Scientists who are justifiably proud of the careful analysis, objectivity and other tenets of scientific method that they follow in their daily pursuits should insist that their associations and spokespersons in Washington adhere to the same standards and methods when evaluating federal spending for R&D. Focusing only on "inputs" is hardly a scientific or objective approach.

3. **Question: In your statement, you expressed concern about a potential "conflict of interest" between DOE's responsibility to spend tax dollars wisely and its efforts to maintain or expand DOE's role in energy and get funding for its programs. Is this really a serious concern?**

Answer to Question 3:

I believe it is a very serious problem. While EIA seeks to be objective, this claim does not apply to DOE's policy and program offices. As explained in more detail in response to question 4, Mr. Romm's testimony reflects little interest in defending the interests of taxpayers. Instead, it was devoted almost exclusively to attempts to justify spending for DOE R&D programs. Mr. Romm's testimony was not an isolated instance. Other evidence also suggests that DOE officials are much more interested in promoting spending for DOE programs than they are in protecting the interests of taxpayers. For example:

1. DOE spends thousands and perhaps millions of dollars on promotional materials, including glossy documents that attempt to defend its programs.

2. Additional millions seem to flow through DOE to contractors, grantees and others that find their way into organizations that use tax dollars to pay for Washington offices, lobbying, contributions to associations and coalitions that seem to spend most of their efforts in keeping tax dollars flowing through DOE. As illustrated in my detailed statement, DOE officials openly encourage contractors and grantees to lobby for more money for DOE programs.

3. As explained in response to question 1, EIA relies almost exclusively on only one basic scenario for future U.S. and world energy market conditions while ignoring other plausible scenarios. DOE policy and program officials carry this "one scenario" approach to extremes -- emphasizing only possible future developments that would create the perception of a looming "energy crisis" or "threat to national security." The perceptions that DOE policy and program officials seek to create are designed to support a larger role for DOE and more spending of tax dollars for DOE's energy supply and conservation programs.

4. There is a clear conflict between DOE's responsibilities to taxpayers (for objectivity in analysis and careful stewardship over tax dollars) and its efforts to obtain more tax dollars for its programs. Too often, it seems that DOE's policy and program officials are more responsive to contractors and grantees who spend tax dollars for energy R&D than they are to taxpayers who provide those funds.

4. **Question: Mr. Romm has given a vigorous defense of DOE's energy R&D investments. Would you please comment as to the validity of his arguments.**

Answer to Question 4:

Taxpayers have every right to expect greater objectivity and balance from the Department of Energy than was reflected in Mr. Romm's testimony. Perhaps most disturbing was the fact that some members of the Committee apparently did not recognize the weaknesses in his arguments and were prepared to accept the views he was presenting. More specifically:

1. Mr. Romm's testimony lacked objectivity and balance. Instead of presenting a balanced picture of U.S. and world energy market conditions and outlook, he chose to cite possible future conditions that would help create the perception of some looming "energy crisis." This, of course, is a common practice of those in government or in special interest groups who wish to build or maintain a large government role and obtain tax dollars for their favorite programs.

2. Mr. Romm's assertion that low energy prices are due to DOE's energy R&D spending is simply not true. In fact, a reduction in federal regulation, greater competition in energy markets, and improved technologies produced in the private sector are the reasons why we have plentiful energy supplies and lower energy prices.

3. As explained in response to question 1, there are many plausible and credible scenarios for the future of U.S. and world energy market conditions. Mr. Romm chose to describe only one of those plausible scenarios -- one that would lend support for a large role for DOE and for continued spending on DOE energy technology development, demonstration and commercialization programs. The scenario that he outlined:
   - Assumed inevitable growth in dependence on oil from Persian Gulf nations,
   - Assumed that nations in the Persian Gulf region would not increase productive capacity above current levels as world oil demand grows -- even though they can increase productive capacity at costs far below current market prices for oil and even though they will continue to need hard currency, and
   - Assumed that oil from those nations is inherently subject to interruption or increases in price.

   This "crisis" scenario has long worked well for the DOE/Contractor Complex in scaring the Congress, the media and the public into providing large amounts of tax dollars for DOE programs.

   But, it is now time for DOE and the Congress to recognize that they owe it to the American people and, in particular, to taxpayers to recognize other equally plausible scenarios that lend less support for continuing a large role for DOE and its spending programs.

4. Most of the arguments Mr. Romm used have worked for DOE in the past but, hopefully, the Science Committee and others in Congress will recognize the weakness of these arguments. For example:

   a. The "insurance" argument. This argument is a common one from those who want to spend our tax dollars. However, it does not provide any useful criteria for evaluating spending levels. The amount of money that anyone spends for insurance should be determined rationally -- based on an objective assessment of the risk *and* the amount of insurance that can be afforded. DOE, however, works to create the perception of a huge risk rather than presenting objective analysis that would contribute to informed debate. DOE does not provide useful answers to such key questions as: How much DOE-type "insurance" is enough? Is the "insurance" allegedly provided by DOE's energy technology spending more important than spending for national defense, Medicare, or basic research? Is the cost of the "insurance" more important than letting hard-working people keep more of their earnings?

   b. "R&D has been Cut." This is a well-worn tactic by those seeking more tax dollars for their programs; i.e., find some past high point in spending and then show how spending has been "cut" from that level. This argument, of course, ignores such questions as:
      - Should spending ever have reached the previous high level?
      - Was money wasted when spending was at the high level?
      - Have conditions changed so that heavy spending is no longer justified?
      - Are there higher priorities for spending the money that is available?

      These questions are particularly important in the case of DOE programs because much of the past spending for energy R&D was "justified" by forecasts of high energy prices, rapid growth in demand, and/or slow growth in supply that have proven to be faulty.

   c. The nation is "under-investing in R&D." Those who use this argument typically focus on the "input" dollars *as if* they were a valid measure of the value received for those dollars. They seldom provide convincing evidence to support their claim. Instead, they find some anecdote, isolated fact, or partisan contention that lends support for their position; e.g., the Japanese are spending more. They also ignore other competitors for the available tax dollars.

   d. "DOE R&D helped produce a useful product." It would be amazing if the DOE/Contractor Complex could not find a few success stories among the energy R&D projects on which more than $100 billion has been spent. Furthermore, the anecdotes are seldom clear or convincing with respect to the role played by the DOE spending or whether the development would have occurred without DOE involvement. Perhaps even more would have been accomplished if the government had not been involved and the resources (people and dollars) tied up by government spending had been allowed to work in a truly entrepreneurial atmosphere.

e. "Energy R&D commands only 2/10ths of a percent of the amount the U.S. spends on energy." This simply is not a meaningful calculation.

5. Your hearing on March 14, 1996 demonstrated that your Committee needs to insist that DOE be more objective and balanced in its assessment of energy markets and our energy outlook and that the Committee needs to insist on better answers to the critical questions about DOE's role and its spending for R&D. Specifically, the Committee should not feel obligated to spend tax dollars on DOE programs unless very convincing answers and hard evidence is supplied to answer the following questions (described in more detail on pages 11 - 16 of my detailed statement for your March 14, 1996 hearing):

   a. Does proposed energy RDD&D program spending distinguish appropriately among support for basic research, applied research, development, demonstration, and deployment (or commercialization) activities?

   b. Has spending on energy development, demonstration, and deployment projects displaced funding for promising basic and applied research?

   c. Are all the projects proposed by DOE really worth funding?

   d. Can DOE justify the billions in tax dollars that have already been spent on energy RDD&D, let alone continued spending?

   e. Do federal agencies really have the capability to carry out a cost-effective "industrial policy" such as that contemplated in DOE's spending for energy supply and conservation technology?

   f. Does DOE adequately address fundamental questions concerning the appropriate role of the government in supporting energy technology projects? Specifically:

      1) Would the technology development occur without a federal subsidy?
      2) Do federal subsidies inevitably flow to "second best" projects?
      3) Do federal subsidies for energy technology projects displace potential private investments?
      4) Do federal energy technology subsidies delay, rather than speed up, the development and commercialization of technologies?

   g. Will DOE's capability to select worthwhile R&D projects be improved by its proposed "Portfolio" approach?

h. Who in the Executive Branch is responsible for assuring that tax dollars for energy technologies are spent wisely?

i. If DOE has the responsibility for guarding public and taxpayer interests, does it have the capability and will to do so?

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Glenn R. Schleede
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March 17, 1996

The Honorable Dana Rohrabacher, Chairman
Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Rohrabacher:

When appearing before your Subcommittee on March 14, 1996, I did not give you an adequate answer to one of your important questions. This letter is to provide a further response to that question and to add comments on several arguments presented during the hearing.

Response to your question. You asked for information on the *costs* that have been borne by consumers, taxpayers, and others because forecasts made by EIA and other organizations have grossly overstated energy prices. I'm not aware of any complete accounting of such costs but, the enclosed paper, *Illustrations of Costs Resulting from High Energy Price Forecasts*, provides enough examples to suggest that total costs are clearly in excess of $100 billion -- and probably much higher. The paper includes some information on extra costs being borne by electric customers in California.

Comments on certain arguments presented during the hearing. I was disappointed by the lack of balance and objectivity on the part of the "policy" witness from DOE, and by scare tactics and specious arguments used to justify spending hundreds of millions of our tax dollars for DOE's energy supply and conservation technology programs. For example:

1. **The "insurance" argument.** This argument is a common one from those who want to spend our tax dollars. The argument is specious because the amount anyone spends for insurance should be determined rationally -- based on an objective assessment of the risk *and* the amount insurance that can be afforded[1]. Attempting to justify DOE energy technology as "insurance" contributes little to an informed debate. Is the "insurance" provided by DOE's

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[1] Chicken Little's friends would have been insurance-bankrupt if they had attempted to insure against the frantic fowl's false warnings that the sky was falling!

energy technology spending more important than spending for national defense, Medicare, or education? Is it more important than letting hard-working people keep more of their earnings?

2. **"R&D has been Cut."** This is a favorite "inside the beltway" tactic; i.e., find a high point in spending and then show how spending has been "cut." Some members of the Committee seemed particularly interested in a graph used to depict the "cuts" in energy R&D. Three graphs showing federal outlays for energy R&D are attached (Attachments A, B and C) to demonstrate the way that clever graphs are sometimes used to mislead unsuspecting observers.

   - Attachment A covers Fiscal Years 1955-1995.[2] This shows the tremendous increase in spending that occurred after the Arab oil embargo when the Nixon, Ford and Carter Administrations seemed to be competing with the Congress to see who could "throw" the most money at energy R&D. This was a period of particularly wasteful energy spending.

   - Attachment B covers only Fiscal Years 1985-1995. It is an example of the way that selective use of data can be used to demonstrate "cuts" in spending of our tax dollars.

   - Attachment C covers the same data as Attachment B but uses a common trick to further mislead people; i.e., it uses $2 billion as the baseline of the graph -- rather than $0.

   Many of the energy R&D projects (e.g., synfuels) subsidized with tax dollars beginning in the mid-70s were "justified" by claims that oil prices would increase to $100 per barrel or more. Most of the projects were failures -- either because of technical infeasibility or because there was no chance that the projects would lead to technologies that would be viable in the private, competitive economy. *Fortunately*, most of those uneconomic projects were stopped in the early 1980s. *Unfortunately*, outlays continued into the mid-1980s because DOE or the Synfuels Corporation had made binding commitments to the projects.

   The point is that periods when great amounts of tax dollars were wasted is hardly a sound basis for arguing that we are not now spending enough on energy R&D. Taxpayers deserve to have *all* spending justified every year -- not just the change from some prior year.

3. **The nation is "under-investing in R&D."** Apparently, this argument will never go away -- and those who use it will never be satisfied whatever the amount of tax dollars spent for R&D. Those who use the argument focus on the "input" dollars *as if* they were a valid measure of the value received for those dollars. All too often they seem unwilling to recognize competing needs, unwilling to participate in setting priorities among competing

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[2] Data are taken from Budget of the United States Government, Fiscal Year 1996, Table 9.8. Data for FY 1996 are not shown on the chart since the numbers shown in the budget document apparently are estimates that were not approved by the Congress.

needs, and unwilling to help weed out low priority efforts and ineffective projects or to take a stand against wasteful energy R&D spending. Furthermore, far too much of the money appropriated for R&D has been used for activities (including lobbying for more R&D spending) that add nothing to our scientific knowledge and that contributes no new technologies that will be successfully in the private, competitive economy.

4. **"The XYZ Lab helped produce a useful widget."** Anecdotes are often beguiling but are generally specious. It would be truly amazing if the DOE/Contractor Complex could not find a few success stories among the energy R&D projects on which more than $100 billion has been spent. But a few successes do not justify spending billions more of our tax dollars on energy R&D. Furthermore, would even more have been accomplished if the government had not been involved and the resources (people and dollars) tied up by government spending had been allowed to work in a truly entrepreneurial atmosphere?

5. **"Energy R&D commands only 2/10ths of a percent of the amount the U.S. spends on energy."** Such a calculation is so meaningless that it really doesn't deserve comment.

6. **DOE needs to help Shell Oil develop renewable energy.** If I recall the statements correctly, DOE's policy witness described the Shell Oil Company as the most profitable corporation in the world. Further, he praised what he contended was Shell's conclusion that the price of renewable energy would drop dramatically from current uneconomic levels and become competitive with fossil fuels. But, he failed to explain why Shell -- with its "large profits" and great confidence in the future of renewable forms of energy would need DOE subsidies to pursue renewable technologies. If his interpretation of Shell's conclusion about the economics of renewables is correct, Shell and other private sector companies will certainly be investing in renewable energy technologies -- without DOE's help or interference.

7. **Impending "energy crisis."** All too many government officials have made their careers by emphasizing the threat of an "energy crisis" due to "excessive" dependence on Mideastern oil. I urge the Committee not to overlook the countervailing points made on pages 7-9 of my detailed statement for your March 14, 1996 hearing.

   Attempts to create the perception of an impending "energy crisis," demonstrate that Thomas Sowell is 100% correct when he explains in his book, *Vision of the Anointed,* that government officials all too often follow a typical pattern. First, they work to create the perception of a "crisis"; then they seek a large ration of tax dollars and authority to "rescue" America with their "solutions." Such actions go a long way in explaining why a growing number of Americans have become disenchanted with the federal government and bristle at "inside the beltway" attitudes.

As a former career employee of the federal government, I was embarrassed by the lack of balance and objectivity demonstrated by DOE's policy witness. We deserve better from all government employees, including political appointees, and from the Department of Energy. We should not have to put up with any government employee -- career or appointed -- that is so willing to put his interest in securing more tax dollars for his favorite programs ahead of his responsibility for balanced and objective analysis and careful stewardship of taxpayers' money. My sympathy goes out to the many dedicated career employees in DOE who must be embarrassed by the cavalier attitudes toward taxpayers that is displayed by some DOE officials.

Sincerely,

Glenn R. Schleede

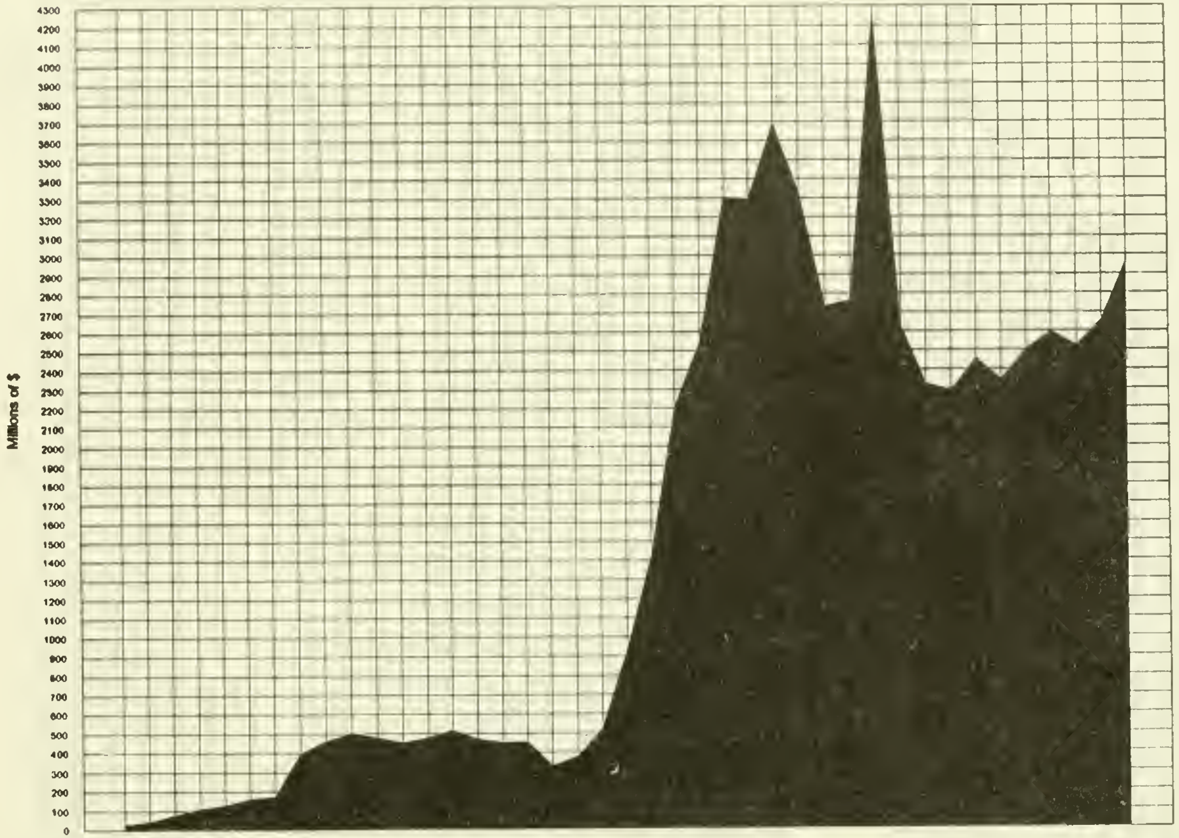
Attachments: Graphs showing Federal
Outlays for Energy R&D

Enclosure: Illustrations of Costs Resulting
From High Energy Price Forecasts

cc: The Honorable Tim J. Roemer
Senior Minority Member
Subcommittee on Energy & Environment

Attachment A

Federal Outlays for Energy R&D - Fiscal Years 1955 - 1995*



	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
$ Outlays in Million $	27	42	77	100	129	150	173	397	462	502	476	452	476	515	400	451	454	329	379	525	933

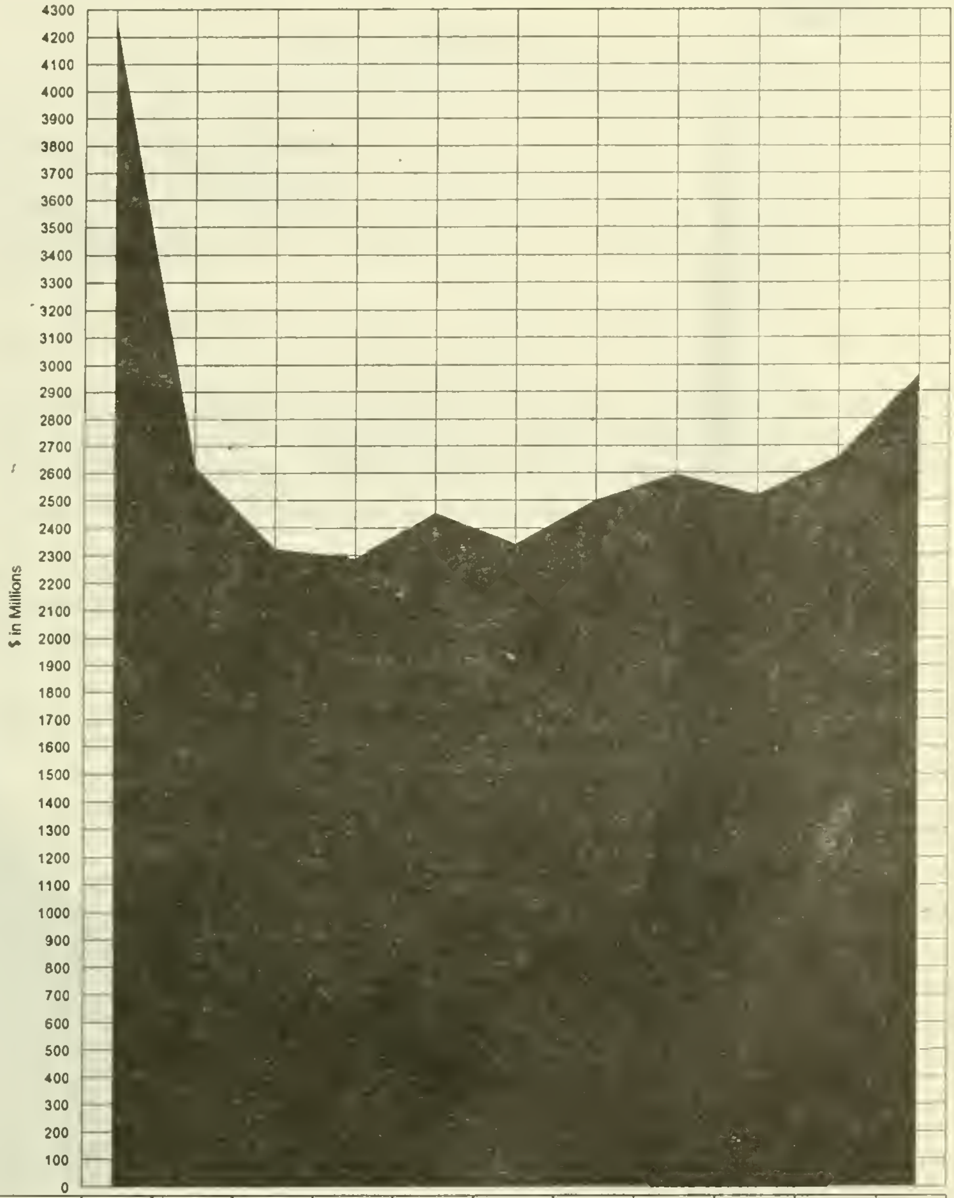
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
$ Outlays in Million $	1424	2197	2542	3304	3269	3681	3330	2726	2762	4249	2622	2321	2287	2454	2342	2501	2593	2517	2654	2959

Data Source: Budget of the United States Government, Fiscal Year 1996, Historical Tables, Table 9.8 * The "Transition Quarter" between 1976 and 1977 is omitted from the graph. Outlays then were $521 million

Attachment B

Misleading Use of Data on Federal Outlays for Energy R&D - FY 1985-1995

Starting with a high point in spending to suggest that energy R&D has been "cut"



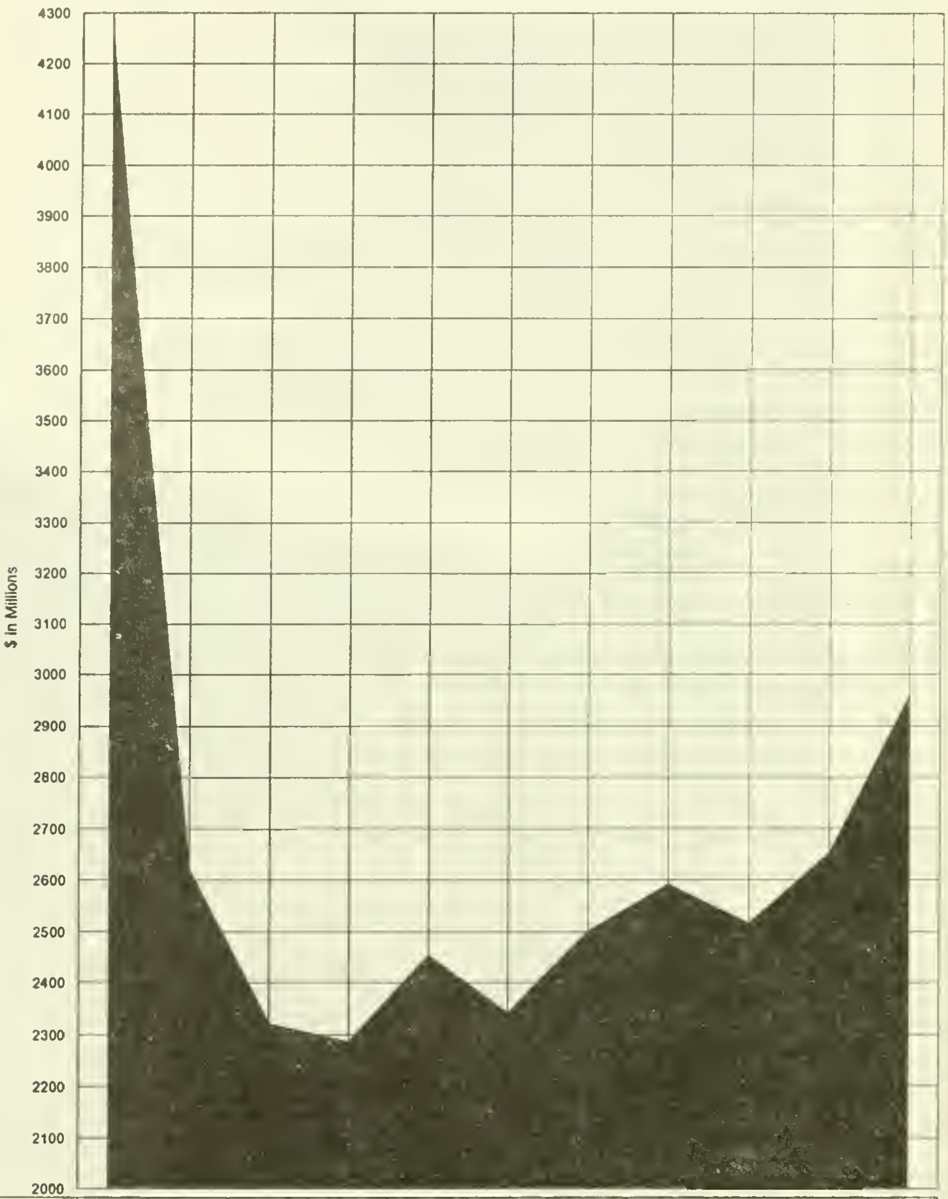
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Outlays in million $	4249	2622	2321	2287	2454	2342	2501	2593	2517	2654	2959

Data Source: Budget of the United States Government, Fiscal Year 1996, Historical Tables, Table 9 8

Attachment C

Misleading Use of Data on Federal Outlays for Energy R&D - FY 1985-1995

Starting with a high point in spending to suggest that energy R&D has been "cut" and using a truncated scale



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
I Outlays in million $	4249	2622	2321	2287	2454	2342	2501	2593	2517	2654	2959

Data Source Budget of the United States Government, Fiscal Year 1996, Historical Tables, Table 9.8.

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April 4, 1996

The Honorable Dana Rohrabacher, Chairman
Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

This letter is to follow up on an important question raised during your March 14, 1996 hearing on U.S. Energy Outlook and Implications for Energy R&D. The question is: Are the tax dollars that the Department of Energy (DOE) proposes to spend for R&D properly allocated among basic and applied research, development, demonstration, and "commercialization" activities?

The President's Fiscal Year 1997 Budget request for two of DOE's large R&D programs demonstrates the need for close scrutiny of DOE's plans. As shown by the table below, DOE's spending plans for the FY 1996 through FY 2002 contemplate:

- Sharp *reductions* in DOE general science programs, which support basic research in nuclear and high energy physics (25% reduction in FY 2000 compared to FY 1997); and

- Sharp *increases* for DOE "Energy Conservation" programs that are focused heavily on the development, demonstration, and "commercialization" of *products* that DOE hopes would be used by industry, commercial establishments, and consumers.

	Budget Authority in millions of dollars[1]						
	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002
DOE General Science Programs	$981	$1,009	$928	$845	$760	$867	$988
DOE Energy Conservation	$613	$715	$736	$756	$778	$799	$822

A strong case can be made for a significant federal role in supporting the basic research that is funded by DOE's general science program. (Also, I believe that two of the last three Nobel Laureates in physics were supported by that program.) However, it is much more difficult to

[1] Budget of the United States Government Fiscal Year 1997, *Analytical Perspectives*, Table 25-1, Functions 251 and 272, pp. 344-345.

justify a major federal role in developing, demonstrating, or "commercializing" consumer and industrial products.[2] Private sector organizations and individuals have a much stronger incentive to pay for such efforts and they are much more capable than DOE to determine *when* it makes sense to pursue product development, demonstration and commercialization activities.

Furthermore, DOE and its predecessor agencies have demonstrated repeatedly that they do not have the expertise to "pick winners." Instead, DOE funded development, demonstration, and commercialization projects have seldom produced products that can compete successfully in the private, competitive economy.

It will be necessary to pay more attention to the priorities within the total dollars spent for R&D as competition increases for the tax dollars that are available after paying for entitlements and interest on the national debt.

I urge you to consider carefully the issue of appropriate federal role as you consider DOE's proposals to cut basic research while increasing spending for energy conservation programs.

Sincerely,

Glenn R. Schleede

cc: The Honorable Tim J. Roemer
Senior Minority Member
Subcommittee on Energy & Environment

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[2] The type of "energy conservation" projects that DOE proposes to pursue with our tax dollars are described on pp. 446-447 of the *Appendix, Budget of the United States Government, Fiscal Year 1997*; on pp. 143-146 of DOE's *FY 1997 Congressional Budget Request, Budget Highlights* (DOE/CR-0039), March 1996; and pp. 243-573 of DOE's *FY 1997 Congressional Budget Request*, Volume 4 (DOE/CR-0037), March 1996.

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February 14, 1996

Dr. Jay Hakes
Administrator
Energy Information Administration (EIA)
U.S. Department of Energy
Washington D.C. 20585

Dear Dr. Hakes:

This letter is in response to your criticisms of my January 30, 1996 letter to the Directors of the Office of Management & Budget and Congressional Budget Office. For ease of reference, Attachments #1 and #2 are copies of the *Electricity Daily*, and *Oil Daily* articles containing your comments, and Attachment #3 is a copy of the January 30 letter.

I appreciate your willingness to participate in and expand the public debate. The issues are important and involve billions of dollars in costs to consumers, taxpayers and investors.

The *Electricity Daily* article covering my January 30, 1996 letter and your response deal with only a few of the issues raised in my letter. Accordingly, I suggest pursuing the debate with a clear listing of real issues and the "non-issues." Such a list follows. Comments on each follow the list.

Issues and non-issues (or "straw men")

1. Does EIA provide valuable data on *past* energy supply, demand and prices? (A non-issue.)
2. Have past energy price forecasts substantially overestimated energy prices?
3. Is EIA the only organization that substantially overestimated energy prices? (A non-issue.)
4. Have energy price forecasts that turned out to be faulty led to decisions by business executives, regulators and other government officials that have proven to be uneconomic?
5. Have these decisions cost consumers, taxpayers and investors billions of dollars?
6. Have EIA and other forecasters substantially lowered their forecasts of future energy prices?
7. Now that EIA and other forecasters have substantially lowered their forecasts of future energy prices, should decisions, estimates and analyses based on past forecasts be reconsidered?
8. Do federal and state government officials now have a special responsibility to reconsider past decisions, estimates and analyses?
9. What are the responsibilities of those who issue energy price forecasts to those who use their energy price forecasts in terms of:
    - Showing clearly the accuracy of previous forecasts?

- Providing clear and prominent warnings concerning the limitations of the forecasts and the risks of relying on the forecast?
- Providing guidance to potential users of forecasts that might help keep them from relying too greatly on energy price forecasts?

10. What are the responsibilities of users of energy price forecasts in terms of:
    - Understanding the role played by energy price forecasts in the economic analyses that they rely on?
    - Understanding the inherent limitations of any energy price forecast?
    - Understanding the assumptions that drive the output of the models that underlie the energy price forecasts that they use?
    - Using a range of potential future energy prices when evaluating alternative courses of action when the success depends on future energy prices?
11. Should EIA continue developing and issuing energy price forecasts?
12. If so, should EIA:
    - Change its methods of forecasting?
    - Include in its forecast a case or scenario that contemplates continuing reductions in the real cost of oil, natural gas and electricity?
13. Is there a systematic upward bias in energy price forecasts?
14. Is there a "conflict of interest" within DOE between EIA's responsibility for issuing objective forecasts and the Department's attempts to develop support for its energy programs?
15. Are there grounds for questioning EIA's reference case forecast that the average price of natural gas delivered to electric generators will climb sharply after 2005 compared to the price of coal delivered to electric generators?

Except for numbers 1 and 3 (which I consider "non-issues"), all of the above questions are raised directly or implicitly in my November 30, 1995 and previous letters. As suggested in my numerous letters to DOE and others, I believe the real issues deserve attention and action. I recognize that neither EIA nor DOE has authority or responsibility to deal with all of them -- which is the reason I have written to the Directors of OMB and CBO.

Specific Comments

The remainder of this letter comments on all 15 questions.

1. **Does EIA provide valuable data on *past* energy supply, demand and prices? (A non-issue.)** This issue is listed only because you raised it. I consider it a "non-issue." Contrary to your comments, I have not questioned the *quality* of EIA data on *past* energy market conditions in my communications. I am an avid user of EIA data on past market conditions. I believe EIA is unequaled in this area of activity. No other organization has the statutory authority nor the resources (tax dollars) to support such an intensive energy data collection and analysis effort. (I understand EIA's budget in fiscal year 1995 was approximately $75 million.) I have questioned whether as much energy data should be collected and presented in the future. This is a quite logical question in view of:

- Increasing competition for those tax dollars available for "discretionary" programs.
- Dramatic changes in energy markets since EIA was created, reduced federal regulation, increasing competition, and dwindling justification for federal market intervention.
- Widespread recognition that the federal role in all areas needs to be reconsidered now that the "era of big government is over."

2. **Have past energy price forecasts substantially overestimated energy prices?** The answer is clearly and demonstrably "yes." See Attachments #4 and #5. The "1995" column on these tables show in 1994$ the crude oil and natural gas (wellhead) prices *forecast* by EIA in its *Annual Energy Outlook* issued from 1985 through 1993. The tables also show EIA's estimate of *actual* 1995 prices for crude oil and natural gas. As the two attachments show:
   - The "actual" crude oil price of $16.81 per barrel in 1995 compares with EIA's forecasts which had ranged from $55.40 to $21.34 per barrel.
   - The "actual" price of $1.60 per Mcf for natural gas in 1995 compares with EIA's forecasts which had ranged from $6.99 to $2.19.

   Specifically, the actual price you show for crude oil in 1995 ($16.81) is 70% below the forecast EIA made in January 1985. The actual price you show for natural gas in 1995 ($1.60) is 77% below the forecast EIA made in January 1985.

   As attachment #4 and #5 show, EIA had reduced its forecasts for 1995 prices in most years after 1985, but never reduced them enough. Similar data could be provided for other energy products and for forecasts made by others.

3. **Is EIA the only organization that substantially overestimated energy prices? (A non-issue.)** No one that I know has *ever* made this assertion. As you know, EIA's *Annual Energy Outlook* documents normally show some information on forecasts made by other organizations such as DRI, WEFA, and GRI. These data show clearly that other forecasters have also substantially overestimated energy prices. I have used EIA forecasts to illustrate the problems caused by energy market forecasts because EIA data are so readily available. The complaint that "By just mentioning EIA, he's giving the impression that we're the only ones who forecast high prices" is not credible.

   However, I believe a good case can be made that *EIA's overestimation* of energy prices in its forecasts have played an especially significant role in decisions that have been costly *because:*
   - EIA forecasts are so readily available at little or no cost, and
   - Issuance of forecasts by a federal government energy agency may have led users to presume that they would be more accurate and objective than forecasts from other sources.

   For these reasons, EIA forecasts probably have been more widely used than their more expensive "brethren" by individuals and organizations (such as state public utility commissions) that are not as knowledgeable about energy markets and forecasts as, for example, major oil companies.

4. **Have energy price forecasts that turned out to be faulty led to decisions by business executives, regulators and other government officials that have proven to be uneconomic?** Again, the answer to this question is demonstrably "yes." Examples include:

   a. Decisions by business executives:
      - Large uneconomic investments in oil exploration, particularly during the period from 1980 - 1984.
      - Loans by savings and loan (S&L) and commercial banks to organizations exploring for oil (contributing to the "S&L crisis" and costly taxpayer bailout).
      - Investments in research, development and demonstration efforts to produce oil from oil shale and "synthetic fuels" from coal.
      - Investments in nuclear power plants on the assumptions that oil and other fossil fuel prices would increase substantially.
      - Power purchase agreements signed by electric utilities that were based on forecasts that oil and gas prices would increase sharply.

   b. Decisions by state public utility commissions (PUCs):
      - Requirements that electric utilities sign contracts to purchase power from non-utility generators based on "avoided cost" calculations that assumed high oil prices (e.g., in California, New York and Maine).
      - Strong encouragement by PUCs that electric utilities provide demand-side subsidies and/or purchase power from renewable energy sources, again based on presumptions of high oil and gas prices.

   c. Decisions by other government officials:
      - Federal subsidies and price guarantees given by AEC, ERDA, DOE and/or The U.S. Synthetic Fuels Corporation for oil shale and other "synthetic fuel" development and demonstration projects (e.g., Solvent Refined Coal projects, Great Plains Gasification Project, and numerous other projects to produce liquids or gas from coal.)
      - Bonneville Power Administration 1994 contract with Tenaska to purchase power from a gas-fired power plant. According to a DOE Inspector General report, the decision was predicated on forecasts of rapidly rising natural gas prices. (Press reports indicate that BPA's attempt to withdraw from this apparently uneconomic contract is being challenged in a $1+ billion lawsuit.
      - Use of high price forecasts by Minerals Management Service (MMS) when estimating the value of oil and gas leases, including ANWR.
      - Mineral Management Service use of high price forecasts resulted in rejection of lease bids only to be followed by acceptance of a lower bid and, therefore, less revenue.

5. **Have these decisions cost consumers, taxpayers and investors billions of dollars?** Again, the answer is clearly and demonstrably "yes." Each of the above decisions, and thousands of others that were based on high energy price forecasts have resulted in costs to consumers,

taxpayers, and shareholders. Unfortunately, these extra costs will continue far into the future because of the investments and contracts that have been made in the past. In the case of electric utilities, many of the investments will be part of the "stranded investments" that will have to be paid by customers, shareholders or creditors and which, in some cases, will be borne by taxpayers.

6. **Have EIA and other forecasters substantially lowered their forecasts of future energy prices?** Again, the answer is clearly and demonstrably "yes." Attachments #4 and #5 show how much lower EIA's latest forecasts are compared to prior years. The forecast price for natural gas at the wellhead in 2010 is down 38% from one year earlier. EIA's January 1995 forecast price for crude oil in 2010 was lowered by 16% from January 1994. A comparison of data in EIA's Annual Energy Outlook for 1994, 1995 and 1996 demonstrates that other forecasters have also substantially lowered their price expectations.

7. **Now that EIA and other forecasters have substantially lowered their forecasts of future energy prices, should decisions, estimates and analyses based on past forecasts be reconsidered?** Failure by business executives and federal and state government officials to reevaluate and reconsider decisions, estimates, and analyses based on past high price forecasts would seem to be foolhardy. Even if past actions cannot be reversed, decision makers and those affected by the decision should be informed when decisions based on past forecasts are no longer viable or will result in costs that can't be justified on the basis of current knowledge.

8. **Do federal and state government officials now have a special responsibility to reconsider past decisions, estimates and analyses?** Again, the answer would seem to be an unequivocal "yes," particularly when you recognize that:
   - Economic analyses based on past energy price forecasts will undoubtedly be changed when the new forecasts are substituted; and
   - The far-reaching impact of the many federal and state government decisions and estimates on consumers, taxpayers, and investors.

   Examples of the decisions, estimates and analyses that need to be reconsidered have been identified in previous letters and earlier in this letter. Matters needing reconsideration, in addition to those identified above, include:
   - Proposed and existing energy efficiency standards issued by DOE and other agencies.
   - Price forecasts that agencies must use in evaluating Federal Energy Management Program (FEMP) actions.
   - Justification for energy RD&D projects (including energy supply and energy efficiency or conservation programs and projects) proposed by DOE and other agencies.
   - Estimates of revenue from oil and gas lease bonuses and royalties.
   - Value of the Naval Petroleum Reserves which are to be sold in accordance with the recently enacted Defense Authorization Act.

- Energy cost savings that can be expected from various programs including "Green Lights" and "Energy Star."
- Energy cost savings claimed by various government officials in speeches, testimony, and reports.
- Estimates of savings associated with energy efficiency and conservation criteria in federal government backed mortgages.
- Estimates of savings and justification for DOE's energy conservation assistance programs.
- Estimates of savings associated with energy projects funded under various foreign aid programs.

In addition, it seems appropriate that DOE should be sure that the President, the Congress, and governors are aware that the original justification for the Low Income Home Energy Assistance Program (LIHEAP) has disappeared since U.S. average home heating oil prices (in 1994$) were down by approximately 56% in 1995 from prices that prevailed when LIHEAP was started. Residential natural gas prices were down by 31% from highs reached in 1983, and residential electricity prices were down by 20% from highs reached during the period from 1982-1985. (See Attachment #6.)

9. **What are the responsibilities of those who issue energy price forecasts to those who use their energy price forecasts in terms of:**
   - **Showing clearly the accuracy of previous forecasts?**
   - **Providing clear and prominent warnings concerning the limitations of the forecasts and the risks of relying on the forecast?**
   - **Providing guidance to potential users of forecasts that might help keep them from relying too greatly on energy price forecasts?**

Several of the previously identified issues are beyond the scope of EIA responsibility, but this issue is not. It seems quite clear that many who have access to EIA and other forecasts are not in a position to evaluate them or use them without exposing themselves and their customers and shareholders to significant risk. I appreciate the fact that you have finally begun including a limited "warning" or "qualification" on your forecasts in *Annual Energy Outlook 1996* (pp. ii and 12). This is a step in the right direction but it is not enough. I believe you have an obligation to take at least two additional steps:

- First, you should show tables similar to Attachments #4 and #5 of this letter so that potential users can see EIA's past track record in forecasting energy prices.
- Second, you should provide guidance to potential users of forecasts that might help prevent over reliance on them.

As you know, I have also suggested that OMB issue guidance on use of forecasts. OMB guidance would be preferable because of the far reaching, adverse impact that price forecasts have had throughout the economy, in the development of budget estimates, and in economic analyses of proposed federal programs. However, OMB guidance would not preclude EIA from including such guidance in its forecast documents where it might more likely be seen by otherwise unwary users of the forecasts.

Ideally, commercial forecasting organizations would also provide similar guidance. Perhaps your leadership on this matter would set a useful example.

10. **What are the responsibilities of users of energy price forecasts in terms of:**
    - **Understanding the role played by energy price forecasts in the economic analyses that they rely upon?**
    - **Understanding the inherent limitations of any energy price forecast?**
    - **Understanding the assumptions that drive the output of the models that underlie the energy price forecasts that they use?**
    - **Using a range of potential future energy prices when evaluating alternative courses of action when the success depends on future energy prices?**

    Clearly, business, regulator and other government users of energy price forecasts bear a large share of the responsibility for the costly decisions that result from using forecasts that turn out to be faulty. EIA cannot be held responsible for all the unwise and uninformed acceptance of forecasts or the selective use of forecasts to support preconceived conclusions. However, including additional warnings and guidance in EIA forecasts, as suggested in 9, above, could be helpful in reducing the number of unwise decisions and the costs that are borne by consumers, taxpayers, and investors.

11. **Should EIA continue developing and issuing energy price forecasts?** I recognize that this is a sensitive issue that understandably evokes a strong EIA response since forecasting (as opposed to collection and analysis of information on the past) is a significant EIA activity. Nevertheless, the question is quite legitimate recognizing:
    - The availability of energy price forecasts from other sources;
    - The track record of past forecasting activities;
    - The dramatic changes in U.S. and world energy markets since EIA began its forecasting activity, including increased competition in energy markets -- which has demonstrated that competition is more effective than government intervention in protecting interests of consumers;
    - The increasing competition within government for the use of tax dollars and
    - Many commodity markets behave quite well without the benefit of federal government price forecasts.

12. **If EIA continues making forecasts, should EIA:**
    - **Change its methods of forecasting?**
    - **Include in its forecast a case or scenario that contemplates continuing reductions in the real cost of oil, natural gas and electricity?**

These issues are too complex to treat in detail in this letter. However, I believe they deserve serious attention. I believe that an objective review by people who do not have a financial or emotional interest in EIA's forecasting methodology would reveal that:

- The NEMS models are exceedingly complex;
- The models produce specious outputs;
- The complexity cannot reasonably be expected to improve forecasting accuracy;
- The models rely extensively on historical data even though energy market conditions (and relationships among variables) have changed dramatically; and
- Policy developers and other users of forecasts could develop equally good analyses of alternative courses of action by using arbitrary assumptions about future energy prices.

With respect to the second part of question 12, EIA has taken a step forward, compared to prior forecasts, by including a case that contemplates roughly level real oil prices (i.e., growing by only .2% per year from 1994-2015 in EIA's "Low Oil Price" case). However, EIA's failure to admit that oil prices could continue to *decline in real terms is unfortunate*. All policy developers and decision makers should be forced to recognize that energy prices can continue downward movement in real dollar terms. *The chances of this occurring is not zero.* I believe that EIA leadership should pay greater attention to the work of prominent economists (e.g., Barnett, Nordhouse) that shows that commodity prices tend to follow a downward long-term trend. EIA should not dismiss the real world developments that could result in further softening of oil markets during the 20-year period covered by EIA's forecasts.

13. **Is there a systematic upward bias in energy price forecasts?** As you know, I have suggested that many publicly available energy price forecasts are affected by "a systematic upward bias." My papers on the subject are readily available to you.[1] Those papers include:
    - A detailed listing of reasons why energy price forecasts may have an upward bias; and
    - An invitation for interested parties to identify countervailing biases if they exist.

    I believe the issue is sufficiently important to warrant EIA's serious consideration.

14. **Is there a "conflict of interest" within DOE between EIA's responsibility for issuing objective forecasts and the Department's attempts to develop support for its energy programs?** I recognize that this is a sensitive issue within DOE. Your reassuring response concerning your final "sign off" authority for EIA's annual forecasts provides some comfort with respect to EIA forecasts. This reassurance is not dispositive for several reasons including:

    - The fact that DOE policy and program officials do not always use EIA forecasts as the basis for DOE policies and proposals. See, for example, DOE's 1991 energy policy proposals that were based on energy demand estimates in 2010 of 118.1 quadrillion Btus[2]

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[1] Attachment 3 to *Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions*, February 20, 1995 and the 1996 edition advance copy dated February 1, 1996.

[2] U.S. Department of Energy, *National Energy Strategy*, Technical Appendix 2, February 1991, Table B-5, p. 100.

while EIA only a short time later issued its reference case forecast showing demand of 106.90 Btus,[3] nearly 10% below the forecast used to develop and support numerous, expensive DOE policy and program proposals.

- Officials of DOE and other government agencies often give speeches and testimony and issue reports that include claims about potential economic benefits of policies and programs that do not identify the energy price forecasts on which claims are based.[4]

- DOE and its predecessor agencies (AEC, ERDA, FEA) have a long history of overestimating energy demand and prices and underestimating energy supplies that would be available at prices below their forecasts. Examples include AEC estimates of raw and enriched uranium required for nuclear power plants, the "Project Independence" reports, and the 1991 National Energy Strategy. Detailed analysis, particularly of justifications used in supporting DOE spending programs, undoubtedly would reveal many more examples.

- Attempts to create or maintain the perception of a "crisis" are a well known technique used by federal government officials when they are attempting to gather public and congressional support for programs that require spending tax dollars, or increasing the role of the federal government.

If these practices have come to an end, the change is not widely known.

15. **Are there grounds for questioning EIA's reference case forecast that the average price of natural gas delivered to electric generators will climb sharply after 2005 compared to the price of coal delivered to electric generators?** This is one of the very specific questions I raised concerning EIA's latest forecasts. You responded in your comments to *The Electricity Daily* that I "had failed to understand the EIA analysis, which was looking at new capacity." Assuming you are refering to the analysis reported on page 32 of AEO96, I have reviewed and do understand it. I would point out, however, that:
- This analysis, while quite useful, appears to deal only with the comparative cost of *new* coal vs. gas capacity and is based heavily on EIA's conversion efficiency ("heat rate") assumptions;
- The same conclusions do not apply to *existing* generating capacity; and
- The analysis does not explain the EIA reference case forecast that markets will permit the average delivered price of natural gas to climb by 2015 to 230% of the price of coal from the 1994 actual relationship of 161%.

Furthermore, it appears that one would have to assume that the average U.S. gas vs. coal price relationship would be controlled largely by new generating capacity efficiencies and would not

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[3] U.S. Energy Information Administration, *Annual Energy Outlook 1991*, Table A1, p. 43.

[4] For example, *Sustainable Energy* Strategy, July 1995 National Energy Plan submitted by the Administration pursuant to Section 801 of the Department of Energy Organization Act.

be constrained by other intra- and inter-fuel competition factors (e.g., gas-on-gas competition). In short, I believe the question is still valid.

I hope you will find this listing and explanation of issues useful as EIA pursues its efforts to provide accurate and objective energy information, even though not all of the issues can be addressed by EIA.

Sincerely,

Henry B. Jr. [illegible]

Attachments:
1. Copy of Electricity Daily article
2. Copy of Oil Daily article
3. November 30, 1995 letter to OMB and CBO
4. Table comparing EIA forecast and actual crude oil prices
5. Table comparing EIA forecast and actual natural gas prices
6. Table showing various real energy prices (In 1994$) for the period from 1973 to 1995

cc: Secretary of Energy
Directors of OMB and CBO

Attachment #1

Article appearing in *The Electricity Daily*, Monday, February 5, 1996:

<u>**EIA Rebuts Schleede Screed**</u>

The **Energy Information Administration** is coming out swinging in the face of criticisms of its energy price forecasts from energy consultant **Glenn Schleede** (ED, Jan. 31). In a written statement to *Electricity Daily*, EIA Administrator **Jay Hakes** accuses Schleede of spreading "misinformation" in a recent letter to the **Office of Management and Budget** and the **Congressional Budget Office**.

Hakes said, "EIA's overestimation of energy prices over the years has been approximated by virtually all groups that do forecasting. In the 1970s and early 1980s forecasters, including EIA, greatly overestimated energy prices. The price collapses of the mid-1980s came largely unanticipated. Even the price estimations of a few years ago are high compared to current projections." Hakes added, "This situation has been recognized for many years and is hardly news. It is likely, however, that current forecasts have a much stronger grasp of the geologic and market forces that affect price than ever before."

Schleede's suggestion that energy prices may continue to fall in real dollars, as they have in the past, "is opben to debate," said hakes. "EIA projects moderate increases in energy prices and some periods of declines in real dollars. However, those who convert the trends of the last few years into long-term projections could be repeating the mistakes of 15 years ago."

Schleede criticized EIA for predicting a divergence between prices of coal and gas for electric generation after 2005. Hakes responded that Schleede had failed to understand the EIA analysis, which was looking at new capacity. He said in the 1996 EIA forecast, "the coal-versus-gas generation investment decision incorporates anticipated capital cost reductions and improvements in heat rates for both pulverized coal units and combined cycle units. Based on engineering estimates, the 1996 *Annual Energy Outlook* assumes that the efficiency of pulverized coal will increase to 42 percent while gas combined cycle is assumed to increase to almost 60 percent.

"Consequently, the cost of producing electricity from pulverized coal in 2015 is projected to be about 44 mills per kWh while the cost to generate electricity from gas combined cycle units is projected to be about 36 mills per kWh. Gas-fired combined cycle generation is competitive in 2015 despite the projected widening gap between delivered coal and gas prices."

Hakes also defended EIA's "national energy modeling system" or NEMS. "With its ability to create 'what if' scenarios," said Hakes, "this model can evaluate the potential consequences of proposed policies. For instance, NEMS is often used to assess the impacts of proposed energy policies on the environment and the impacts of new tax policy on energy use. Modeling of energy (or anything else, for that matter) is an inexact science, but decisionmaking is a better process with nonpartisan models than without them."

Hakes also took issue with Schleede's complaint that EIA can be manipulated by its **Department of Energy** parent and its political masters. "As the final sign-off on EIA's work, including the Annual Energy Outlooks," Hakes said, "I can report that no one has tried to 'slant' our results. And if they did, they would not be successful. Open and nonproprietary systems, regular review by academic, government, industry experts, and--most of all--the integrity of EIA analysts would not allow it to happen."

Although EIA projections may not differ significantly from those made by private organization, great weight is given to independent, government forecasts," the complaint said.

Hakes said he's pleased the government figures carry more weight.

"The critics are right. There has been an increasing use of our projections over the years. That puts some pressure on us," he said.

Private companies, for example, have used the numbers to lure more customers.

Last year, before made its latest revisions to gas price forecasts, Virginia Power ran newspaper ads comparing the steep gas price increase predicted by EIA with stable electricity prices.

Citing the lost business, American Gas Association (AGA) president and Chief Executive Michael Baly in December threatened to "take an active role in eliminating EIA's forecasting responsibilities" if figures were not lowered this year.

But with last month's 38% reduction in the projected gas price for 2010, gas producers for now are content with EIA.

The revisions represent a"quantum leap" in government forecasting, according to Paul Wilkinson, AGA vice president of policy analysis.

Observers say modest price estimates are still hard to come by amid the lingering fears of an energy crisis such as the one that created the price run-ups of the 1970s and early '80s.

"Back 20 years ago, there was the expectation that oil prices would increase continuously for the foreseeable future. In 1981, people were talking about $100 bbl of oil," said Edward Murphy, director of financing for the American Petroleum Institute.

"It's taken a lot for that mindset to be killed."

In its 1984 AEO, for example, EIA said 1995 oil prices (in constant 1994 dollars) would average $55.40/bbl and gas would run about $6.99/Mcf.

The high forecasts over the years have led to some questions about EIA's role within DOE.

Though billed as "policy-neutral," EIA's high forecasts suggest an upward bias aimed at validating DOE claims of an imminent energy crisis, Schleede argues.

He has called on the government to redesignate EIA as a wholly independent statistical agency.

By law, Hakes noted, DOE has no direct authority over any of EIA's functions, including forecasting.

I'm the final sign-off," he said. "I think everybody knows that."

Attachment #2

Article appearing in *The Oil Daily*, Thursday, February 8, 1996:

Critics Maintain Fire AT EIA Despite Cut In Price Forecasts, by Katherine Culbertson, Oil Daily Staff Writer

WASHINGTON -- The Energy Information Administration (EIA) may have lowered its expectations for energy prices over the past few years, but it hasn't been able to silence all its critics.

Chief among the detractors is Glenn Schleede, who as president of Energy Market & Policy Analysis Inc. since 1992 has admonished EIA for issuing misleading forecasts.

In the latest Annual Energy Outlook (AEO), released Jan. 11, EIA--a semi-independent agency of the Department of Energy (DOE)--lowered long-term forecasts for both oil and natural gas.

In 1994 dollars, EIA now says oil in 2010 will cost $23.70/bbl and domestic natural gas $2.15/Mcf, down from last years estimates of $24.62/bbl and $3.46/Mcf.

Schleede welcomed the revisions as "belated" recognition of change in energy markets.

But given the EIA's predictions of increasing prices, he said the agency still is missing the downward trend evident since the 1980s.

"Real energy prices have been trending downward and forecasts have been lowered, yet most forecasts continue to show price increases," he said.

Though Schleede says he doesn't "mean to pick on EIA," EIA Administrator Jay Hakes disagrees.

"By just mentioning EIA, he's giving the impression that we're the only ones who forecast high prices," Hakes told *The Oil Daily*.

"All organization have been high with their projections," he said.

EIA's latest forecasts for gas prices in 2010 are some 16¢-52¢ lower than other predictions put out by leading forecasters.

Schleede has countered that EIA should be held to a higher standard because its figures are so widely used.

"Anyone can go to the government printing office and buy a copy of the Annual Energy Outlook for [$18]," he said.

Also, free copies of the AEO are mailed out to federal, state and local government agencies, public libraries and the media.

Last September, the Interstate Natural Gas Association of America filed a similar complaint with the Federal Energy Regulatory Commission.

Attachment #3

Energy Market & Policy Analysis, Inc.
P.O. Box 3875
Reston, Virginia 22090-3875
(703) 709-2213; Fax 709-2214

Glenn R. Schleede
President

Overnight Mail:
1414 Hemingway Court
Reston, VA 22094

January 30, 1996

The Honorable Alice M. Rivlin
Office of Management & Budget
Washington, DC 20503

The Honorable June E. O'Neill, Director
Congressional Budget Office
Washington, DC 20515

Dear Directors Rivlin and O'Neill:

Summary: This letter updates and adds to my letters of November 1 and 30, 1995 that describe OMB and CBO actions needed to minimize the *costly impact of energy price forecasts on consumers, taxpayers, and shareholders*. The need for your actions has grown because:

- Past energy price forecasts have substantially overestimated energy prices and have already cost consumers, taxpayers and shareholders billions of dollars.

- New price forecasts issued on January 11, 1996 by the Energy Information Administration (EIA) in its Annual Energy Outlook 1996 are significantly lower than past forecasts. For example, the forecast for wellhead natural gas prices in 2010 is down 38% from EIA's January 1995 forecast. EIA's latest forecast for crude oil prices in 2010 is down 19% from it's January 1994 forecast and 36% from it January 1992 forecast. (Details in Attachment #1).

- Proposals, decisions, actions, and claims based on earlier forecasts are now out of date and need to be reconsidered, lest they result in even more unnecessary costs for consumers, taxpayers and shareholders.

- Serious questions remain concerning the validity of EIA's latest forecasts. Real energy prices have trended downward since the early 1980s (See Attachment #2) and increasing competition in energy markets portends further reductions, yet EIA continues to forecast that most energy prices will increase.

As explained in previous letters, energy price forecasts, including those prepared by the U.S. Department of Energy (DOE), have widespread impact. For example:

- Energy price forecasts affect thousands of economic analyses and decisions made by private sector organizations, public utility commissions, and other government officials.

- In the federal government energy price forecasts affect:
  - Budget estimates, for both revenues and expenditures;
  - Economic analyses used to justify energy efficiency standards, subsidy programs (including DOE's energy research, development and demonstration programs), and the Federal Energy Management Program (FEMP); and
  - The validity of claims of "energy savings" made by government officials.

Specific Problems and Recommended Actions. Previous letters have listed a number of actions needed to reduce the adverse effects of faulty energy price forecasts. This letter updates the list.

1. *DOE/DOC November 1995 Energy Price Forecast for FEMP.* Two months ago -- in November 1995 - DOE and the Department of Commerce (DOC) distributed new forecasts[1] that must be used by federal agencies and certain private sector organizations until November 1996 for FEMP life-cycle cost analyses. This DOE/DOC document is based on outdated, higher energy EIA forecasts, particularly for natural gas. DOE and DOC should be directed to withdraw this document and provide updated forecasts.

2. *Energy Efficiency Standards.* Energy efficiency standards for appliances and other products issued by DOE are based on economic analyses that incorporate EIA price forecasts. Use of high energy price forecasts overstate potential savings in energy costs and result in more stringent standards than are justified. Accordingly, DOE should be directed to:
   - Begin immediately using EIA's new energy price forecasts when evaluating the economics of any energy efficiency standards now being considered.
   - Prepare additional economic evaluations using even lower future energy prices than those recently issued by EIA. This action is appropriate in light of the DOE/EIA history of overestimating future energy prices. To assure an adequate range of possibilities, these additional evaluations should include at least:
     - One case that assumes that real energy prices, including world oil prices will remain level indefinitely, and
     - One case that assumes that real energy prices, including world oil prices, will *continue* on a downward trend.
   - Reevaluate all energy efficiency standards that have already been issued to see whether they would still be justified using EIA's latest energy price forecasts.
   - Make public the results of these evaluations and reevaluations so that consumers are not misled by out-of-date government analyses and regulatory decisions.

3. *Oil and Gas Leases.* Price forecasts affect Mineral Management Service estimates of:
   - The value of potential leases of federal lands for oil and gas exploration and development, and

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[1] Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis 1996, NISTIR 85-3273-10 (1095) prepared by the U.S. Department of Commerce for U.S. DOE, Federal Energy Management Program.

- Revenue (federal and state) that will be received from bonus and royalty payments from oil and gas leases on federal lands are based on energy price forecasts.

Whether EIA forecasts are used for these purposes is unclear. In any case, valuation procedures and budget estimates for oil and gas leases, including the Alaskan National Wildlife Refuge (ANWR), should be reconsidered in light of new market fundamentals and lowered oil and gas price forecasts. In addition, states that receive revenue from federal leases should be advised that such revenue may be lower than previously estimated.

4. *Value of Naval Petroleum Reserves.* DOE has, in the past, made estimates of the value of the Naval Petroleum Reserves using highly questionable energy price forecasts and analytical procedures. For example, in an April 1994 report, DOE's gas price assumption for 1995 is some 30% above the actual U.S. average. Also, one set of price assumptions was used when analyzing two of three alternatives for the future handling of the NPRs. DOE used a set of *higher* price assumptions when evaluating a third alternative, thus producing a biased result. Apparently, the third alternative -- creation of a government corporation to take over the NPRs -- was the alternative proposed by those preparing the report. The value of the NPRs should be recalculated using realistic oil and gas price forecasts, including scenarios that recognize that the very real possibility that oil and gas prices will remain level or continue to decline in real dollar terms.

5. *Economic justification for proposed energy RD&D Subsidies.* DOE and other agencies use energy price forecasts whenever they attempt to use economic analysis to justify proposed energy research, development and demonstration (RD&D) subsidies. Whether DOE program offices use EIA forecasts or others is unclear. In any case, DOE and other agencies should prepare economic analyses to support such subsidy programs and they should use realistic energy price forecasts when doing so. In addition to EIA's Reference Case forecast, agencies should prepare analyses using forecasts that recognize the possibility that oil and gas prices will remain level or continue to decline in real dollar terms. Such a requirement should be imposed on all proposed energy RD&D expenditures, including, fossil, nuclear or renewable energy and energy conservation.

6. *Costly private sector decisions due to high price forecasts.* High energy price forecasts issued by EIA and commercial forecasting organizations have contributed to uneconomic capital investment and long-term contract decisions in the private sector. For example:
   - High price forecasts lead to overestimates of future revenue from investments in energy production ventures.
   - High price forecasts for one energy source and low estimates for another influence choices among energy sources when making capital investment in facilities that use energy (e.g., electric generating plants) or making long-term contracts (e.g., for power purchases or fuel purchases).
   - Individual and institutional investors have been misled.

EIA has included a "warning" concerning use of its forecasts in *Annual Energy Outlook 1996*. This is a useful step, but EIA should also warn anyone who has used *past* forecasts that analyses, decisions, or actions based on them should be reconsidered.

7. *Utilities' "Avoided Costs" and "Stranded Investments."* Price forecasts have played a major role in overestimates of "avoided costs"[2] by electric and gas utilities and by state utility commissions. These overestimates made high cost purchase power contracts and demand-side subsidies appear attractive. However, these contracts and subsidies have led to billions of dollars in unnecessarily high electric and gas bills for consumers. They have also contributed to uneconomic ("stranded") investments that will be costly for consumers, shareholders, or both as the electric industry becomes more competitive. There are many cases around the country where this has occurred. For example:
   - A Maine PUC member has indicated that much of the high cost of power in Maine is attributable to decisions based on high energy price forecasts.[3]
   - DOE's Inspector General has concluded that Bonneville Power Administration (BPA) erred in using high gas price forecasts when deciding to sign a contract to purchase power from a privately owned gas-fired generating plant.[4] This contract has far reaching implications for Bonneville's customers and, potentially, for U.S. taxpayers. BPA's attempt to withdraw from the arrangement apparently is being challenged in a $1+ billion lawsuit.

   State public utility commissions, governors, and legislators, in particular, should be specifically informed of the significant changes in EIA's forecasts of future prices and urged to reconsider any decisions, actions, or requirements based on previous forecasts.

8. *Claims by government officials.* Reports, testimony, and speeches made by officials from DOE, EPA, other agencies, and government contractors often include claims of alleged "energy savings." For example, the July 1995 National Energy Policy Plan submitted by the Administration, *Sustainable Energy Strategy*, makes numerous claims about "savings" that will be achieved by 2000 or 2010 (e.g., pages 23, 25, 26, 27, 30, 45). Any such claim *must* be based on some assumption or forecast of future energy prices. All such claims should be reevaluated in light of lower energy price forecasts. All future reports, testimony, and speeches should be screened to avoid false or misleading claims.

9. *Government role in Energy Forecasting.* It is time to reconsider whether forecasting of energy prices is an appropriate federal government role. Energy price forecasts are available

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[2] In the case of electricity, the phrase, "avoided cost," is generally used to describe the cost that an electric utility would incur if it added capacity needed to provide additional electricity demand. Such "avoided cost" calculations have been used to evaluate bids and proposals from other organizations that wish to provide the electricity, or to evaluate the cost of load management or conservation measures that could be taken to avoid the increase in electricity demand.

[3] See Enclosure #2, p. 3 and NARUC Bulletin No. 49-1993, December 6, 1993, p. 2.

[4] Office of Inspector General, U.S. Department of Energy, *Audit of Bonneville Power Administration's Energy Resource Programs*, DOE/IG-0379, September 1995.

from a variety of commercial forecasting organizations. EIA is, in effect, competing with such organizations. Further, dozens of other commodity markets operate efficiently without federal market forecasts.

10. *Other Actions if EIA is to Continue Issuing Forecasts.* If EIA is to continue issuing energy demand, supply, and price forecasts, several additional steps are needed:

   a. *EIA reconsideration of forecasts in Annual Energy Outlook 1996 (AEO96).* While EIA made progress in AEO96 in reflecting recent market conditions and lowering price forecasts, several aspects of the EIA model, the input assumptions, and the resulting forecasts deserve reconsideration. These include:
      - The EIA presumption that world oil prices will inevitably increase.
      - The absence of a realistic "low" case in EIA's forecasts; i.e., one that recognizes the possibility that energy prices will continue to decline in real terms indefinitely.
      - The inconsistencies between EIA's forecasts of delivered fuel prices for electric generating companies, particularly between coal and natural gas. EIA has forecast substantial divergence between delivered coal and natural gas prices after 2005, with natural gas prices growing rapidly and coal prices declining slightly. It is not clear that market forces, including interfuel competition, will allow such divergence.
      - The strong possibility that EIA has not taken adequately into account the downward pressure on fuel prices (particularly coal and natural gas) that will result from growing competition and downward cost pressure in the electric industry. About 40% of all the Btus consumed in the U.S. are used to generate electricity. Electric generators will be working hard to reduce fuel costs as competition increases and the "automatic" pass-through of fuel costs (the "fuel clause") disappears.
      - The failure to reflect in EIA's forecasts of end user prices for electricity and natural gas the virtual certainty that growing competition within and between the electric and gas industries will result in significantly lower real prices. Organizations, including distribution companies, in both industries are taking steps to reduce costs and prices and such steps are likely to continue and intensify.

   b. *Scenario-based forecasts.* EIA bases its forecasts largely on a single scenario that *assumes* growing dependence on oil from OPEC and an inevitable, significant increase in world oil prices from current levels. In EIA's forecasting model, this "inevitable" oil price increase assumption, in turn, "forces" EIA's natural gas price upward. EIA has slavishly adhered to its oil market assumptions despite downward trends in oil prices and strong evidence that commodities typically experience long-term price depreciation, not appreciation. If EIA is to continue making energy market forecasts, it should add at least two scenarios to the one currently being used. One should reflect the possibility that oil and other energy prices will be level over the long-term.[5] Another should reflect the possibility that oil and other energy prices will *continue* to decline in real terms.

c. *Reevaluate NEMS.* The National Energy Modeling System (NEMS) used to produce energy demand, supply, and price forecasts is a relatively new and expensive undertaking. However, experience thus far should be sufficient to provide the basis for a thorough reevaluation of the need for such a complex and expensive modeling program. As market forces continue to bring energy demand and supply into balance and push energy prices lower, it may be time to reduce DOE/EIA energy data collection, analysis and modeling activities.

d. *Consistency of EIA Forecasts with other Government Reports.* EIA's independence should be maintained and EIA should be shielded from any attempt by policy officials, subsidy program managers, or special interest groups to use EIA's energy forecasts to serve their particular interests. However, steps are also needed to either assure consistency -- or clearly explain differences -- among assumptions used by EIA in preparing forecasts and those used by other government officials when:
   - Making revenue and spending estimates for the President's budget.
   - Preparing important economic reports.
   - Preparing economic evaluations of existing and proposed policies and programs.
   - Justifying proposals to the public and to Congress.

   To achieve these results, it may be necessary to establish an OMB-led peer review committee, with participation from the Council of Economic Advisers and the Treasury Department to either:
   - Review the EIA forecasts before they are released to the public to accomplish the above objective, or
   - Prepare and issue a report immediately after EIA's forecasts are released that explains differences between EIA assumptions and forecasts and those being used elsewhere in the federal government.

11. *Organizational Location of EIA.* Current law provides that EIA is an independent agency within DOE but EIA's close relationship with other DOE energy functions may weaken that independence. The organizational location of EIA deserves reconsideration. DOE and its predecessor agencies have a long and unfortunate history of overestimating future energy demand and prices. Recent history suggests that those in charge of DOE's energy policy and program functions seem to find it necessary to try to create a public perception of an "energy crisis" to build Administration and Congressional support for continued spending of billions of tax dollars on DOE's energy programs. Such an atmosphere seems incompatible with EIA's responsibility for producing unbiased information on energy.

---

[5] Short-term volatility in oil and natural gas prices should be expected for a variety of reasons, including weather, facility problems, and other temporary conditions.

Thus, the continued presence of EIA within DOE raises questions about EIA's real independence and whether its location leads to forecasts that are designed in part to justify DOE energy programs. Removal of EIA from DOE should reduce the potential for a "conflict of interest" between EIA's responsibility for independent forecasts and DOE official's desire to build support for DOE's spending programs. Perhaps EIA should be removed from DOE and made a part of an independent statistical agency.

12. *Guidance on the use of energy price forecasts.* As explained above, energy price forecasts --whether prepared by EIA or others -- play an important role in many government and private sector decisions and actions. As indicated, forecasts that have proven to be faulty and improper use of forecasts has cost consumers, taxpayers, and shareholders billions of dollars. In view of this, OMB should issue a Circular or other directive that provides clear instructions to federal agencies on the use of energy price forecasts in government proposals, decisions, and actions. Such a directive should:
    - Recognize that no one can assure that their energy price forecast will be accurate, and
    - Accordingly, require that agencies use at least three alternative future energy price paths when evaluating proposed policies, programs, regulatory requirements, or other actions. At least one alternative should assume moderate (perhaps 1% per year) increases in real prices; one should assume level real prices, and one should assume that real prices will *continue* to decline. When decisions are dependent upon future energy prices, the alternative relied upon by an agency should be clearly identified and the choice among alternatives definitively justified.

I hope this letter explains adequately the important role contribution that energy price forecasts have made in decisions that have proven to be unwise and that have cost -- and continue to cost -- billions of dollars. I urge you to consider the proposals carefully. The action needed should not be left to DOE because of that Department's "conflict of interest" and because the actions and implications described extend well beyond DOE's authorities and responsibilities. Also, based on past attempts to address the problems, it seems unlikely that corrective actions will be taken unless OMB, CBO and/or the appropriate Congressional committees address the issue that have been identified.

Sincerely,

Glenn R. Schleede

Attachment:
1. Comparison of past EIA forecasts
2. Past energy prices in constant 1994$

cc: Secretary of Energy
Secretary of Commerce
Secretary of the Interior

Attachment #4

DOE /EIA Annual Energy Outlook Reference Case Price Forecasts: 1984-1996

(Data as shown in AEO Reports but Converted to 1994$)

Energy Product	Publication	Release Date	Price Projections shown in reports - converted to 1994$ 1995	2000	2005	2010
A. Crude oil - Average refiner acquisition cost for imported crude oil - dollars per barrel						
	AEO 1984	1/85	55.40			
	AEO 1985	2/86	40.09			
	AEO 1986	2/87	34.62	42.77		
	AEO 1987	3/88	28.24	38.79		
	AEO 1989	1/89	25.01	34.00		
	AEO 1990	1/90	23.70	32.30	38.22	42.87
	AEO 1991	3/91	26.72	28.62	34.52	38.08
	AEO 1992	1/92	23.16	29.39	33.96	37.19
	AEO 1993	1/93	21.34	24.55	27.98	31.41
	AEO 1994	1/94		21.61	25.97	29.37
	AEO 1995	1/95		19.52	21.94	24.62
	AEO 1996	1/96		19.27	21.86	23.70
What did price turn out to be? (in 1994$)			16.81			

Data Source: Energy Information Administration, Annual Energy Outlook 1996, January 1996, Table A1

Energy Market & Policy Analysis, Inc. 1/29/96 EMPA

Attachment #5

DOE /EIA Annual Energy Outlook-Reference Case Price Forecasts: 1984-1996

(Data as shown in AEO Reports but Converted to 1994$)

Energy Product	Publication	Release Date	Price Projections shown in reports - converted to 1994$ 1995	2000	2005	2010
B. Natural gas wellhead price - Lower 48 onshore & offshore - dollars per Mcf						
	AEO 1984	1/85	6.99			
	AEO 1985	2/86	5.38			
	AEO 1986	2/87	5.11	7.17		
	AEO 1987	3/88	3.59	5.07		
	AEO 1989	1/89	3.40	4.75		
	AEO 1990	1/90	2.61	3.75	5.07	6.54
	AEO 1991	3/91	2.36	2.91	4.55	5.61
	AEO 1992	1/92	2.25	3.03	4.12	5.18
	AEO 1993	1/93	2.19	2.74	3.65	3.95
	AEO 1994	1/94		2.52	3.01	3.62
	AEO 1995	1/95		2.18	3.08	3.46
	AEO 1996	1/96		1.89	1.99	2.15

What did price turn out to be? (in 1994$) 1.60

Data Source: Energy Information Administration, Annual Energy Outlook 1996, January 1996, Table A1

Energy Market & Policy Analysis, Inc. 1/29/96 EMPA

Attachment #6

Average Annual Energy Prices in Constant 1994$

1973 to 1995

1/30/96

Year	Crude Oil* $ per Bbl.	Natural Gas Wellhead** $ per Mcf	Motor Gasoline (all types)- Retail (Include taxes) $ per gallon	Refinery Price Finished Gas-oline for Resale (without taxes) $ per gallon	Residential Heating Oil Retail $ per gallon	Residential Natural Gas $ per MMBtu	Residential Electricity Cts. per kWh
1973	12.46	0.67				3.94	7.6
1974	35.16	0.84				4.02	8.7
1975	35.68	1.13				4.38	9.0
1976	32.50	1.40				4.77	8.9
1977	32.79	1.78				5.30	9.3
1978	30.47	1.90	1.36	0.91	1.02	5.35	9.0
1979	41.69	2.27	1.70	1.23	1.35	5.73	8.8
1980	59.59	2.80	2.15	1.65	1.71	6.47	9.5
1981	59.24	3.17	2.16	1.70	1.91	6.86	9.9
1982	50.51	3.70	1.93	1.46	1.75	7.78	10.4
1983	42.39	3.75	1.77	1.28	1.56	8.77	10.4
1984	40.00	3.68	1.66	1.15	1.51	8.48	10.4
1985	36.06	3.35	1.60	1.12	1.41	8.18	10.4
1986	18.21	2.52	1.21	0.69	1.09	7.59	9.6
1987	22.86	2.11	1.21	0.74	1.01	6.99	9.3
1988	17.68	2.05	1.17	0.70	0.99	6.64	9.1
1989	21.01	1.96	1.23	0.76	1.05	6.55	8.8
1990	24.23	1.90	1.36	0.88	1.18	6.46	8.7
1991	20.05	1.76	1.28	0.75	1.09	6.24	8.6
1992	18.98	1.81	1.24	0.71	0.97	6.14	8.6
1993	16.47	2.08	1.20	0.64	0.93	6.29	8.5
1994	15.51	1.88	1.17	0.60	0.88	6.41	8.4
1995 (Est.)	16.81	1.60	1.18	0.61	0.84	6.07	8.3

* Refiners acquisition cost of imported crude oil ** Lower-48 states wellhead prices

Source: Energy Information Administration, Monthly Energy Review, Tables 9.1, 9.4, 9.6, 9.8c, 9.9, & 9.11.

Energy Market & Policy Analysis, Inc. *EMPA*

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(703) 709-2213; Fax 709-2214

Glenn R. Schleede
President

Overnight Mail:
1414 Hemingway Court
Reston, VA 22094

April 25, 1996

Mr. Jay Hakes, Administrator
Energy Information Administration
U.S. Department of Energy
Washington, DC 20585

Dear Dr. Hakes:

As you are well aware, EIA's Annual Energy Outlook 1996 (AEO96) forecasts that U.S. average electricity prices will change very little between 1995 and 2015 (i.e., no more than .5% per year). Graphs based on AEO96 forecasts are enclosed (residential, commercial, industrial and all users).

Early revision of EIA's AEO96 electricity price forecasts seems essential now that the Federal Energy Regulatory Commission (FERC) has issued Orders 888 and 889, and in view of the widespread expectation than actions already underway will result in *substantially* lower prices.

I recognize that it is difficult at this time to forecast the *extent* that electricity prices will decline as a result of FERC's action, the ongoing electric industry restructuring, and increasing competition that is already underway. I also understand that you have a study of the matter underway. However, early action by EIA is necessary because reliance on AEO96 forecasts by private sector, regulatory agency and other government officials could result in decisions that are uneconomic and costly for consumers, taxpayers, and investors. Specifically, I urge you to:

- Inform all users of the Annual Energy Outlook as soon as possible that electric prices are almost certain to be lower than those forecast in AEO96.
- Expedite the completion and publication of your study of the impact of electric industry restructuring, and issue revised price forecasts at the earliest possible time.
- Inform users of the Annual Energy Outlook that competition from lower electric prices for end users, together with increasing competition underway in the gas industry, are also likely to result in lower natural gas prices for end users than those reflected in AEO96.
- Inform others in DOE and other government agencies that rely on EIA price forecasts of the high probability that electric and gas prices for end users will be lower than those forecast in AEO96.
- Urge others in DOE and officials in other government agencies to:
  - Take into account the expectations of lower electric and gas prices for end users, and
  - Revise budget estimates, justifications for energy R&D spending programs, and claims of energy cost savings that have already been submitted to the Congress.

The expectation that electric prices will be lower is especially clear now that the FERC has issued its Orders 888 and 889. Consider, for example, the following quotes from the April 25, 1996 issue of the *Electricity Daily*:

> "The order should have major economic impacts, however. In the final environmental impact statement on the proposal, FERC calculated that the order will produce direct cost savings of $3.8 billion to $5.4 billion, just on the basis of plant efficience, lower reserve margins and the like. The FERC staff said indirect savings from introducing competition into wholesale markets will dwarf those, but can't be calculated at this point.
>
> "Chair Betsy Moler said, "Today's actions by the commission will benefit the industry and consumers to the tune of billions of dollars every year. They will give us an electric industry ready to enter the 21st century. These rules will accelerate competition and bring lower prices and more choices to energy consumers."

Electric industry officials (e.g., Dr. Richard Balzhiser, President and CEO of the Electric Power Research Institute) have estimated that electric prices will decrease by "25% or more."

Early action by EIA, as suggested above, could go a long way toward heading off unwise and costly decisions based on AEO96 and similar forecasts by others. Such actions could be especially important in the case of state public utility commissions (PUCs) since they often make decisions based on long-term energy price forecasts. Furthermore, PUCs may not have the resources to assess, independently, the validity of EIA forecasts or those available from commercial forecasting organizations.

Thank you for your consideration of the above recommendations.

Sincerely,

Enclosures

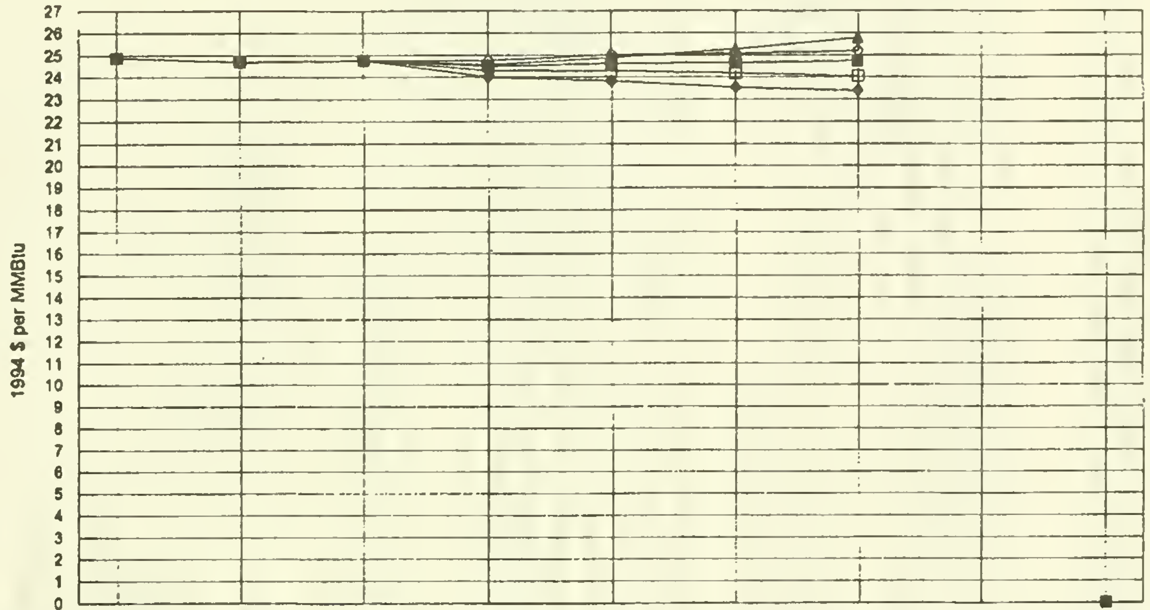
Glenn R. Schleede

..AND WILL DWARF ANY "SAVINGS" THAT RESULT (HONESTLY) FROM DOE R+D PROGRAMS!

Enclosure #1

EIA's AEO96 Forecast for Residential Electricity Prices - 5 Cases

1993-1995 - Actual; 2000 - 2015 - Forecast



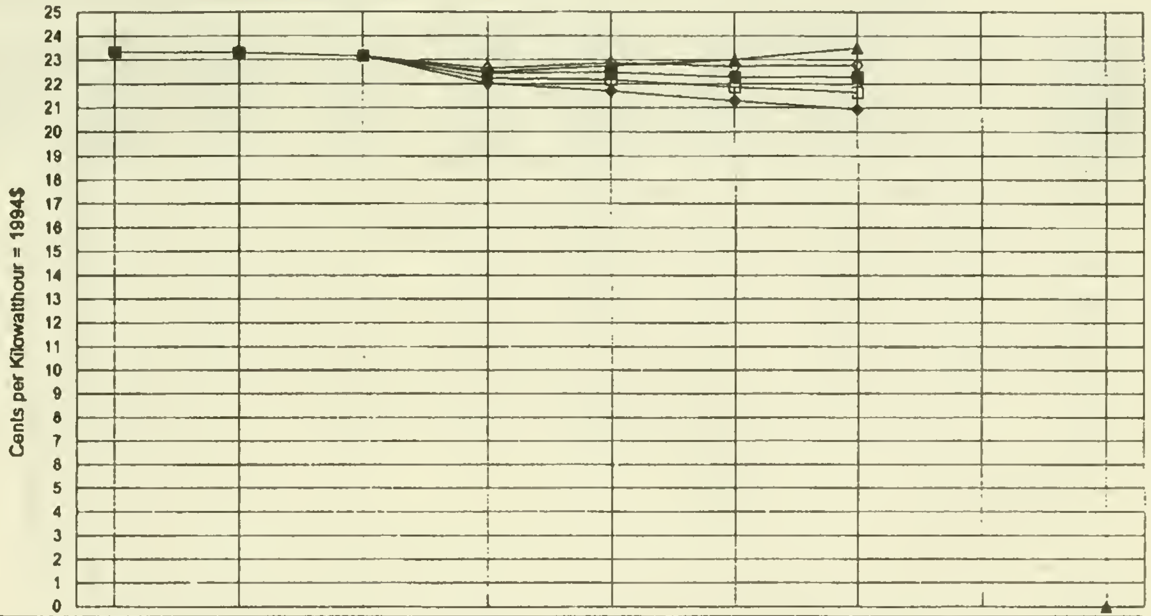
	1993	1994	1995	2000	2005	2010	2015		Ann.Chg.*
■ Reference Case	24.67	24.67	24.74	24.49	24.62	24.83	24.72		0.0%
◆ Low Econ. Growth	24.87	24.67	24.74	23.99	23.82	23.54	23.38		-0.3%
▲ High Econ. Growth	24.87	24.67	24.74	24.56	24.86	25.26	25.78		0.2%
⊡ Low World Oil Prices	24.87	24.67	24.74	24.31	24.29	24.18	24.04		-0.1%
◇ High World Oil Prices	24.67	24.67	24.74	24.75	25.01	25.07	25.18		0.1%

Data Source: U.S. Energy Information Administration, Annual Energy Outlook 1996, Tables A1,A3,A8,B1,B3,B8,C1,C3,C8. * Annual % Change 1994-2015.

Enclosure #2

EIA's AEO96 Forecast for Commercial Electricity Prices - 5 Cases

1993-1995 Actual -- 2000-2015 Forecast



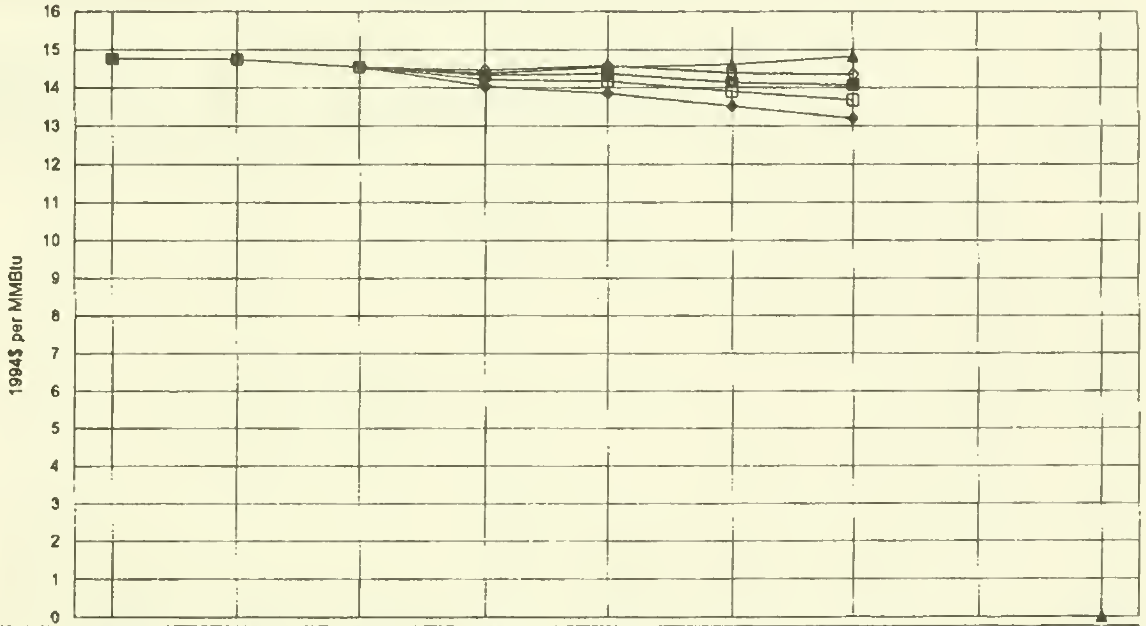
	1993	1994	1995	2000	2005	2010	2015		Ann.Chg.*
■ Reference Case	23.34	23.3	23.15	22.43	22.49	22.27	22.29		-0.2%
◆ Low Econ. Growth	23.34	23.3	23.15	22.00	21.69	21.27	20.94		-0.5%
▲ High Econ. Growth	23.34	23.3	23.15	22.49	22.74	22.99	23.49		0.0%
⊡ Low World Oil Prices	23.34	23.3	23.15	22.22	22.17	21.84	21.85		-0.3%
⊖ High World Oil Prices	23.34	23.3	23.15	22.65	22.85	22.71	22.78		-0.1%

Data Source: U.S. Energy Information Administration, Annual Energy Outlook 1996, Tables A1,A3,A8,B1,B3,B8,C1,C3,C8. * Annual % Change - 1994-2015.

Enclosure #3

EIA's AEO96 Forecast for Industrial Electricity Prices - 5 Cases

1993-1995 Actual; 2000-2015 Forecast



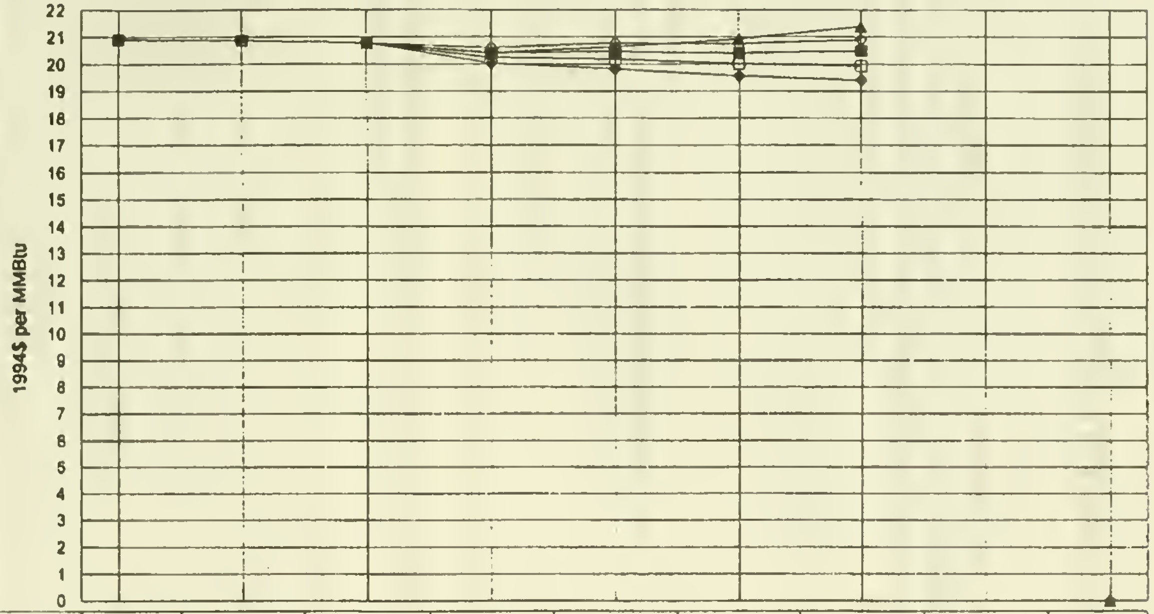
	1993	1994	1995	2000	2005	2010	2015		Ann. Chg.*
■ Reference Case	14.76	14.75	14.55	14.33	14.37	14.14	14.07		-0.2%
◆ Low Econ. Growth	14.76	14.75	14.55	14.04	13.86	13.52	13.20		-0.5%
▲ High Econ. Growth	14.76	14.75	14.55	14.38	14.55	14.61	14.82		0.0%
□ Low World Oil Prices	14.76	14.75	14.55	14.21	14.18	13.90	13.68		-0.4%
◇ High World Oil Prices	14.76	14.75	14.55	14.46	14.58	14.39	14.35		-0.1%

U.S. Energy Information Administration, Annual Energy Outlook 1996, A1,A3,A8,B1,B3,B8,C1,C3,C8. * Annual % Change - 1994-2015.

Enclosure #4

EIA's AEO96 Forecasts for Electricity Prices - All Users Combined - 5 Cases

1993-1995 - Actual; 2000-2015 Forecast



	1993	1994	1995	2000	2005	2010	2015		Ann.Chg.*
■ Reference Case	20.89	20.85	20.77	20.39	20.48	20.38	20.48		-0.1%
◆ Low Econ. Growth	20.89	20.85	20.77	20.02	19.81	19.54	19.38		-0.3%
▲ High Econ. Growth	20.89	20.85	20.77	20.41	20.64	20.90	21.38		0.1%
⊡ Low World Oil Prices	20.89	20.85	20.77	20.22	20.18	20.01	19.92		-0.2%
⊖ High World Oil Prices	20.89	20.85	20.77	20.59	20.78	20.74	20.88		0.0%

Data Source: U.S Energy Information Administration, Annual Energy Outlook 1996, Tables A1,A3,A8,B1,B3,B8,C1,C3,C8. * Annual % change from 1994-2

Illustrations of Costs Resulting from High Energy Price Forecasts

That Are Borne by Consumers, Taxpayers, and Shareholders

By

Glenn R. Schleede*

March 17, 1996

*Energy Market & Policy Analysis, Inc., P.O. Box 3875, Reston, Virginia. Phone: 703, 709-2213

Illustrations of Costs Resulting from High Energy Price Forecasts that are Borne by Consumers, Taxpayers, and Shareholders

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March 17, 1996

Illustrations of Costs Resulting From High Energy Price Forecasts

Undoubtedly, there is no complete accounting of the *huge costs that have been incurred by consumers, taxpayers, shareholders, and investors* as a result of decisions that were based on high energy price forecasts that have proven to be faulty.

However, it is possible to identify key categories of extra costs and, in some cases, estimates of the dollar magnitude of the costs that have been and still are being incurred because the Energy Information Administration (EIA) and other forecasters drastically overestimated energy prices and/or energy demand. This paper provides illustrations involving:

- The electric industry
- The natural gas industry
- Investments in oil and gas exploration in the late 1970s and early 1980s
- Bank failures resulting from non-performing loans to some energy companies
- Tax dollars wasted on impractical energy R&D projects
- Overbuilding of nuclear capacity by TVA and in the Pacific Northwest
- Bonneville Power Administration's contract to purchase power from a NUG
- Minerals Management Service (MMS) over estimating the value of oil and gas leases
- Biased analyses by DOE and lobbying organizations -- based on high price forecasts

A. Electric industry

A large share of the extra costs resulting from high energy price forecasts will be borne by electric industry consumers, shareholders, and other investors -- and potentially by taxpayers -- because of:

- Faulty estimates by utilities and PUCs of "avoided costs"[1] because of high forecasts of energy prices and/or demand.
- Heavy investments in long-lived capital intensive assets such as electric generating plants.
- Federal government and/or state PUC requirements that utilities sign long-term contracts to buy power from non-utility generating firms (NUGs).
- Independent power producers' (IPPs) decisions to build electric generating plants and electric utilities' decisions to sign power purchase contracts with IPPs.
- PUC requirements or encouragement that utilities invest in or buy power from generating units that use "renewable" energy.
- PUC requirements or encouragement that electric utilities subsidize actions by customers to reduce electricity use or shift uses to low demand periods ("demand-side" measures).
- Long-term fuel supply contracts with prices that proved to be above market.

---

[1] "Avoided costs" are estimates of the cost that an electric utility would incur if it produced electricity with its own facilities rather than buying from others or rather than subsidizing conservation.

1. **The role of faulty energy price forecasts.** Faulty, high energy price forecasts contributed in a major way to the extra costs because utilities have been using large amounts of oil, coal, and natural gas to fuel electric generating units and EIA and other forecasters drastically overestimated the prices for these fuels. The high fuel prices led to high PUC and utility estimates of "avoided costs." For example:
   - California Public Utility Commission (CPUC) President Daniel Fessler recently reported[2] that the CPUC assumed that oil prices would be $118 per barrel when they calculated avoided costs.
   - A Commissioner from the Maine PUC has reported that Central Maine Power Company's avoided cost calculations assumed oil would cost $100 per barrel.[3]

2. **High avoided costs led to high cost of power purchases, commitments to "renewables," and heavy subsidization of "demand-side" measures.** The high estimates of avoided costs were then used by PUCs and/or electric utilities as the basis for:
   - Prices in contracts that electricity that utilities:
     - Were required to sign with owners of "qualifying facilities" (QFs) pursuant to the Public Utility Regulatory Policy Act (PURPA), and
     - Agreed to sign with IPPs and other non-utility generators (NUGs).
   - Commitments that some utilities were required to make to invest in or buy power from generating facilities fuel by "renewable" energy.
   - Economic analyses that helped determine the level of subsidies that utilities would provide to encourage customers to avoid use of electricity or other forms of energy or to shift uses to periods of low demand.

3. **Over-investment in generating facilities.** Faulty forecasts of high energy prices and rapid growth in electricity demand also contributed to over-investment in generating facilities. For example:

   - Investments in nuclear generating plants that were justified in part by forecasts of high oil prices. No nuclear plants were ordered after 1973 and some ordered before 1973 were canceled. However, construction continued on some nuclear plants because owners assumed the plants would be an economical way of avoiding the use of oil that was forecast to cost $100 per barrel or more. Lower oil price forecasts probably would have led to cancellation of more nuclear plants -- with the result that utilities would be facing less "stranded costs" than they now face.

   - Investments in IPP-owned generating units and utilities' decisions to sign contracts with IPPs were often predicated on forecasts of rapid growth in electricity demand. The prices for power from IPPs were often based on high energy price estimates and decisions by IPPs to build, and financial institutions to finance projects were also based on expectations of high electricity demand and high fuel prices. In most cases, electric

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[2] Seminar on February 27, 1996 -- Johns Hopkins University's Strategic and International Studies (SAIS)

[3] NARUC Bulletin No. 49-1993, December 6, 1993, p.2.

utilities and their customers bear the high costs. However, in some cases (e.g., in California) the price that is paid for electricity will drop to market levels after the contracts have been in effect for 10 years. At that point the IPP owners and/or their creditors will bear the cost risk.

As electricity demand growth slowed and it became obvious that many proposed QF and IPP generating units would not be needed, some electric utilities have "bought their way out" of contracts -- resulting in rather high costs for customers in the short term but savings in the longer term.

4. **Long-term fuel contracts with prices above market levels.** Some electric utilities and non-utility generators have entered into long-term contracts for fuel (usually natural gas, coal, or oil) for their generating facilities. (Non-utility generators were often required to sign long-term fuel supply contracts in order to get financing for their facilities.) The price for fuel in these contracts was often based on high fuel price forecasts. These contracts also add extra, potentially stranded, costs.

5. **Magnitude of the extra costs now faced by electric industry customers, shareholders, and creditors, and, in some cases, by taxpayers.** Many estimates have been made of the magnitude of the high costs that are now being faced -- some of which may become "stranded costs." The exact amounts of these costs can only be estimated since they depend, in many cases, on the future market price for electricity. If the market price for electricity drops as most observers expect, "stranded" costs will increase. Examples of estimates of the extra costs and "stranded" costs now being faced include the following:

   - An official of Southern California Edison (SCE) reported in 1994[4] that SCE's customers had already incurred above market costs of **$2 billion** during the period from 1985 through 1993 and face an additional **$5.9 billion** in the years ahead (with annual costs peaking at **$900 million in 1996**). These extra costs were attributed to CPUC requirements that SCE enter into power purchase contracts with PURPA "qualifying facilities" and generators using renewable energy.

   - Cambridge Energy Associates estimated in March 1995 that California utilities face stranded costs in the range of $13 billion to $26 billion -- depending upon the market price of electricity in the years ahead.[5]

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[4] Presentation by L. D. Hamlin, Southern California Edison to a Conference on State Trends in Energy and the Environment, Santa Fe, New Mexico, June 14, 1994.

[5] Cambridge Energy Associates, Decision Brief, *Shedding Light on Stranded Costs* by Gary Simon and Aldyn Hoekstra, March 1995, pp. 2-3.

- Moody's Investor Service estimated in August 1995 that total stranded costs for U.S. investor owned utility companies at "$50 to $300 billion, depending upon on market price assumptions."[6]

6. **Who will pay?** As indicated by the above sources, the actions by state PUCs and electric utilities, *often based on faulty energy price forecasts*, have resulted in huge costs -- some of which may become "stranded costs" as the electric industry becomes more competitive. These extra costs will eventually:
   - Be paid by electric customers through their monthly bills;
   - Be borne by investors in electric utilities or IPPs in the form of write-downs if the costs can be recovered from customers; or
   - Be borne by creditors if the utilities and/or IPPs become bankrupt.

   In some cases, some of the costs may be shifted to *taxpayers*. This will occur if:
   - Electric utilities are permitted to accelerate the depreciation of their assets, thus reducing their tax payments to federal, state and local governments;
   - Lower profits, losses, or bankruptcies result in reduced corporate income tax payments to federal or state governments; or
   - Tax-paying utilities' assets are sold off to entities that can finance the purchases with tax-exempt bonds. This approach is contemplated in the proposed sale of certain assets of the Long Island Lighting Company to the Long Island Power Authority (LIPA).

B. Natural Gas Industry

Decisions based on high estimates of energy prices and demand have also added extra costs for natural gas industry customers, shareholders, and creditors, and for taxpayers. The causes and the effects are somewhat less complex in the gas industry than in the electric industry. Examples of extra costs in the gas industry include:

1. **High cost gas purchase contracts signed by gas pipelines.** Many gas pipeline companies signed "take or pay" contracts for natural gas supplies during the late 1970s and early 1980s based on forecasts that gas supplies were running out and the prices would increase rapidly. However, market prices for natural gas at the wellhead decreased in the early 1980s (particularly after the ill-effects of the Natural Gas Policy Act of 1978 had passed). This left pipelines with large commitments for gas at prices well above market-clearing levels.

2. **Existing and potential excess pipeline capacity.** Changes in regulation, including open access to interstate pipelines (FERC Order 436) and unbundling of pipeline services (FERC Order 636), has resulted in major changes in the natural gas industry. Slower than forecasted increases in natural gas demand in California has resulted in excess pipeline capacity in the West. Further, as local gas distributing companies (LDCs) across the nation

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[6] Moody's Investors Service, ***Stranded Costs will Threaten Credit Quality of U.S. Electrics***, by Paul Fremont and Robijn Hornstra, August 1995, p.1.

give up firm capacity commitments that they no longer need under the new market structure (when contracts expire), interstate pipelines in other regions may be faced with excess capacity. Such developments may lead to further financial strains in the industry and to costs that will have to be borne by consumers, shareholders, creditors, or taxpayers.

C. Investments in Oil and Gas Exploration

During the late 1970s and early 1980s, hundreds of millions of dollars were invested in oil and gas exploration based on forecasts that oil and gas prices would increase rapidly. Many of these investments have had to be written off at tremendous cost to investors.

D. Bank Failures Resulting from Non-performing Loans to Energy Companies

During the 1980s, many commercial banks and savings and loan (S&Ls) institutions experienced non-performing loans to oil and gas exploration companies and other energy firms that had made investments based on forecasts of high oil and gas prices. In some cases, the costs of non-performing loans were borne by owners and shareholders of the banks and S&Ls. In other cases, the costs have been borne by taxpayers who have paid the costs of the S&L bailouts.

E. Government Spending for Energy Research, Development, Demonstration and Commercialization Projects

Federal agencies (Atomic Energy Commission, Energy Research and Development Administration, Federal Energy Administration, U.S. Synthetic Fuels Corporation, and Department of Energy) have spent some $100 billion tax dollars on energy supply and conservation technologies since 1955 -- with the vast majority spent since 1975. Many of the projects that were subsidized were "justified" on the basis of high energy price and energy demand forecasts that have proven to be faulty. A large share of this money has been wasted because the projects proved to be technically infeasible or impractical, or to have no realistic chance of producing or conserving energy competitively in the marketplace. In short, much of the money was wasted. The projects on which the large dollars were wasted included the proposed Liquid Metal Fast Breeder Reactor (LMFBR), oil shale projects, synthetic fuels form coal projects (including SRC-1 and SRC-2, the "solvent refined coal" projects; and the Great Plains Gasification Project).

F. Overbuilding of Nuclear Generating Plants by TVA and in the Pacific Northwest

High forecasts of electricity demand contributed to the overbuilding of nuclear generating capacity by the Tennessee Valley Authority (TVA) and in the Pacific Northwest:

- According to the GAO, "TVA is $26 billion in debt and has invested $14 billion in nonproducing nuclear assets..."[7]

- Commitments to build nuclear generating plants in the Pacific Northwest that were not needed led to the largest municipal bond default in U.S. history.

Apparently only the interest expense for TVA's $14 billion in nonproducing nuclear assets is being passed through to TVA's customers. Eventually, of course, someone will have to stand the cost of the $14 billion principal.

GAO has concluded that TVA's financial condition puts it at a competitive disadvantage for the future when the electric industry will be more competitive.

G. Bonneville Power Administration's Contract to Purchase Power from an IPP

DOE's Inspector General has concluded that Bonneville Power Administration erred in *using high gas price forecasts* when deciding to sign a contract to purchase power from a privately owned gas-fired electric generating plant.[8] This contract has far reaching implications for Bonneville's customers and, potentially, for U.S. taxpayers. BPA's attempt to withdraw from the arrangement apparently is being challenged by the plant developer in a $1+ billion lawsuit.

H. Overestimating the value of Leases and Lease Revenues

The Department of the Interior's Minerals Management Service (MMS) estimates the value of blocks of public lands that are offered for lease. Also, for federal budget purposes, MMS must develop estimates of the revenue that will be received from lease bonus payments and royalties received by the Federal Government. All these estimates depend to some extent on future energy price expectations, but information on the price forecasts used by MMS is not readily available.

During the balanced budget discussions of 1995, it became clear that MMS estimates of the potential value of leasing of ANWR was based on outdated fuel price forecasts. Whether MMS has developed new estimates is unknown.

MMS' over-estimate of the value of one lease block in the Western Gulf of Mexico (Brazos A-52) led to a loss of approximately $11 million during the 1980s. The instance involved a bid of approximately $26 million by an oil and gas exploration company for the lease. MMS turned down the bid as inadequate. The following year, the same company submitted a lower bid and it was again turned down. In the third year, the same company bid approximately $15 million for the same lease block. The bid was then accepted. Apparently, MMS had overvalued the

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[7] General Accounting Office, *Tennessee Valley Authority - Financial Problems Raise Questions About Long-Term Viability*, August 1995, p. 3.

[8] Office of Inspector General, U.S. Department of Energy, Audit of Bonneville Power Administration's Energy Resource Programs, DOE/IG-0379, September 1995.

lease initially largely because it was using a high forecast of natural gas prices. As natural gas prices continued their downward trend, MMS apparently realized that it had overestimated the value of the lease. Meanwhile, the U.S. Treasury received some $11 million less in lease bonus revenue than it would have received had a more realistic natural gas price forecast been used and the initial bid been accepted.

I. **Biased Analyses Based on High Price Forecasts**

In addition to the above cases where high price forecasts have resulted in demonstrable costs to consumers, taxpayers, and investors, there are other instances where the use of energy price forecasts raises important public policy issues. Instances such as the following should not be overlooked as the Congress considers problems caused by faulty forecasts.

1. **DOE's biased analysis of the costs and benefits of alternatives for the future of the Naval Petroleum Reserves (NPRs).** In April 1994, DOE prepared an unusually biased analysis of the value of the NPRs using questionable price forecast data and even more suspect analytical procedures.[9] DOE's gas price assumption for 1995 was some 30% above the actual U.S. average and even further above prices in California where most of the NPR's gas reserves are located. The highly suspect analytical technique involved the use of one set of price forecasts to analyze two of three alternatives for the future handling of the NPRs. DOE then used higher price assumptions when evaluating a third alternative. Apparently the third alternative -- creation of a government corporation to take over the NPRs -- was the alternative favored by those preparing the report. It is quite amazing that the DOE leadership would allow such an biased analysis to be issued.

2. **Federal agency estimates of savings from potential Federal Energy Management Program (FEMP) projects.** DOE issued a price forecast in November 1995 [10] that Federal agencies and certain private sector organizations apparently are required to use during the next year to evaluate FEMP projects. The forecast was rendered obsolete by EIA's energy price forecast issued in January -- two months after the DOE/Commerce forecast.

3. **Questionable claim of "energy cost savings" by a lobbying organization.** A November 1995 report by American Council for an Energy Efficient Economy includes a claim that "appliance standards already adopted will save consumers $132 billion (i.e., energy cost savings minus the increased first cost) over the lifetime of products purchased by 2030."[11]

   Any estimate of "energy savings" during such a long period of time (some 40 to 55 years, including the life of the appliances) is unlikely to be valid. Information in the report suggest

[9] U.S. Department of Energy, Organizational Alternatives for the Naval Petroleum and Oil Shale Reserves, April 1994.

[10] *Energy Price Indices and Discount Factars for Life-Cycle Cost Analysis 1996*, NISTIR 85-3273-10 (1095), prepared by the U.S. Department of Commerce for U.S. DOE, Federal Energy Management Program.

[11] American Council for an Energy Efficient Economy, *Natianal Appliance Efficiency Standards: Cost-Effective Federal Regulations*, November 1995, p. 6.

that the estimate was based on energy price expectations that are at least three years old. The $132 billion energy cost savings estimate undoubtedly would be much lower if it were based on EIA's latest, sharply reduced energy price forecast. The estimate would be even lower if EIA had reflected in its forecast that reductions in electric rates that are almost certain to occur as the electric industry becomes more competitive.

These three examples illustrate the need for the Congress to be very wary of analyses, claims and justifications presented by the DOE/Contractor Complex.

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Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions

- 1996 Edition -

During the past 16 years, most energy price forecasts have substantially overestimated future energy prices. Decisions based on these high price forecasts have often turned out to be uneconomic, and have cost consumers, taxpayers, and shareholders billions of dollars.

Many business leaders, regulators and other state and federal government officials are continuing to use energy price forecasts as a basis for their decisions without questioning the forecasts and without taking precautions to protect against forecasts that may be faulty. Some may not understand the role that price forecasts are playing in their decisions.

Important and costly decisions that *have been and still are being* based on forecasts of future energy prices include investments by the private sector in facilities to produce, transport and use energy; estimates by utility executives and regulators of utilities' "avoided costs" and long-term marginal costs, and calculations of the value of potential "stranded investments"; calculations of savings expected from investments in energy efficiency and conservation; calculations of the economic costs of alternative energy sources for new facilities; and federal government officials' decisions to spend tax dollars for energy research and development, and their estimates of the value of and revenue from mineral leases on federal lands.

The history of faulty price forecasts and recent significant (30+%) downward adjustments in forecasts for some energy prices indicate that *decisions made on the basis of older price forecasts need to be reconsidered, and precautions should be taken to minimize the potential that even the newer, lower forecasts will turn out to be invalid.*

An Information Paper for Clients and Colleagues

by

Glenn R. Schleede

February 1, 1996

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Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions
- 1996 Edition -

Preface to 1996 Edition

The first edition of the paper with the above title was published on February 20, 1995. It proved to be very popular. Hundreds of copies have circulated in the United States and Canada and I have also responded to several requests from Western Europe.

In January 1996, EIA substantially reduced its forecasts for wellhead natural gas prices (e.g., year 2010 prices by 38% from its January 1995 forecast). During the past year, other commercial suppliers of energy forecasts have also reduced forecasts for natural gas prices and for other energy sources. These downward adjustments led to two questions:

1. Now that forecasters have made progress in recognizing substantial changes in U.S. and world energy markets, should one be comfortable with the newer forecasts? A review of some of the forecasts suggests the answer to this question is clearly "No." There are many reasons to continue to be concerned about the validity of energy price forecasts.

2. Do those decision makers who have relied on past forecasts need to do anything now that forecasts have been revised downward? The answer to this question is clearly "Yes." In fact, decisions made on the basis of past forecasts are likely to turn out much differently than expected. Failure to reconsider such decisions could easily lead to even more unnecessary costs for consumers, taxpayers, and investors.

These two considerations led to me to conclude that the February 20, 1995 paper should be updated and published as the "1996 Edition."

As always, comments on the paper are welcome.

GRS

Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions
- 1996 Edition -

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Energy Price Forecasts are Leading Business Executives, Regulators, and Other Government Officials to Make Uneconomic Decisions

- February 1996 Edition -

Executive Summary

During the past 16 years, most energy price forecasters have substantially overestimated future energy prices. Decisions based on these high price forecasts have often turned out to be uneconomic. These uneconomic decisions have cost consumers, taxpayers, and shareholders billions of dollars.

Despite this history, many business leaders, regulators and other state and federal government officials are continuing to use energy price forecasts as a basis for their decisions without questioning the forecasts and without taking precautions to protect against forecasts that may be faulty. Some may not understand the role that price forecasts are playing in their decisions.

Among the important and costly decisions that *have been and still are being* based on forecasts of future energy prices are the following:

- Investments by the private sector in facilities to produce, transport and use energy;
- Estimates by utility executives and regulators of utilities' "avoided costs" and long-term marginal costs, and calculations of the value of potential "stranded investments";
- Calculations of savings expected from investments in energy efficiency and conservation;
- Federal energy efficiency standards for appliances and other products;
- Calculations of the economic costs of alternative energy sources for new facilities; and
- Federal government officials' decisions to spend tax dollars for energy research and development, and their estimates of the value of and revenue from mineral leases on federal lands.

During the past 18 months, many energy forecasters have lowered significantly their estimates of future energy prices. For example, in January 1966, the U.S. Energy Information Administration (EIA) lowered its estimate of year 2010 wellhead natural gas prices by 38% from one year earlier and 62% from 5 years ago. EIA's latest forecast for crude oil prices for 2010 are down by 4% from one year ago and 38% from 5 years ago.

EIA's downward revisions are a welcome, if belated, recognition of changes that have occurred in U.S. and world energy markets. However, there are strong reasons to question whether the recent lower price forecasts are low enough. EIA and many other forecasters are still projecting significant price increases, particularly after the year 2000 -- even though real prices have been trending downward since the early 1980s and strong intra and inter-fuel competition prevails.

The history of faulty price forecasts and recent significant downward adjustments in price forecasts provide two strong messages to decision makers:

- Analyses and decisions based on older price forecasts are out of date and should be reconsidered.

- Precautions should be taken to minimize the potential that even the newer, lower forecasts underlying their decisions will turn out to be invalid.

Purpose and Content of this Paper

Since the energy shocks of the 1970s, energy price forecasts that have proven to be invalid have been a major factor in decisions that turned out to be uneconomic. These decisions have been very costly for consumers, taxpayers, and shareholders. Some have caused severe financial strain and bankruptcies.

Recent evidence suggests that some decision makers are continuing to rely on forecasts, perhaps unwittingly, in ways that could lead to more uneconomic and costly investment decisions, and to unwise public policies.

This paper has been prepared as a warning to unwary business executives, regulators, and other government officials:

- To be very careful about their use of energy price forecasts, and to suggest steps that should be taken by decision makers. Somebody's energy price expectations underlie most economic analyses of long-term energy investments, contracts, and other commitments. Decision makers should know whose forecast is being used and how the forecast was developed. They should understand the impact of the forecast on the economic analyses they are using as the basis for decisions. They should also be prepared to accept the consequences if the forecast turns out to be invalid.

- To be aware that government and commercially available forecasts of energy prices have been revised downward substantially in recent months, making it necessary to reconsider decisions based on previous forecasts.

The remainder of this paper deals with the following topics:

- The pervasive but often hidden role of energy price forecasts in business, regulatory, and public policy decisions.
- The uneconomic decisions, based on past energy forecasts, that have cost consumers, taxpayers, and shareholders billions of dollars.
- The significant decline in prices in recent forecasts compared to one, two, or five years ago.
- The contrast between a decade long decline in real energy prices and the continuing tendency of some forecasters to predict that prices will increase.
- The significant but unrecognized implications for investment, contract and public policy decisions of the downward trend in real prices and forecasts and the need to reevaluate past decisions.
- The indications that some business executives, regulators, and other government officials are basing decisions on questionable energy price forecasts.
- The steps that can be taken to reduce exposure to questionable forecasts.

A. Energy price forecasts play a pervasive but often hidden role in business, regulatory, and public policy decisions.

Many business executives, regulators and other government officials seem to be aware only generally that past forecasts of high energy demand and prices turned out to be wildly inaccurate, and that forecasts of energy supply that would be available at moderate prices turned out to be too low. *Some are aware that these forecasts led to some very costly decisions for consumers, taxpayers and shareholders.*

The realization that past forecasts proved to be incorrect has led to some, but apparently not enough, healthy skepticism about energy forecasts. Many people are continuing to use questionable forecasts, perhaps without even knowing they are doing it.

It is not unusual to hear a high level executive, regulator, or government official to say, "I don't believe any of those damn energy forecasts." The same person may then sit down and look at an economic analysis that shows a net present value (NPV) or internal rate of return (IRR) for an important energy decision *without realizing that somebody's forecast of future energy prices underlies the estimates he or she is relying upon.*

B. Uneconomic decisions costing consumers, taxpayers, and shareholders billions of dollars have been based on past energy price forecasts.

Almost everyone that is heavily involved in energy matters now recognizes that thousands of energy decisions made during the past 16 years turned out to be uneconomic because they were based on assumptions and forecasts that energy prices -- particularly oil prices -- would increase rapidly. For example, Commissioner Welch of the Maine Public Utility Commission is reported to have told the 1993 Annual Convention of the National Association of Public Utility Commissioners (NARUC)that:

> "Much of the high cost of power in Maine is attributable to the price impact of QF contracts signed in the mid-1980's committing Maine utilities to large purchases based upon avoided cost calculations assuming, in hindsight, an incredibly bad forecast price for oil of $100/ barrel by the end of 1990's."[1]

Utility executives and regulatory commissioners in Maine were not the only people who relied upon energy market forecasts that proved to be faulty. For example:

- Oil and gas producers invested large amounts of money in exploration and development based on high price forecasts.

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[1] *NARUC Bulletin* No. 49-1993, December 6, 1993, p. 2.

- Gas pipeline companies signed contracts for the purchase of natural gas at high prices based on high gas and oil price forecasts.

- Electric utilities invested in large base-load nuclear and coal-fired power plants and signed long-term coal contracts (some with built-in price escalators) based on high forecasts for electricity demand and for oil prices.

- Federal officials proposed and Congress passed laws that prohibited building of new gas-fired powerplants and industrial facilities and restricted the use of natural gas in existing facilities, based on assumptions that the U.S. was running out of natural gas. The U.S. Synthetic Fuels Corporation provided funding for research and development (R&D) projects, and provided price guarantees for oil shale and coal gasification projects, based on assumptions or forecasts that energy demand and prices would increase significantly.

- Banks, retirement fund managers, insurance companies, and other financial institutions provided loans for investments in energy production, transportation, and utilization facilities that proved to be uneconomic. Some contributed to costly savings and loan bank failures.

- The U.S. Department of Energy spends large amounts of tax dollars and the U.S. government has provided large tax subsidies on technologies that are not economic.

The costs of uneconomic decisions such as these are still being borne by those who ultimately pay the bills: customers, taxpayers, and shareholders. Other costs lie ahead. For example:

- Investments in oil and gas exploration that proved to be uneconomic are reflected either in higher costs for products, lower return for investors, or both.

- Overestimates of electric utilities' avoided costs (due to high oil price forecasts) led to above market costs for electricity purchased from non-utility generators (NUGs). These costs are being paid by electric customers, or they are a part of the investments that utilities believe may be "stranded" as the electric industry becomes increasingly competitive.

- Costs of government contracts, grants, loans, loan guarantees, and price guarantees for energy research, development and demonstration projects based on high energy price forecasts are being borne by taxpayers.

C. Real energy prices have come down and newer forecasts have been lowered substantially, but forecasters continue to project price increases.

During the past 16 years, energy markets have behaved quite differently from the way forecasters predicted. Newer forecasts have begun to reflect the changes and lowered their estimates of future energy prices, but there are strong reasons to question whether even the new, lower forecasts are low enough.

1. **Downward trend in real energy prices.** Most real energy prices (i.e., prices adjusted for inflation) in the U.S. have trended downward. Attachment #1 shows prices in constant 1994$ for various energy products based on data from EIA's *Monthly Energy Review,* which provides information back to 1973 for some products and to 1978 for others. Examples of downward trends include the following (all data in 1994$):

   a. Crude oil prices averaged $15.51 per barrel in 1994, compared to a high (in 1994$) of $59.59 in 1980. The trend is moving closer to the 1973 $12.46 price that had not reflected the full impact of the increases that occurred in 1973-74 and 1979-80.

   b. Natural gas wellhead prices were $1.88 per thousand cubic feet (Mcf) in 1994 (a year of relatively high prices in recent years), down from a high of $3.75 in 1983. (Prices were lower in the 1970's but these comparisons to earlier years are not meaningful since prices were held to artificially low levels by federal wellhead price regulation.)

   c. Retail gasoline prices, *including taxes* were $1.17 per gallon in 1994, compared to a high of $2.16 in 1981.

   d. Refinery wholesale prices for gasoline for resale, excluding taxes, were $.60 per gallon in 1994, compared to a high of $1.70 in 1981. Gasoline prices in 1994, excluding taxes, appears to be an all-time low.

   e. Residential heating oil prices averaged $.88 per gallon in 1994, down from a high of $1.91 in 1981.

   f. Residential natural gas prices were $6.41 per million Btus (MMBtu) in 1994, down from a high of $8.77 in 1983.

   g. Residential electricity prices averaged $.084 per kilowatthour in 1994, down from a high of $.104 in 1982-1985.

   Based on 10 months of 1995 data now available, average oil prices are likely to be slightly higher than 1994 and natural gas and electricity prices lower in 1995 than in 1994.

2. **Latest energy price forecasts are substantially lower than prior years.**

   a. **EIA's *Annual Energy Outlook 1996.*** The new *Annual Energy Outlook* issued in January 1996 finally brings EIA's price forecasts down *substantially* from prior years, particularly for natural gas. While late, this is a promising step toward recognizing the changes that have occurred in U.S. and world energy markets during the past decade.

Attachment #2 is a table showing *in 1994$* the prices EIA has forecast for crude oil and natural gas wellhead prices over the past 10 years for the years 1995, 2000, 2005, and 2010. As the table shows:

- EIA's latest forecast of $23.70 per barrel for *crude oil* in 2010 is:
  - 3.7% below its $24.62 forecast issued *one* year ago (January 1995).
  - 24.5% below its $31.41 forecast issued *three* years ago (January 1993).
  - 44.7% below its $42.87 forecast issued *six* years ago (January 1990).

- EIA's latest forecast of $2.15 per thousand cubic feet of natural gas at the wellhead in 2010 is:
  - 37.9% below its forecast of $3.3.46 issued *one* year ago (January 1995).
  - 45.6% below its forecast of $3.95 issued *three* years ago (January 1993).
  - 67.1% below its forecast of $6.54 issued *six* years ago (January 1990).

Tables similar to those in Attachment #2 could be constructed for other energy projects -- with similar results.

b. Forecasts by other organizations.

The Gas Research Institute (GRI) released preliminary information in August 1995 on its 1996 baseline forecast. The prices shown in this forecast compare as follows with those in GRI's 1994 baseline forecast released in August 1994 (all numbers in 1994$):

	2000	2010
• Crude oil price assumption - per barrel		
• 1995 baseline forecast	$18.52	$20.46
• 1996 baseline forecast	$16.17	$16.17
• Natural gas acquisition (lower-48) - per million Btus		
• 1995 baseline forecast	$2.44	$2.60
• 1996 baseline forecast	$2.37	$2.28[2]

GRI latest forecast indicates that it expects oil prices to remain flat in real dollars.

EIA's *Annual Energy Outlook* (AEO) provides comparisons with certain commercially available energy price forecasts, typically those issued by Data Resources Incorporated

[2] This would be $2.27 per Mcf, compared to $2.15 per Mcf forecast in EIA's *Annual Energy Outlook 1996.*

(DRI) and the WEFA Group. AEO95[3] and AEO96[4] show the following DRI and WEFA forecasts for world crude oil prices (all shown in 1994$):

	2000	2010
• DRI - Spring Summer 1994	$25.17	$28.64
• DRI - October 1995	$16.54	$21.99
• WEFA - 3rd Quarter 1994	$20.78	$21.80
• WEFA - 3rd Quarter 1995	$19.55	$20.88

In its 1995 forecast shown above, DRI has reduced substantially its forecasts for 2000 and 2010. WEFA had already lowered its forecasts by the 3rd Quarter of 1994. In their forecasts released in 1995, DRI, WEFA and GRI are forecasting oil prices for 2000 and 2010 lower than EIA's forecast released in January 1996.

3. **Despite real price trends and substantial lowering of its new forecasts, EIA is still projecting that prices will increase significantly in the future.**

While real energy prices have declined and many forecasters have lowered forecasts, some forecasts continue to predict substantial price increases. These expected increases deserve careful consideration by anyone using the forecasts.[5]

EIA's AEO95 Reference Case[6] forecasts show the following *annual rates of increase* in real energy prices during the period from 1994 to 2015:[7]

• World oil prices	2.4%
• Natural gas wellhead prices	1.5%
• Coal mine mouth prices	-0.5%
• Residual oil delivered to electric generators	2.1%
• Natural gas delivered to electric generators	1.4%
• Coal delivered to electric generators	-0.3%

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[3] EIA *Annual Energy Outlook 1995*, Table 3, p.7 and p. 66.

[4] EIA, *Annual Energy Outlook 1996*, Table 3, p.8 and p. 63.

[5] There are a variety of potential explanations for projected increases. One that deserves attention -- the possibility that publicly available energy price forecasts have a systematic upward bias -- is addressed later in this paper.

[6] EIA, *Annual Energy Outlook 1995*, Tables A1 and A3, p. 73 and p. 76.

[7] The rates vary widely from year to year during the period.

These rates of increase may seem small, particularly when compared with past increases. Nevertheless, they are significant, particularly when compounded over a 16 or 21 year period. Also, the significant differences in projected rates of increase in prices of fuels delivered to electric utilities raise questions about the internal inconsistency of forecasts and whether market forces (intra-fuel and interfuel competition) will permit such price differentials. Forecasted increases such as these need to be evaluated carefully by decision makers.

D. Downward adjustments in forecasts make it necessary to reconsider investment, contract, and public policy decisions.

The large downward adjustments in energy price expectations shown in forecasts during the past year, including EIA's 38% downward adjustment in 2010 natural gas wellhead prices, have significant economic implications for decisions on energy related investments, contracts, regulatory decisions, government spending programs, and public policies. It is less than clear that decision makers have recognized that forecasts have been changed or that they are being taken into account by business executives, regulators, or other government officials. For example lower future price expectations will mean that:

- Energy production investments will provide less revenue than expected.
- Input energy costs for facilities that use energy (e.g., electric generating plants) will be lower than expected.
- Savings expected from energy conservation and energy efficiency projects and government energy efficiency standards will be less than expected.
- Newer technologies dependent on energy sources other than fossil fuels (e.g., renewables) have tougher economic standards to meet.

Among the more specific decisions that are likely to be affected by lower energy price forecasts are the following:

1. Decisions made by individuals and organizations in the private sector concerning investments and long-term contracts involving energy production, transportation and use.

2. State public utility commissions (PUCs) and other regulators' decisions that are affected by energy price expectations, such as estimates of gas and electric utilities' future marginal costs and avoided costs, costs and benefits of energy efficiency and conservation programs, costs of renewable energy sources, the prudence of capital investments and fuel procurement activities, and estimates of "stranded investments."

3. Decisions and estimates made by federal government officials relating to revenue expectations and justification for proposed spending programs, including:

a. Estimates of savings associated with proposed energy efficiency standards (e.g., appliances, equipment, motor vehicles).

b. Estimates of the costs and benefits of proposed energy efficiency and conservation projects covered by the Federal Energy Management Program (FEMP).

c. Estimates of the value of oil, gas, and coal leases on federal lands, and the revenue that may be received from lease sales and royalties.

d. Estimates of the benefits and costs associated with various proposed energy research, development, and demonstration activities.

e. Estimates of the benefits and costs associated with various environmental requirements affecting energy production, transportation and use.

f. Estimates of the potential revenue from energy taxes, and the effects on the economy of proposed energy taxes and energy tax incentives.

E. **Recent evidence indicates executives, regulators and other government officials are basing decisions on questionable forecasts.**

Two recent pieces of evidence suggest that some decision makers may not yet be aware of the recent downward trends in real energy prices and energy price expectations, or that they have other reasons for using energy price forecasts that are questionable at best.

1. **Bonneville Power Administration.** DOE's Inspector General (IG) has concluded that DOE's Bonneville Power Administration (BPA) erred when, in 1994, it assumed rapid increases in natural gas prices when signing a $2.2 billion contract to purchase electricity from a privately owned gas-fired generating plant.[8] This contract has far reaching implications for Bonneville's customers and, potentially, for U.S. taxpayers. The IG concluded that BPA would be paying more for the electricity than it could recover from its sale. BPA's attempt to withdraw from the contract apparently is being challenged in a $1 + billion lawsuit.

2. **Recent U.S. DOE/Department of Commerce energy price forecast.** In November 1995, DOE issued a document entitled, "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis 1996," that was prepared for DOE by the Department of Commerce. Apparently, federal government agencies and some private sector entities are *required* to

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[8] Office of Inspector General, U.S. Department of Energy, *Audit of Bonneville Power Administration's Energy Resource Programs*, DOE/IG-0379, September 1995.

use the numbers in this document during the next year in economic analyses of potential energy efficiency and conservation projects under the Federal Energy Management Program (FEMP). Unfortunately, the numbers in the document are based on old EIA data which have been rendered obsolete by EIA's January 1996 forecasts, particularly for natural gas.

As indicated earlier, the use of high energy price forecasts *overstates* savings that can be achieved from energy efficiency and conservation measures.

3. **Analysis done for the U.S. Department of Energy.** An August 1994 analysis for DOE of integrated resource plans (IRPs) prepared by 27 U.S. electric utilities during the period from 1991 through 1993 revealed that a very wide range of price expectations were used in preparing integrated resource plans, particularly in the case of natural gas prices.[9] The report indicated that: "The range went from a low of 2% [per year increase] in real terms (or perhaps 5% in nominal terms assuming 3% inflation) to a high of 12% in nominal terms (or perhaps 9% in real terms). The potential impact of these projections is profound. If gas prices are projected to increase at 2%, gas is more likely to be chosen as the fuel for new capacity or repowering...On the other hand, gas is unlikely to be selected for any purpose if prices are projected to rise at 12% annually."

   Apart from the choice of fuel for power generation, such price expectations could be having a very significant impact on electric utilities calculations of savings that could be expected from energy efficiency and conservation measures. The study did not attempt to determine the rationale or the motivation of the utilities for using such high and widely varying price expectations, or whether forecasts were questioned by PUCs or intervenors.

F. **Several facts and concerns about energy price forecasts deserve attention.**

There are a variety of facts and concerns about energy price forecasts that should be noted by people who use such forecasts as a basis for their economic analyses and decisions. Several are discussed below.

1. **What organizations are now making energy market forecasts?** Energy demand, supply, and price forecasts are made by a variety of government and private organizations. Several have already been identified in the preceding pages. To summarize:

   a. EIA annually publishes a *long-term forecast* of U.S. energy demand, supply and prices. EIA also publishes quarterly a short-term forecast.

   b. The National Institute of Science and Technology (NIST), a part of the U.S. Department of Commerce, prepares (for DOE) price forecasts (allegedly based on

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[9] The EOP Foundation, *A Report to the U.S. Department of Energy on the Role of Integrated Resource Plans (IRPs) in a Rapidly Changing Electric Industry,* August 23, 1994, Grant Number DEFG4493R410608, pp. 37-38, 42, D-17.

information from EIA) that Federal agencies are required to use in analyzing the costs and benefits of projects to conserve energy or use it more efficiently.

c. Many organizations in energy industries (oil and gas companies, electric and gas utilities, etc.) develop their own forecasts for use in their analysis of their investment, production, and marketing decisions. Except for regulated companies, these forecasts generally are confidential and are seldom made public.

d. Commercial forecasting and consulting organizations, such as Data Resources Incorporated (DRI), WEFA, Petroleum Industry Research Associates (PIRA), and National Economic Research Associates (NERA) are in the business of providing energy market forecasts for their clients.

e. Research and trade associations, such as the Gas Research Institute (GRI), and the American Gas Association (AGA) develop energy market forecasts primarily for their members. Their forecasts are often made available to others upon request.

f. A variety of other economic analysis and consulting organizations develop forecasts for their clients.

g. Other organizations within DOE and other federal government organizations (or contractors on their behalf) make forecasts that are different from those developed by EIA.

2. **Have all past energy market forecasts turned out to be wrong?**

During the past 16 years, very few publicly available energy price forecasts have been accurate. Most have overestimated energy demand and prices, and underestimated supplies.[10] Confidential forecasts developed by organizations in the energy industries for their own use may have been more accurate than forecasts issued by government and commercial forecasting organizations.

As indicated earlier, most government and widely used commercial forecasts have predicted and continue to predict increasing energy prices while real energy prices have trended downward. As demonstrated in Attachment 1, most energy prices have declined in real terms (i.e., when adjusted for inflation) during the past 20 years.

3. **Is it possible to develop an accurate energy price forecast?** No one knows for sure what future energy markets will bring. For example, no one predicted accurately the sharp increases in oil prices that occurred in 1973-74 and 1979-1980, or the sharp drops that

[10] Some energy analysts and consultants have argued that energy prices are likely to remain generally flat or decline from early 1990 levels over the long term.

occurred in 1986. Despite the inadequacy of foresight, projections of energy prices must be made and used in analyses of the economics of any long-term investments, commitments, government spending programs, or other public energy policies.

Forecasts are exceedingly difficult to make during periods of price volatility. Also, historical periods that included controls on prices (such as oil and natural gas) add confusion. More reliable forecasts may be somewhat easier to develop now that prices have become more stable than in the 1970s and early 1980s, and since prices for primary energy sources are no longer regulated by the federal government. However, none are likely to predict short-term volatility accurately.

It does appear to be the case that forecasting organizations that have close and direct contact with people participating in energy markets and that focus heavily on market fundamentals are the most successful with their forecasting activities.

In addition, there may be other factors at work which affect energy price forecasts. These are discussed below in connection with the question of whether there are systematic upward biases in energy price forecasts.

4. **The Danger of "Consensus" Forecasts.** Some energy market forecasters and users of forecasts place considerable weight on the fact that two or more of the government and publicly available commercial forecasts tend to show similar forecasts. As illustrated earlier, EIA typically includes in its *Annual Energy Outlook* a comparison of its forecasts with those made by certain other organizations. Actually, it is unwise to derive comfort from fact that several forecasts are roughly similar because:

   - Many forecasters use very similar assumptions (including underlying economic assumptions), computer models, and procedures, with the result that outputs are unlikely to differ, and

   - Many of the so-called "consensus" forecasts, like EIA, have consistently overestimated energy prices.

5. **Is there a systematic upward bias in energy price forecasts?** The poor track record of most energy forecasters and the high cost to the nation of uneconomic decisions based on those forecasts quite naturally raises the question of whether there is a systematic upward bias that has affected energy price forecasts during the past 16 years. Attachment 3 explores this issue in some detail and concludes that:

   - There are many reasons to suspect that there is a systematic upward bias that is directly related to the interests of the forecasting organizations, and

- That there does not appear to be compensating downward pressure that would offset the upward bias.

G. How can decision makers protect themselves from making more uneconomic decisions because energy price forecasts may turn out to be inaccurate?

Clearly, there are no sure ways to prevent uneconomic decisions. Decision makers will have to accept the fact that foresight is limited. However, there are steps that can be taken that will give the decision maker a more firm basis for making decisions. In brief, they are:

1. Recognize that any analysis of the economics of a long-term investment decision, contract commitment, regulatory decision, or public policy that will be affected by future energy prices *includes somebody's forecast of future energy prices.*

2. Evaluate the forecasting organization and the way its forecasts are developed, including:

    a. Who made the forecast. Keep in mind that wide usage of forecasts from a particular organization may not be an important consideration.

    b. The track record of the forecasting organization during the past 10 years. Require the forecaster to present tables like those in Attachment #2 so that you can evaluate the forecaster's track record. The tables should include a comparison of forecast prices and actual prices like those in Attachment #2.

    c. What the assumptions are that drive the forecast (including, but not limited to assumptions about economic growth, disposable income, U.S. industrial mix, energy demand, energy supply, energy efficiency improvements).

    d. What internal relationships (e.g., relationships between crude oil prices and other energy prices) have been fixed ("hard-wired") in the model.

3. Recognize that the outputs from forecasting models are largely dictated by the input assumptions and "hard-wired" relationships in the model.

4. Learn as much as possible about the *fundamentals* of the energy markets that are important to the decision.

5. Resist temptations to base decisions on "forecasts" of future energy markets showing up in newspapers and magazines. Such "forecasts" often are superficial, based on the views of a very few people who may or may not be knowledgeable about energy markets, and often have a purpose other than supplying the best available estimates to someone making an important decision. For example, such forecasts may be the work of someone trying to get

attention for a particular proposal or, even, to get someone to make an investment or other decision that is beneficial to the "forecaster" or the forecaster's organization.

6. Insist that you be presented analysis from more than one organization and that the forecasts reflect different views of potential energy markets. Using several forecasts that reflect the current "consensus" view adds nothing significant that one forecast from the group doesn't provide.

7. Insist that you be presented economic analyses based on:

   a. At least three future energy price paths (in effect a "high," "mid," and "low"). The mix should include a forecast that holds energy prices level in real terms and a forecast that shows energy prices continuing to decline in real terms.

   b. *Different price trajectories for different energy sources.* For example, if a decision is being made among alternative energy sources (e.g., coal, oil, and natural gas), the *differences* between energy price paths will often be more important than the price trajectories themselves.

8. Be sure that alternative decisions are tested against various price paths and different trajectories. An alternative that comes out well against all price paths and price trajectories will be rare. Proposed decisions that don't come out well against some of the paths and trajectories should be considered very carefully before going ahead.

9. Watch out for the bias, conscious or unconscious, of the organizations or person(s) proposing the decisions, doing the economic analysis, or preparing the forecast on which the economic analysis is based. It is often easy to bias the results of a price forecast or an economic analysis to support a preferred conclusion.

10. Recognize that, in the final analysis, virtually all long-term commitments involve risk. The decision-maker cannot know in advance that the "right" forecast has been used or that the right decision has been made if that decision depends on a long term energy price forecast.

11. Consider whether there are ways of hedging against risks and whether the costs of hedging are reasonable.

Attachment 1

Average Annual Energy Prices in Constant 1994$

1973 to 1995

1/30/96

Year	Crude Oil* $ per Bbl.	Natural Gas Wellhead** $ per Mcf	Motor Gasoline (all types)- Retail (Include taxes) $ per gallon	Refinery Price Finished Gasoline for Resale (without taxes) $ per gallon	Residential Heating Oil Retail $ per gallon	Residential Natural Gas $ per MMBtu	Residential Electricity Cts. per kWh
1973	12.46	0.67				3.94	7.6
1974	35.16	0.84				4.02	8.7
1975	35.68	1.13				4.38	9.0
1976	32.50	1.40				4.77	8.9
1977	32.79	1.78				5.30	9.3
1978	30.47	1.90	1.36	0.91	1.02	5.35	9.0
1979	41.69	2.27	1.70	1.23	1.35	5.73	8.8
1980	59.59	2.80	2.15	1.65	1.71	6.47	9.5
1981	59.24	3.17	2.16	1.70	1.91	6.86	9.9
1982	50.51	3.70	1.93	1.46	1.75	7.78	10.4
1983	42.39	3.75	1.77	1.28	1.56	8.77	10.4
1984	40.00	3.68	1.66	1.15	1.51	8.48	10.4
1985	36.06	3.35	1.60	1.12	1.41	8.18	10.4
1986	18.21	2.52	1.21	0.69	1.09	7.59	9.6
1987	22.86	2.11	1.21	0.74	1.01	6.99	9.3
1988	17.68	2.05	1.17	0.70	0.99	6.64	9.1
1989	21.01	1.96	1.23	0.76	1.05	6.55	8.8
1990	24.23	1.90	1.36	0.88	1.18	6.46	8.7
1991	20.05	1.76	1.28	0.75	1.09	6.24	8.6
1992	18.98	1.81	1.24	0.71	0.97	6.14	8.6
1993	16.47	2.08	1.20	0.64	0.93	6.29	8.5
1994	15.51	1.88	1.17	0.60	0.88	6.41	8.4
1995 (Est.)	16.81	1.60	1.18	0.61	0.84	6.07	8.3

* Refiners acquisition cost of imported crude oil ** Lower-48 states wellhead prices

Source: Energy Information Administration, Monthly Energy Review, Tables 9.1, 9.4, 9.6, 9.8*c*, 9.9, & 9.11.

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Attachment 2

DOE/EIA ANNUAL ENERGY OUTLOOK REFERENCE CASE ENERGY PRICE FORECASTS: 1985-1996

(DATA AS SHOWN IN AEO REPORTS BUT CONVERTED TO 1994$)

1/30/96

Energy Product	Publication	Release Date	Vintage of $ in EIA Report	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2005	2010	2015
				Price Projections shown in reports - converted to 1994$														
A. Crude oil - Average Refiner acquisition cost for imported crude oil - dollars per barrel																		
	AEO 1984	1/85	1984$	38.78	37.39	37.39	38.78	40.16	41.55					55.40				
	AEO 1985	2/86	1985$		33.41	30.73	30.73	33.41	36.08					40.09				
	AEO 1986	2/87	1986$			20.05	21.05	22.11	23.21					34.82	42.77			
	AEO 1987	3/88	1987$				21.18	22.20	22.48	22.56	22.57	23.67	26.88	28.24	36.79			
	AEO 1989	1/89	1988$					17.46	18.21	19.82	19.31	20.78	22.95	25.01	34.00			
	AEO 1990	1/90	1989$						19.52					23.70	32.30	38.22	42.67	
	AEO 1991	3/91	1990$											26.72	29.62	34.52	36.09	
	AEO 1992	1/92	1990$											23.18	29.39	33.90	37.19	
	AEO 1993	1/93	1991$											21.34	24.86	27.99	31.41	
	AEO 1994	1/94	1992$												21.61	26.97	29.37	
	AEO 1995	1/95	1993$												19.62	21.94	24.62	
	AEO 1996	1/96	1994$												19.27	21.66	23.70	26.43
Actual prices converted to 1994$				36.08	18.21	22.88	17.87	21.01	24.22	19.73	18.98	16.47	15.51	18.61				
B. Gas Wellhead price - Lower 48 onshore & offshore - dollars per mcf																		
	AEO 1984	1/85	1984$	3.70	3.66	3.88	4.14	4.46	4.67					6.99				
	AEO 1985	2/86	1985$		3.37	3.29	3.19	3.31	3.58					6.36				
	AEO 1986	2/87	1986$			2.47	2.78	2.98	3.16					5.11	7.17			
	AEO 1987	3/88	1987$				2.38	2.47	2.57	2.89	2.82	3.04	3.28	3.59	5.07			
	AEO 1989	1/89	1988$					1.99	2.12	2.28	2.80	2.91	3.17	3.40	4.75			
	AEO 1990	1/90	1989$						2.10					2.81	3.75	5.07	6.54	
	AEO 1991	3/91	1990$											2.36	2.91	4.55	5.81	
	AEO 1992	1/92	1990$											2.25	3.03	4.12	5.18	
	AEO 1993	1/93	1991$											2.19	2.74	3.65	3.95	
	AEO 1994	1/94	1992$												2.52	3.01	3.82	
	AEO 1995	1/95	1993$												2.18	3.08	3.48	
	AEO 1996	1/96	1994$												1.89	1.99	2.15	2.57
Actual prices converted to 1994$				3.35	2.52	2.11	2.05	1.96	1.90	1.76	1.81	2.08	1.88	1.60				

* Estimates based on 9 months of actual data.

Data Sources: Energy Information Administration, Annual Energy Outlook, 1984 through 1996; and Monthly Energy Review

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Attachment 3

The Potential for Systematic Upward Bias in Energy Market Forecasts

During the past 16 years, energy price forecasts that grossly overestimated prices have played a major role in decisions that have turned out to be uneconomic -- at great cost to consumers, taxpayers, and shareholders. The decisions include investments in facilities to produce, transport, convert, use, and conserve energy; long-term contracts; and spending for energy R&D projects.

This history leads to three important questions:

- First, are current forecasts still overestimating future energy demand and prices?
- Second, is there *systematic* upward bias in widely used energy price forecasts?
- Third, if there is, directly or indirectly, a systematic upward bias in energy price forecasts, what should be done by decision-makers to correct for the bias?

This paper deals with the second issue.

Experience with energy markets and energy forecasts reveals several clearly identifiable reasons why energy demand and price forecasts tend to have an upward bias. There do not appear to be offsetting downward biases. Potential sources and reasons for upwardly biased forecasts include the following:

1. **Forecasts used in attempts to influence public policy.** Policy makers in Washington and the media are often targets of energy market forecasts that have an upward price bias. Sources include:

   a. **Interest groups seeking preferential treatment.** Forecasts of high energy demand or high energy prices tend to support the objectives of various interest groups that focus their attention on Washington, D.C. Such interests may want special treatment in the form of contracts, cash subsidies, loans or loan guarantees, favorable tax treatment, access to mineral resources on public lands, protection against regulations that increase cost, creation or continuation of groups within the government that defend their interests, and/or statements of support for interest group objectives from high level government officials.

      Forecasts that suggest high potential for energy shortages, sharp increases in energy demand and prices, or high emissions from energy facilities have often proven to be effective in creating a "crisis" expectation. Examples from the past few years include:

      1) Emphasis on high oil import dependence and U.S. dollar outflow from organizations favoring energy taxes or seeking favorable tax treatment, import duties on oil, access to public lands for resource development, subsidies for R&D, changes in licensing or permit

2) Forecasts of inadequate supplies of natural gas to meet potential demand and sharply rising prices by organizations representing competing energy sources, and from gas producers seeking tax breaks for exploration and production.

3) Forecasts of high usage of coal and other fossil energy sources leading to increased emissions, with the forecasts from organizations favoring tighter regulatory controls or taxes to discourage emissions of regulated pollutants and "greenhouse gases," and from organizations representing non-fossil energy sources.

b. **Government agencies pushing particular policies and programs.** Government agencies can also introduce upward bias in energy demand and price forecasts. They, too, recognize the need for a crisis or perceived crisis to move Washington to accept *their* proposals. Examples during the past few years include agencies seeking funds for energy R&D programs, tighter energy efficiency standards, opening of federal lands for energy development, higher taxes on energy, and taxes or tighter standards on emissions.

c. **Analysts or consultants pushing a particular policy position or seeking attention.** Washington is a favored place for energy and natural resource policy analysts and consultants to push their favorite solution to an actual or perceived public policy problem. The resulting publicity provides personal satisfaction, additional business and, perhaps, invitations for more speeches. Members of this broad group are unlikely to attract attention unless they predict some sort of crisis or unusually high benefit if their proposal is adopted.

2. **Forecasts developed by private individuals and organizations are used to promote particular projects.** Outside the Washington arena there are fertile grounds for the use of forecasts that predict high prices, particularly for oil and natural gas. For example, companies in energy industries must consider investments in exploration and production, new energy facilities or programs, energy efficiency and conservation projects, or energy R&D projects.

   Those seeking internal company approval or outside financing for projects find it easier to produce favorable economic analyses to support their proposals *if* they use forecasts of high prices for oil, natural gas or whatever the competing energy source happens to be. Further, once an energy investment is committed beyond recall, there is a continuing incentive to predict high prices for competing energy sources to head off questions about the wisdom of the investment.

3. **Forecasts produced by professional forecasting organizations may become entangled in client interests.** Market and price forecasts produced by professional energy forecasting organizations vary widely in quality and in their expectations. Some are quite good. Others have a reputation for providing high price forecasts. The reasons a professional forecasting organization might produce high price forecasts appear to include the following:

   - Some individuals or organizations responsible for procuring forecasts from outside firms want high forecasts to help justify preconceived positions, projects or spending levels favored by the individual or his employing organization.

- High price forecasts, particularly when supplied by outside "experts," are useful when attempting to justify continuation of an incomplete project *after* energy market conditions have changed.

- Once a client organization has decided on a course of action based on an outside forecast, *the forecaster is reluctant to show lower prices, even when market conditions change.*

4. **Forecasts produced to encourage investments.** Investment firms may also be a source of high energy demand and price forecasts. Such forecasts might be used to encourage investments in particular projects or companies that would benefit *if* energy prices rise.

5. **Forecasts produced by people who have a greater fear of being wrong on the low side than the high side.** The unexpectedly high oil prices and, to a lesser extent, coal prices during the period from 1973 to early 1981 were a shock for many individuals and organizations. That experience seems to have contributed to a situation, particularly in government agencies, where individuals are very reluctant to be faced with a situation where energy supplies are less plentiful or energy prices *higher* than they have forecast. There appears to be a perception that penalties would be greater for being under prepared than over-prepared for a potential energy "emergency," or for underestimating rather than over-estimating energy prices. Unfortunately, these people usually do not suffer the consequences of their overestimation of demand and prices.

6. **Underlying causes of biases in energy market forecasts.** The potential existence of systematic upward bias in energy demand and price forecasts deserves attention by anyone that makes decisions that are affected by energy price forecasts. Biased forecasts may be intended in the case of some examples listed above, but there are other potential sources of error in energy market forecasts. Lack of foresight undoubtedly tops the list. But, for purposes of this discussion, three other potential reasons deserve comment:

   a. **Complex models and questionable assumptions.** Complex models driven by hundreds of assumptions and "hard-wired" relationships are always a source of concern. Unfortunately, assumptions and prescribed relationships within models are all too often not recognized, understood, or evaluated by users of forecasts. Often, forecasters may not understand the uses of their forecasts or have an opportunity to explain limitations.

   b. **Outdated baseline information.** Some forecasts are plagued by lack of current baseline information because of rapid changes in energy markets (e.g., natural gas, electricity), difficulty in obtaining accurate data, and/or limited direct contact with energy markets that could provide current information for use in baselines.

   c. **Static vs. dynamic analysis.** Some forecasters overlook the dynamic nature of energy markets. Millions of individuals and organizations make decisions daily that affect energy supply, demand and prices. A small change in some market factor (supply, demand, price, regulatory requirement, purchase of a more or less energy efficient product, etc.) can have a major impact on energy markets -- particularly in times of strong interfuel competition. Forecasters who are not directly involved in working energy markets are often unaware of the alternatives that are available to individuals and organizations making decisions affecting those markets, particularly alternatives that result in lower prices.

d. **Overestimating lead times.** Some forecasters overestimate the lead time needed for markets to adjust to new signals, either by reducing demand or bringing on new supplies. The unexpected length of the infamous "gas bubble" was due in part to the failure of forecasters to recognize that: (a) many gas producers had explored for and found reserves but had not begun production because the gas was not needed, (b) lead times needed to bring proved, non-producing reserves into production are often quite short, and (c) investing in new exploration did not make sense if the producer had an ample supply of proven reserves that were not yet in production. Forecasters need to recognize that statements made by energy producers about long lead time requirements may be a symptom of frustration with government requirements or business conditions and are not necessarily an accurate prediction of the time that will be required to complete a particular action, such as bringing a new production well on line.

e. **Failing to recognize marginal resources.** Even a small, lasting increase in oil prices means that some economic alternative will be available tomorrow that wasn't available yesterday. A slightly higher price may make it economic to invest in a piece of equipment or process change to increase energy supplies or reduce energy use. For example, higher energy prices may mean that it is *now* more economic for an electric utility to subsidize an action to reduce electricity demand. A small change in price may change the economics.

f. **Clinging to "depletion" theories.** Some forecasters choose to predict rising energy prices on the theory that resources such as oil are finite and eventually will run out. This approach contrasts with those who believe that the prices for oil, natural gas, other energy sources will behave like other commodities and are more likely to remain level or decline in the long term.

g. **Failure to recognize technology improvements.** Some forecasters fail to take into account the potential for technology to continue to work to reduce costs of finding and producing energy resources, including natural gas and oil.

Some forecasters seem not to recognize adequately the effect of alternatives that are "at the margin" of today's price. For example, millions of barrels of heavy oil or oil from tar sands cannot be produced economically today but may be economic if oil prices rise significantly.

Promoters of new energy technologies seem to ignore supply and demand alternatives available "at the margin." They may assume that their favorite energy technology will automatically become economic if prices rise. Such assumptions tend to ignore: (a) other energy sources or demand side alternatives at the margin that may become economic first, and (b) the possibility that progress is being made in other technologies that may make them even more competitive.

Those who use energy market forecasts as the basis for their decisions, or use them in analyses done for decision-makers, should be alert to the possibility of bias. As a minimum, they should test proposed courses of action under a variety of energy supply, demand and price scenarios, including scenarios with *lower energy demand and prices, and more plentiful supplies* than are shown in "consensus" forecasts.

PRESENTATION BY L. D. HAMLIN

SOUTHERN CALIFORNIA EDISON

STATE TRENDS IN ENERGY AND THE

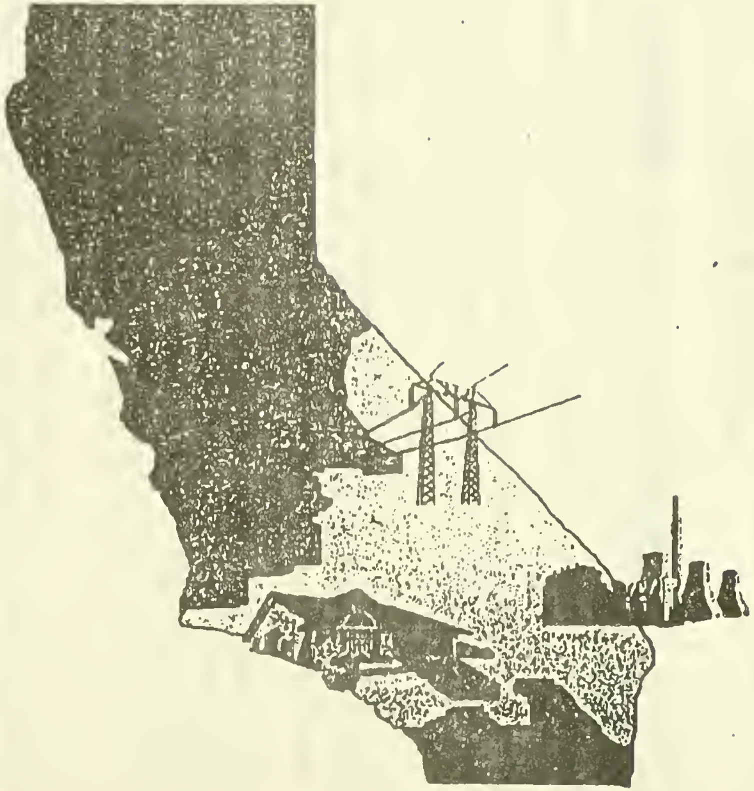
ENVIRONMENT CONFERENCE

JUNE 14, 1994

SANTA FE, NEW MEXICO

SLIDE #1

In the early 1900s, electricity was recognized as an essential service and utilities were granted exclusive franchises to develop the necessary energy facilities



<u>Business Characteristics</u>

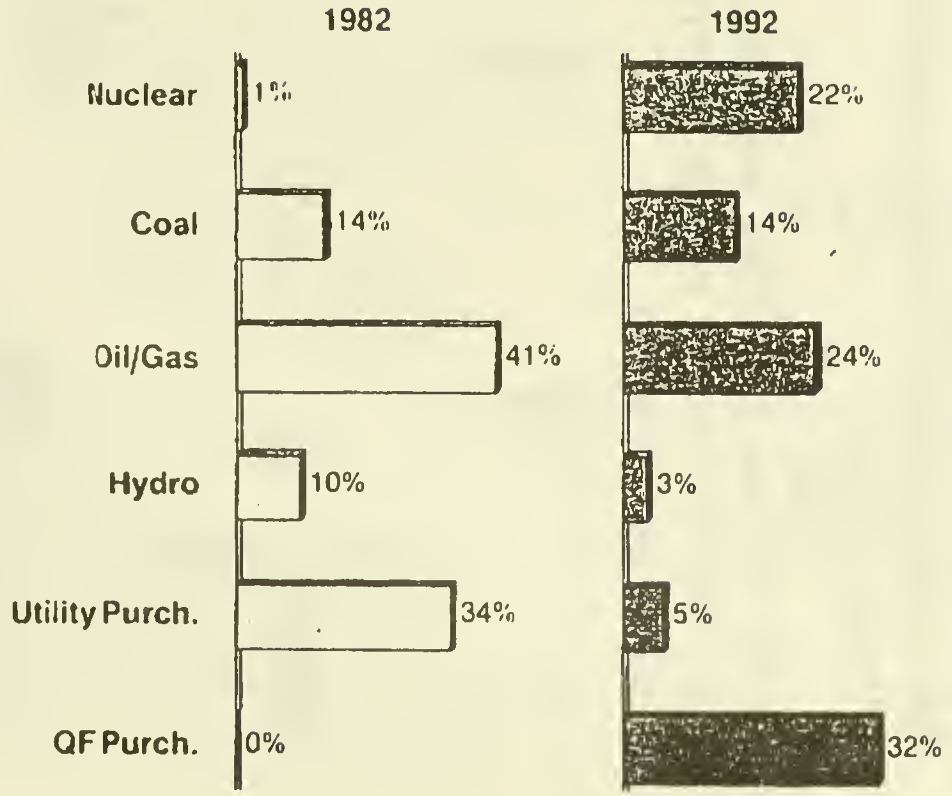
- Natural monopoly
- Vertical integration

<u>Regulatory Compact</u>

- Obligation to serve
- Reasonable profit

Edison Generation Mix

"Edison's Generation Mix Has Changed Significantly Over The Past 10 Years"



- Addition of Nuclear
- Elimination of Oil
- Addition of QFs
- Reduction in Utility Purchases
- Reduction in Gas Production

Southern California Edison genuinely is an environmental utility. We are sincere about it. We work at it.

Let me add a few more facts about us -- as important background for a discussion of life along the fault line.

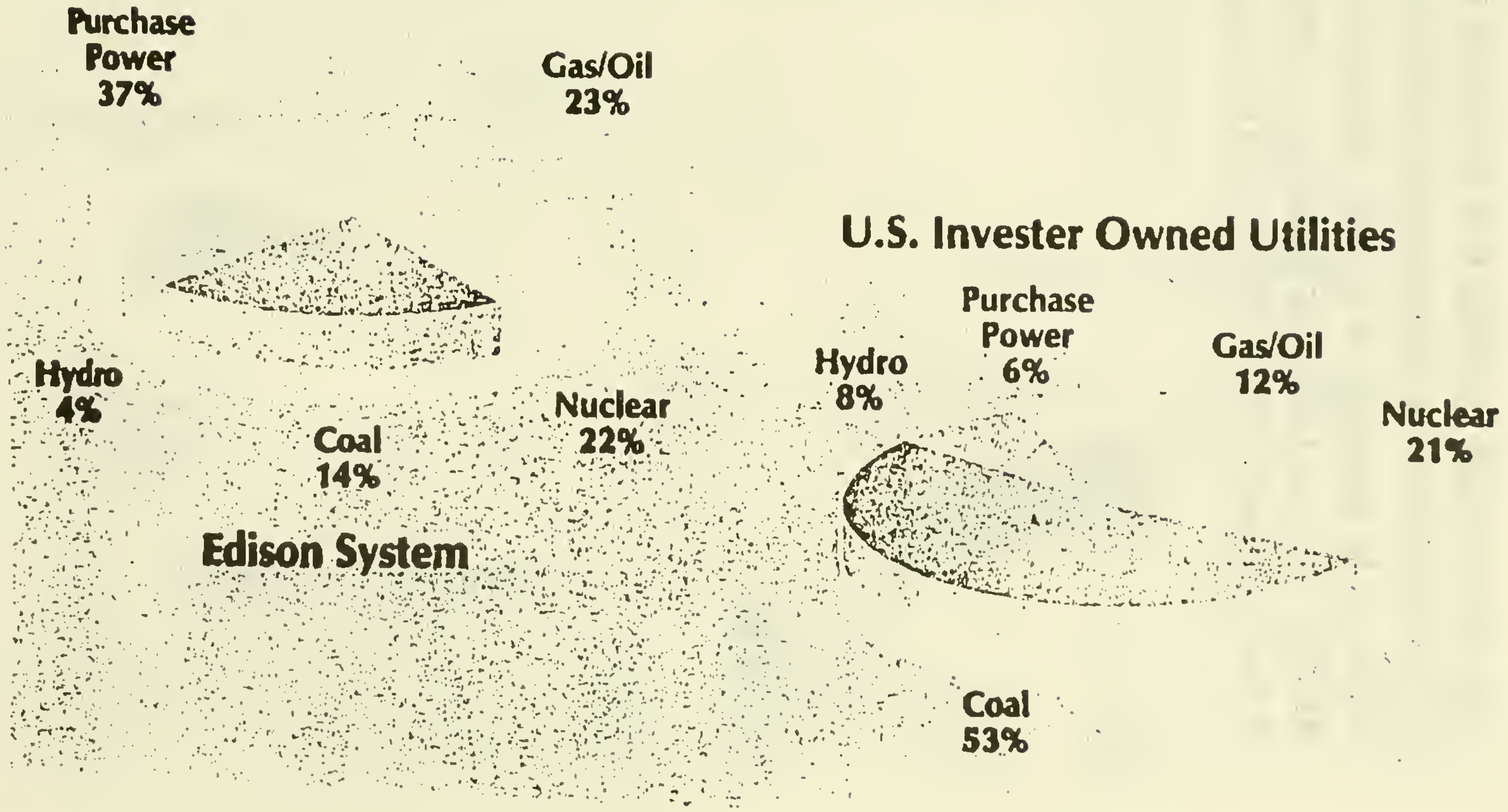
Like the average United States utility, we rely on nuclear energy for about one-fourth of our energy.

Unlike the average utility, we purchase more than one-third of our energy from other parties -- six times the norm.

Slide #3

SLIDE 03

Resource Energy Comparision

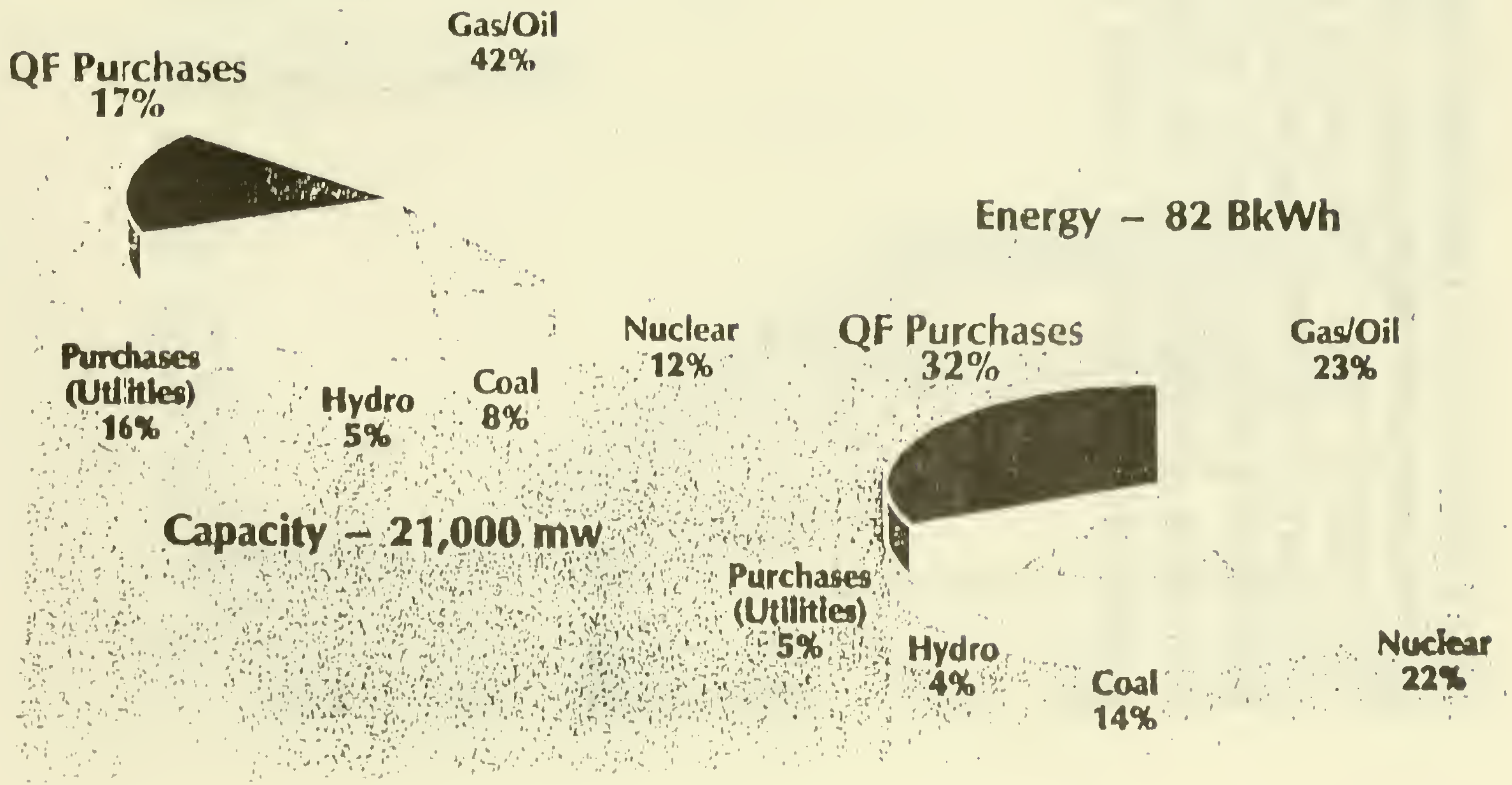


And <u>very much</u> unlike the average utility, we are committed to contractual arrangements that force us to acquire a major component of our energy from qualifying facilities -- equaling 17% of our capacity, and 32% of our energy.

<u>Slide #4</u>

SLIDE #4

Edison Capacity and Energy Mix

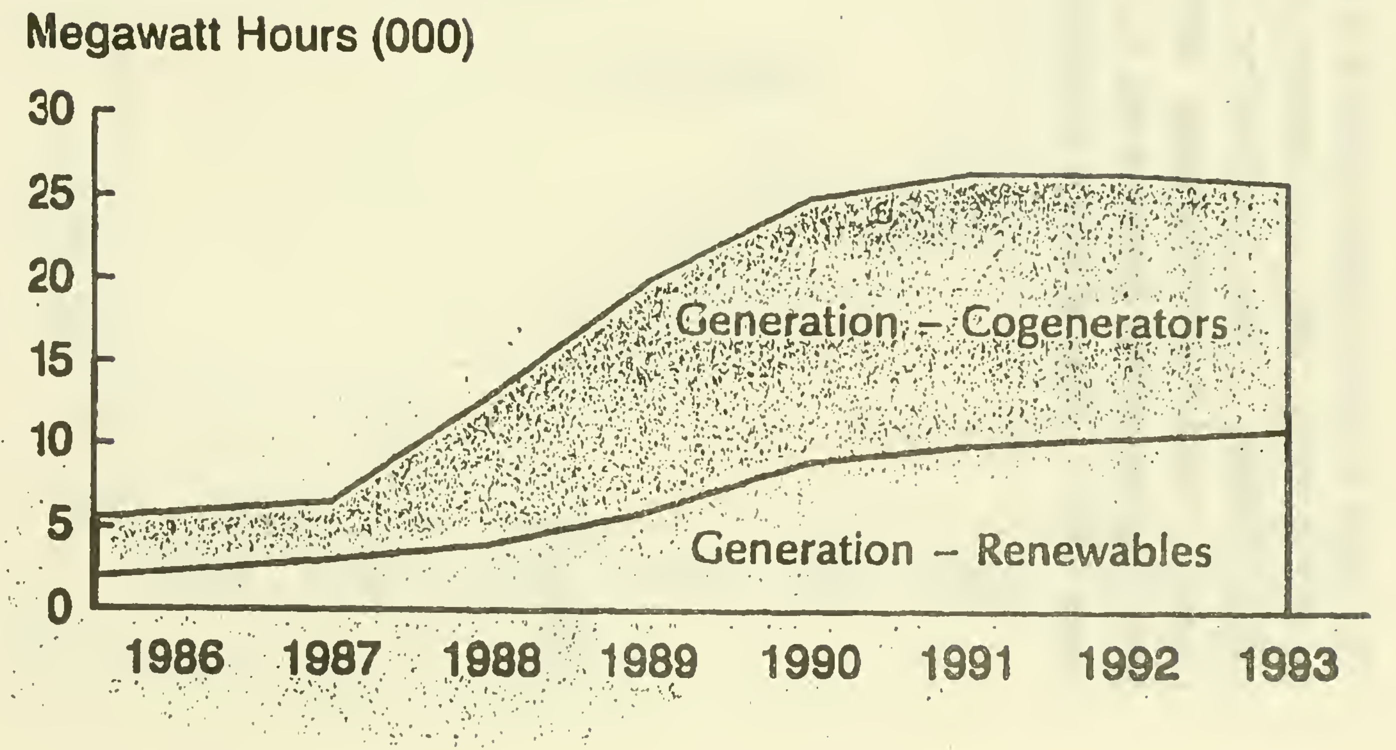


The amount of our generation supplied by renewables and cogeneration climbed steadily from 1986 to 1992. The picture you see here was painted by California regulators, who saw the PURPA law as a golden opportunity to introduce competition ... and presumably lower power generation costs ... in the California mix.

<u>Slide #5</u>

SLIDE 63

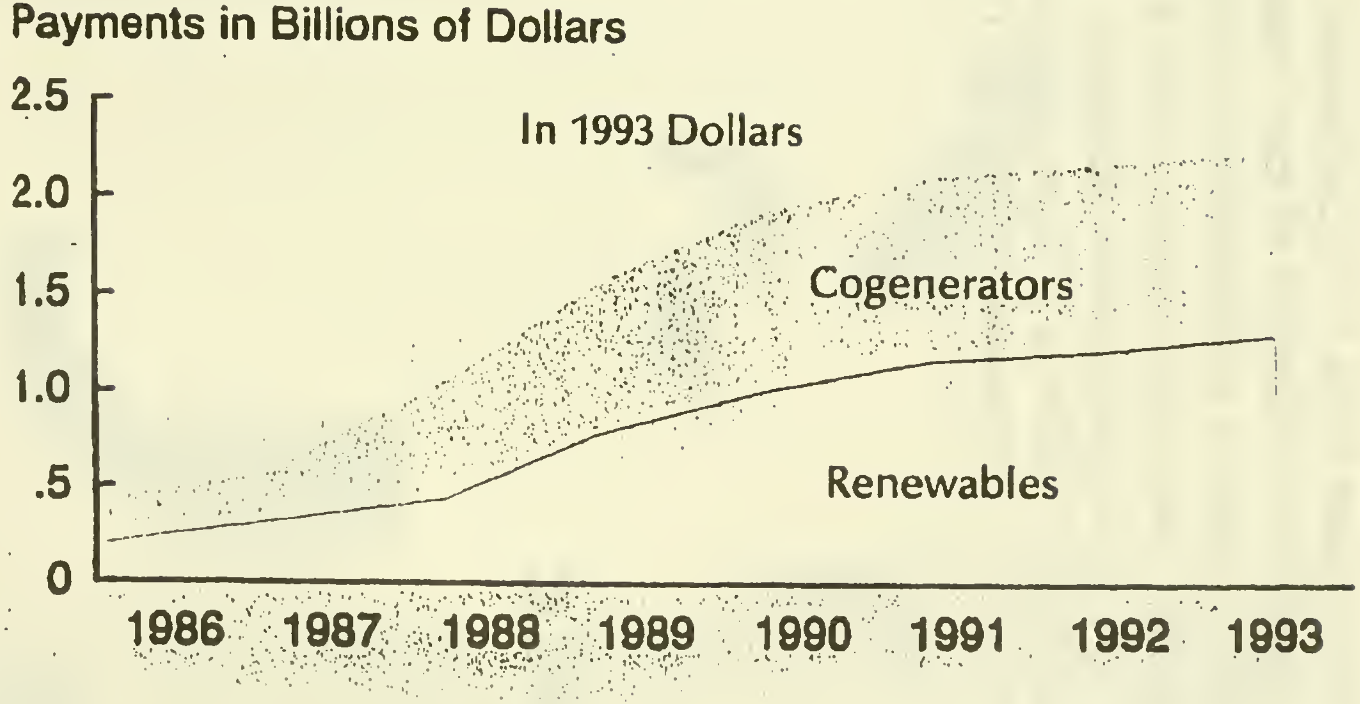
Generation by Renewables and Cogenerators



The cost of such power has the same profile as the supply. We now spend well over two billion dollars a year purchasing this kind of power -- and it is mandated. Both renewables and cogeneration come onto our system as base load. They are not dispatchable.

Slide #6

Payments to Renewables and Cogenerators

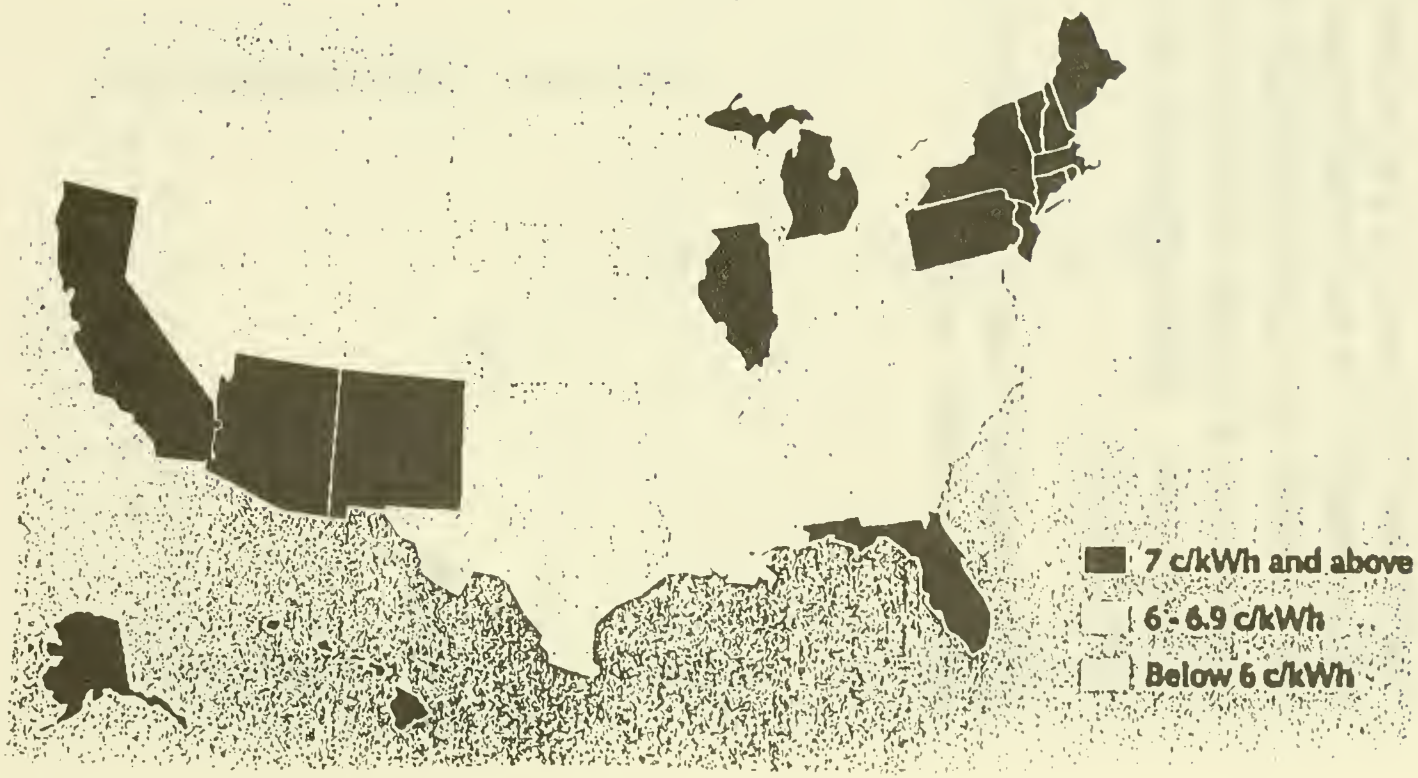


This proved to be a miscalculation.
The result and degree of that miscalculation can be seen in a comparison of California electric rates with those of other states. We are in the highest priced category. Each of Southern California Edison's kilowatt-hours costs our customers an average of ten cents.

Slide #7

SLIDE #7

1990 Electric Rates by State
Average Electric Rates



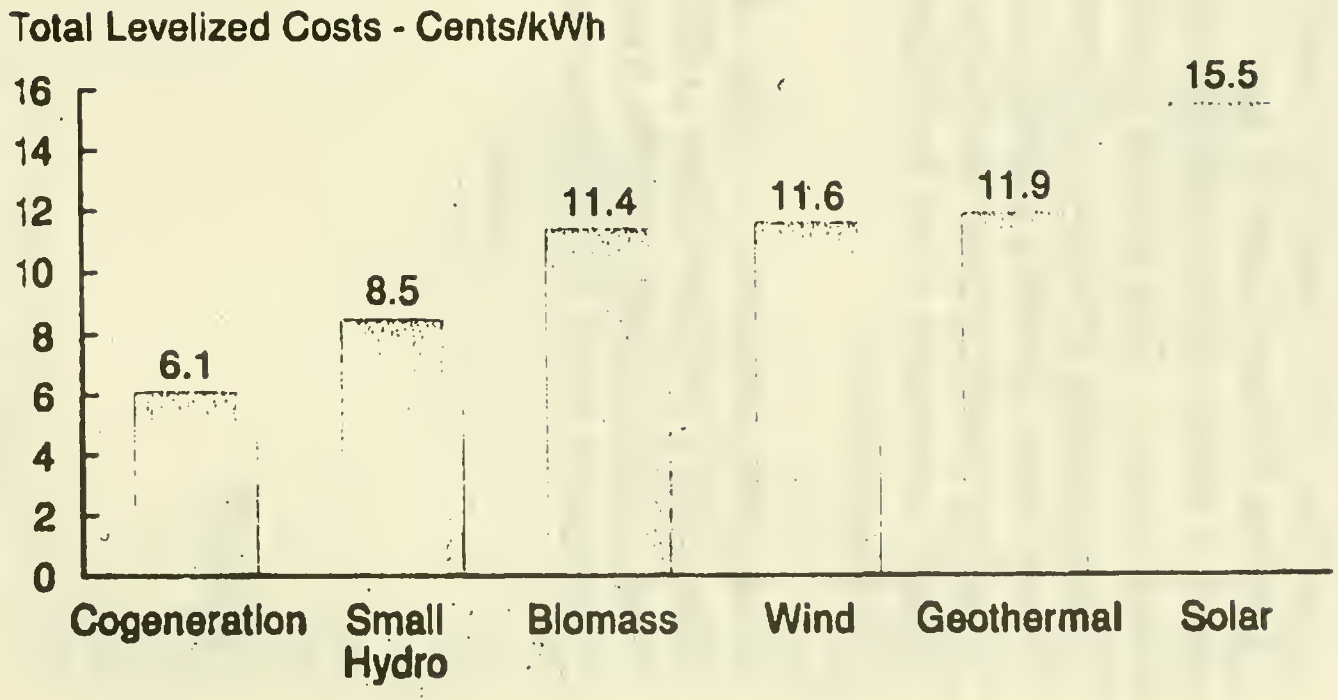
For those who are not yet moved to tears by these graphs, let me break these costs down a bit. In 1993, our customers paid for cogen power at an average total cost of 6.1 cents per kilowatt-hour. Solar walks off with all the prizes at 15.5 cents.

All renewables average higher than our average system costs.

Slide #8

SLIDE #8

QF and Renewable Resource Costs
Cents/kWh



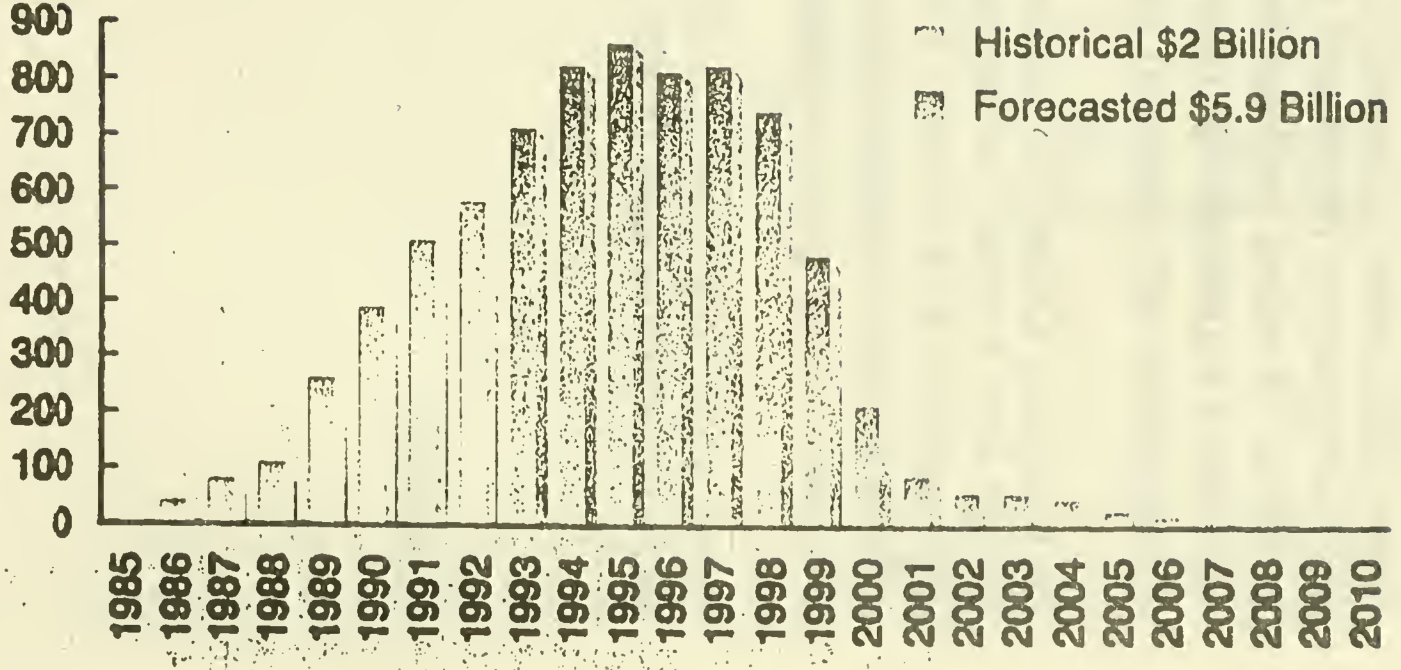
And the costs mount up over the years. As Everett Dirkson used to say -- a million here and a million there, pretty soon you're talking real money. The annual payments above market costs that our customers make to QF's have been climbing steadily since 1986 -- already totalling over two billion dollars. This year, we project more than $800 million in such overpayments.

The peak will come in 1996, when our customers will pay close to $900 million more than market costs to QF's that were created by regulators to be competitive sources of power.

Slide #9

SLIDE #9

Payments to QF's Above Market Costs



After 1996, these payments begin to diminish, as the regulatory mandated subsidies expire. In about 15 years, the wonderful impact of this regulatory experiment in utility micro-management will have run its course.

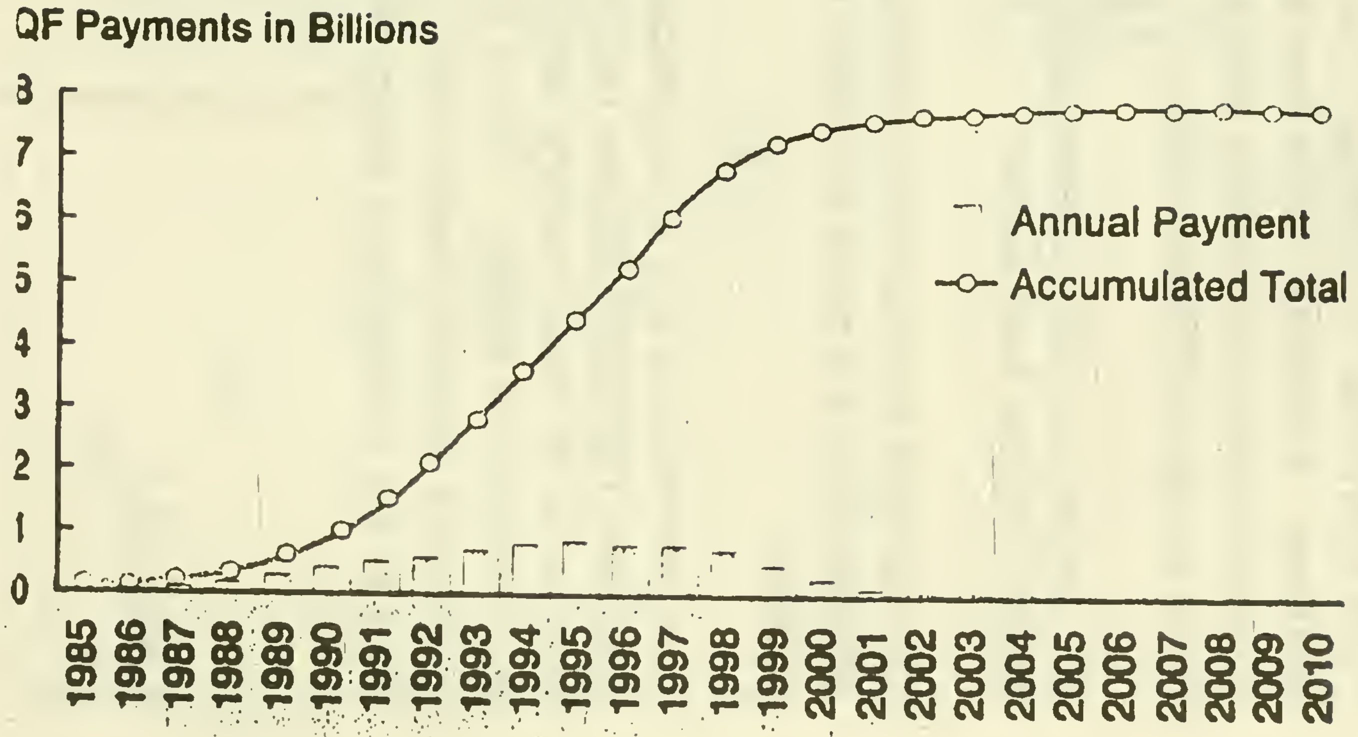
By then, our California customers will have parted with a totally unnecessary and unproductive $7.9 billion. This single chart is a picture of what happens when market forces are over-run by good intentions.

Think about this when you think about a government-operated health care system.

<u>Slide #10</u>

SLIDE #10

Payment to QF's Above Market Costs



Here is another comparison that speaks volumes. It depicts vividly the fault line that runs through our company today as we struggle to be an environmental utility.

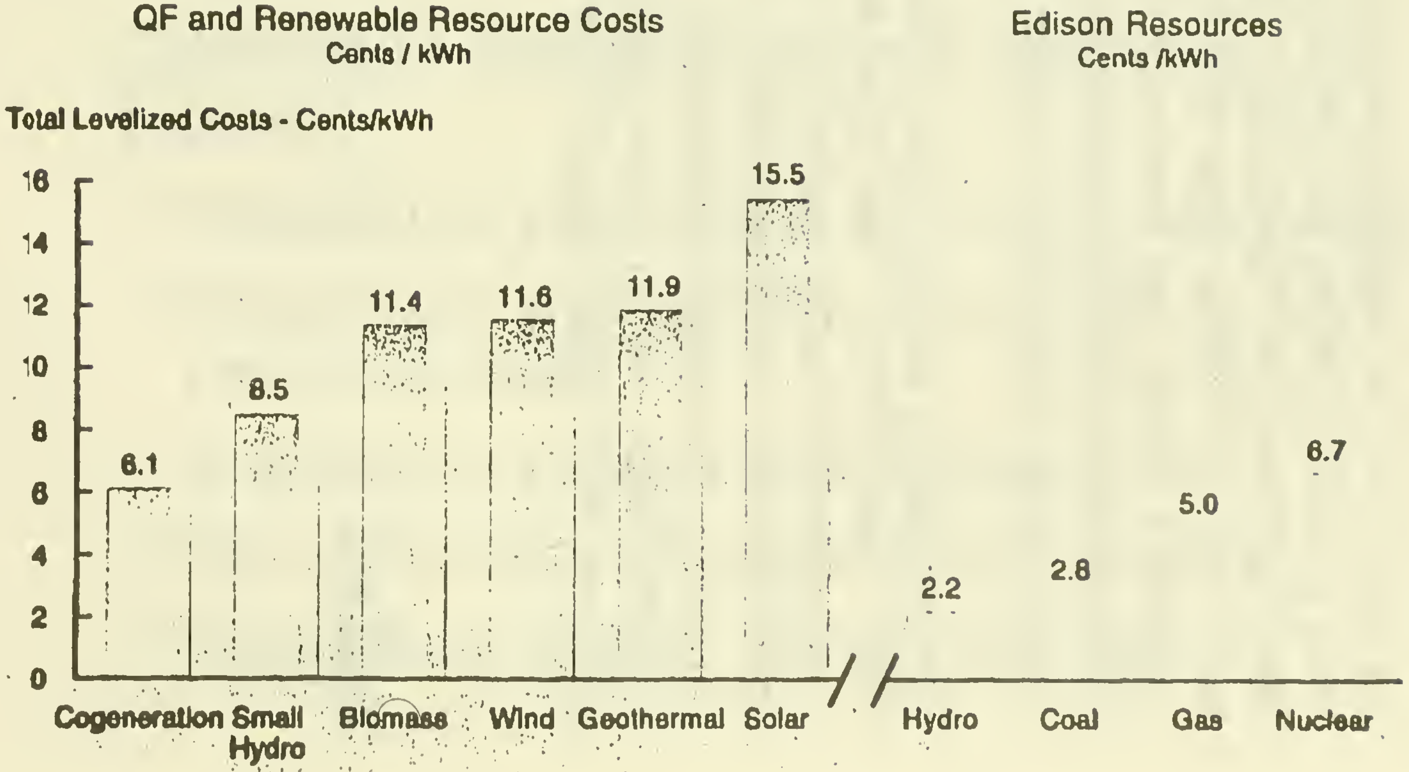
On the left are the cogeneration and renewable costs that you saw earlier.

On the right are Edison's resource costs, ranging from 2.2 cents for hydro to 6.7 cents for nuclear.

The net result of this sharp disparity is that Southern California Edison customers pay one cent more for their average kilowatt-hour than they should be paying. These cogen and renewable overpayments alone add just over 10% to our market cost structure.

<u>Slide #11</u>

Generation Resource Costs



To round out the regulatory influences, we also have a function within the CPUC called the Biennial Resource Plan Update. One of its tasks is to tell utilities when and how much new capacity it needs, and how much of that capacity will come from renewable resources. This process is referred to as the BRPU.

This regulatory cluster ... the CPUC staff ... DRA ... and BRPU ... has forced micro-management of utility operations -- a regulatory command and control approach. They specify demand ... the need for generation ... what type of generation ... when it must come on line ... and how much each kilowatt-hour will cost.

Slide #12

SLIDE #12

Regulatory Command and Control

California's electric resource planning process

- Regulators plan utility electricity demand
- Regulators plan utility generation resource need
- Regulators specify generation type
- Regulators specify generation timing
- Regulators specify generation cost

We think there is a better way -- better for the California economy, better for the environment ... and better for Southern California Edison as a business enterprise.

Step one ... acknowledge that regulatory command and control ... micro-management ... doesn't work. The numbers prove it. Social engineers may have worthy goals, but they should have the humility it takes to attain them.

Second ... social engineering mandates should be eliminated as mandates. They may well be worthwhile as goals. It is the methods that we're concerned about -- not the good intentions.

Slide #13

Third ... both we and our regulators, working together, should adopt a business-driven focus. That focus, properly managed, can attain all sensible environmental goals, and do it at market prices.

We believe that this is as true for you as it is for us. What happens in California may sometimes happen in large print, like that famous Hollywood sign, but we know that the fault line between environmental and regulatory goals and competitive costs runs through every other utility in America.

Slide #13 - continued

SLIDE #13

Competitive Performance Mandate

- Regulatory command and control doesn't work
- Eliminate social engineering mandates
- Adopt a business-driven focus

We recognize that the pattern that fits the future for one utility will differ from that of others. But for what it may be worth to you ... and perhaps as background for the panel discussion that we are going to hold shortly ... let me describe what we see as an ideal way to build a future Southern California Edison -- as an environmental utility, and simultaneously as a competitive utility.

We would begin by bringing a new visibility to the relationship between environmental benefits and their costs. California customers should be able to make a decision on the issue. It is, after all, their quality of life and their personal finances that are at stake.

Slide #14

The first step toward that goal would be to separate Edison's power generating capability and take it out of the core utility. That power portfolio, balancing all generation assets in the same mix, could compete at somewhere between 5 and 6 cents per kilowatt-hour. One of its great advantages would be freedom from much of the administrative overhead that is part of utility operation. A power generation entity needs few lawyers or auditors or customer service personnel ... no more than an independent power producer needs them.

Slide #14 - continued

A power generation entity offering kilowatt-hours at that price would establish a clear market level. Other sources of energy -- whether cogen or renewable -- would have a clear target to shoot at -- and a tough competitor to beat. Because we would sell our power at a price based on our capacity mix, we would not have to consider write-downs of our facilities. We are convinced that they are competitive in meeting the needs of our electric system.

Probably the most satisfying fact about such an arrangement would be our ability to show one and all that we can compete with any alternate source -- including cogen plants.

<u>Slide #14 - continued</u>

SLIDE #14

Separating Power Generation Capability From the Rate Base

- Could compete at 5-6 cents per kilowatt hour
- Freedom from administrative overhead
- Establishes a clear market level

Mr. Joseph J. Romm
Acting Principal Deputy Assistant Secretary
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Answers to Followup Questions

HEARING OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

on

U.S. Energy Outlook and Implications for Energy R&D

Thursday, March 14, 1996
2318 Rayburn House Office Building

Followup Questions Submitted to

Mr. Joseph J. Romm
Acting Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy,
U.S. Department of Energy

Prepared and Oral Testimony

Q1. On page 5 of your prepared testimony, you state: "One analysis by DOE's Oa Ridge National Laboratory in Tennessee put the cost to the U.S. economy over th past 25 years of over reliance on OPEC oil, including the cost of price shocks, at $ trillion. Oak Ridge has estimated that a price shock in 2005 could cost the U.S economy hundreds of billions of dollars."

Please provide copies of this analysis and estimate, including the supportin documentation.

A1. The cost to the U.S. economy of over reliance on OPEC oil is estimated in a report by th Oak Ridge National Laboratory: The Outlook for U.S. Oil Dependence," by David I Greene, Donald W. Jones and Paul N. Leiby, May 11, 1995, report number ORNL-6873 [*Note: A copy is attached.*]

ornl

ORNL-6873

OAK RIDGE
NATIONAL
LABORATORY

LOCKHEED MARTIN

The Outlook for U.S. Oil Dependence

David L. Greene
Donald W. Jones
Paul N. Leiby

MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

UCN-13673 ([illegible])

ORNL-6873

THE OUTLOOK FOR U. S. OIL DEPENDENCE

David L. Greene
Center for Transportation Analysis

Donald W. Jones
Paul N. Leiby
Energy and Global Change Analysis

Oak Ridge National Laboratory

prepared for

Office of Transportation Technology
U. S. Department of Energy

May 11, 1995

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ABSTRACT

Market share OPEC lost in defending higher prices from 1979-1985 is being steadily regained and is projected to exceed 50% by 2000. World oil markets are likely to be as vulnerable to monopoly influence as they were 20 years ago, as OPEC regains lost market share. The U.S. economy appears to be as exposed as it was in the early 1970s to losses from monopoly oil pricing. A simulated 2-year supply reduction in 2005-6 boosts OPEC revenues by roughly half a trillion dollars and costs the U.S. economy an approximately equal amount. The Strategic Petroleum Reserve appears to be of little benefit against such a determined, multi-year supply curtailment either in reducing OPEC revenues or protecting the U.S. economy. Increasing the price elasticity of oil demand and supply in the U.S. and the rest of the world, however, would be an effective strategy.

ACKNOWLEDGEMENT

The authors wish to thank Phil Patterson and Barry McNutt for their interest and support, and colleagues Jerry Hadder and Randy Curlee for their comments on earlier drafts. Any remaining errors are the author's responsibility. This report is dedicated to Michael Greene.

1. THE "OIL PROBLEM"

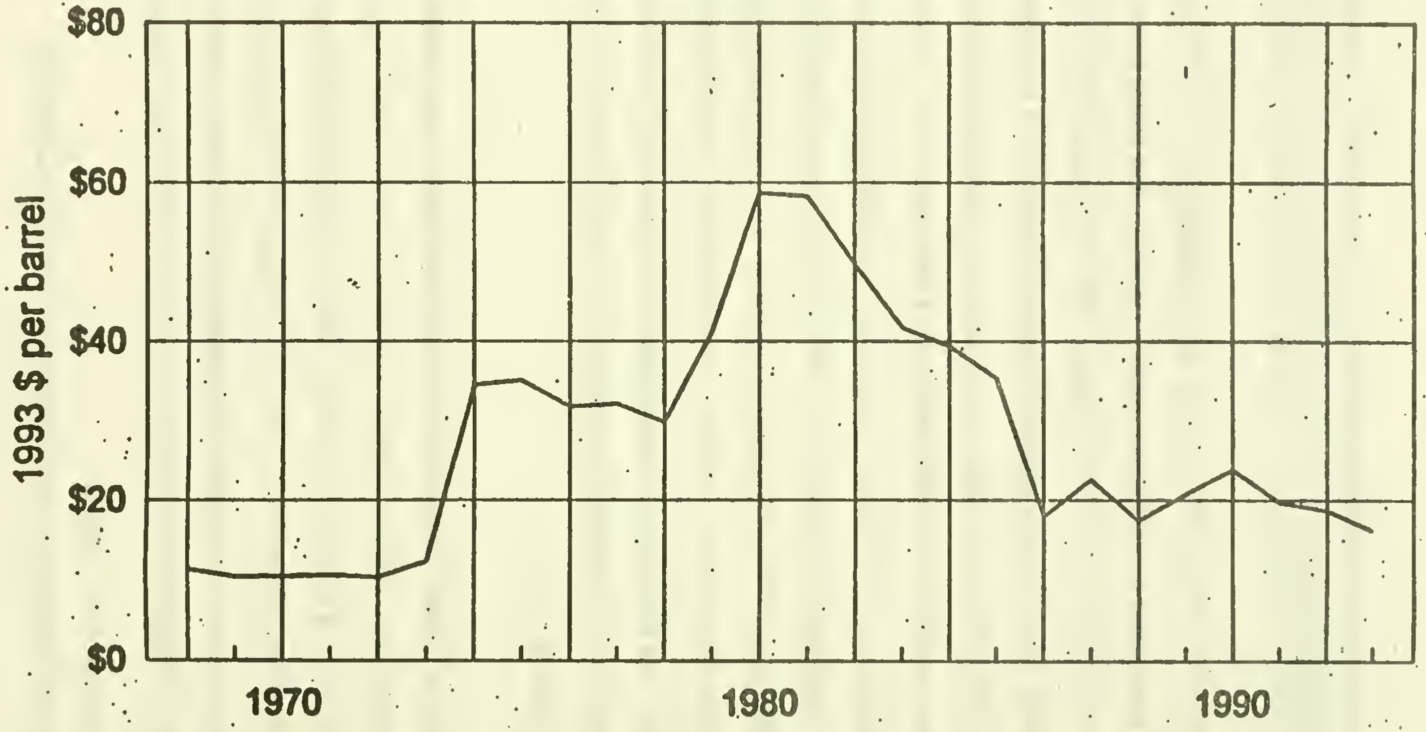
.1 INTRODUCTION

n October 1973, the Arab members of the Organization of Petroleum Exporting Countries OPEC) announced an oil boycott against countries that aided Israel during the "October Var." From September 1973 to December 1973, they reduced their crude oil production by .2 MMBD. World oil prices doubled between October 1973 and January 1974 (Figure 1). Again in 1979-80 a 5.4 MMBD loss of production from Iran and Iraq, about 9% of world roduction, resulted in another doubling of the price of oil. In both instances, OPEC nembers restrained production in succeeding years, electing to keep prices at the new higher evels. From May to December of 1990, total oil output from Kuwait and Iraq fell by .8 MMBD, about 7.6% of world oil production. From the second to the fourth quarter of 990, oil prices again nearly doubled, from $17.50 to $33 per barrel (1993 $).[1] This latest rice shock was short-lived in comparison to the others, as Saudi Arabia put its enormous lack capacity to use, expanding production by 3 MMBD to make up most of the lost supply Tatom, 1993, p. 138).

he cost to the United States of oil price shocks and supply manipulation by the OPEC cartel as been enormous. Recent estimates put the cumulative costs from 1972 to 1991 at over 4 trillion 1993 $ (Greene and Leiby, 1993). Monopoly pricing of oil hurt the U. S. conomy in three different ways. First, by making oil scarcer, higher oil prices reduced the utput the economy was capable of producing with the same resources. Second, sudden, rastic price changes further reduced domestic product because wages and prices cannot

[1]Prices in this paper are 1993 dollars, except where indicated otherwise.

Figure 1. Crude Oil Prices, 1968-1993
Refiner Acquistion Costs of Imported Crude Oil



U.S. Dept. of Energy, Annual Energy Review 1993, table 5.20.

adjust quickly enough to maintain full employment of the factors of production. Thus, in the short-term, the economy could not even attain the lower long-run potential gross domestic product (GDP). Finally, monopoly pricing transfers the wealth of U. S. citizens to the owners of foreign oil in the form of monopoly rents. Each one of these was a major component of the $4 trillion loss the economy suffered over the past two decades.

But will this ever happen again? Today oil supplies are abundant. Oil prices are relatively low and OPEC appears to be in disarray. Is the oil problem over? That is the question this paper addresses. It begins by considering the nature of the oil market and the factors that allow OPEC to wield monopoly power. Oil resources, according to our best estimates, are as concentrated as ever in the Persian Gulf and in the OPEC nations. With the rest of the world (ROW) drawing down its reserves at nearly twice the rate at which OPEC is using its reserves, OPEC's share of world oil supply must rise, and that is exactly what is happening. With an increase in market share comes a greater ability to raise prices. Fundamental economics ordains that the potential market power of the OPEC cartel depends on its market share, the ability of consumers to reduce oil use in response to higher prices, and the ability of ROW producers to expand oil supply in response to a reduction by the cartel. Not only is OPEC's market share rising toward its historic high point, but recent studies (cited below) provide no evidence of increases in the price elasticities of world oil supply and demand. Greater market share and continuing world dependence on OPEC oil will give the cartel the opportunity to raise oil prices. The chance to gain enormous wealth will give them the motive. In a public speech in March of 1993, Francisco R. Parra, former Secretary General of OPEC and senior executive of Petroleos de Venezuela made it clear that he understood both.

> "To most observers, it seems obvious that the individual and collective interests of OPEC member countries would be well served by a speedy and substantial increase in the price of crude oil - say, to $25 - to be followed over a period of time by a series of smaller ones to at least keep pace with inflation."

> "It also seems obvious that OPEC has the collective power to achieve such an increase in prices. Why not do so?"
>
> "The prize is $5 billion per month." (Parra, 1994, pp. 18-19, p. 23.)

Next, the factors that determine the impact of oil price increases on the U. S. economy are examined. Unfortunately, it appears that future oil price shocks would be just as harmful to the U. S. economy as those of the past. Recent studies reaffirm that oil price increases cause gross national product (GNP) to fall and prices to rise (e.g., Moosa, 1993) and suggest no significant differences between the impacts on the U. S. economy of the 1990 price shock and those of 1973-74 and 1979-80 (Tatom, 1993; Mork, Olsen and Mysen, 1994). The reason is that little of fundamental importance has changed. The cost of oil as a percent of U. S. GNP, a key determinant of the macroeconomic impact of a price shock, was 1.5% in 1973. It was 1.5% in 1992, as well. Oil imports, the other key determinant of the loss of U. S. wealth during a price shock, supplied 35% of U. S. oil use in 1973 and peaked at 46% in 1977. U. S. petroleum imports were 44% in 1993 and averaged 46% through the first 10 months of 1994 (U. S. DOE/EIA, 1995a, table 1.8). Of course, the U. S. now has the strategic petroleum reserve, 592 million barrels of oil to be drawn on in a supply emergency. The real issue for world oil prices is total world stocks, however. In 1973 petroleum stocks held by Organization for Economic Cooperation and Development (OECD) countries amounted to 2.6 billion barrels, about 44 days of total world consumption. At the end of September 1994, OECD stocks totaled 3.7 billion barrels, equal to to 57 days of world oil use. Government-owned reserves accounted for nearly all of the increase, totaling 919 million barrels or 14 days additional supply (U. S. DOE/EIA, 1995c, tables 1.1c, 1.3 and 1.6). If used properly the additional reserves will help, but are unlikely to prevent a determined supply reduction by OPEC nor protect the U. S. economy from its effects.

Finally, the potential future costs of monopolistic oil supply and supply curtailments are explored using a simple simulation model. Beginning with a U. S. Department of Energy forecast as a Base Case, a two-year supply reduction comparable in size to those of the past, is simulated. Such a supply cutback, beginning in 2005, is likely to cost the U. S. economy half a trillion dollars. The Strategic Petroleum Reserve, indeed, the strategic stocks of all OECD countries combined, appear to be an ineffective defense against such a supply reduction. Increasing the short- and long-run elasticities of oil demand and supply by 50% to 100% on the other hand would be an effective strategy. This, however, would require major advances in the technology of transportation energy use and liquid fuels supply.

1.2 IS THE WORLD "RUNNING OUT OF OIL"?

The answer to this question seems patently obvious: Yes, the world's oil resources are ultimately finite and subject, eventually, to being exhausted. But we are interested in a different question: is the economic theory of exhaustible resources the appropriate theoretical context for analyzing the world oil market today? Interestingly, the answer to this question turns out to be no. Leading oil market economists have concluded that the brilliant theory of depletable resources developed by Hotelling (1931) is not particularly useful to describe the world oil market, primarily because it pertains to a strictly limited, known quantity of oil. As Adelman (1990, p. 9) has pointed out over and over again,

> "Oil reserves are not a one-time stock to be used up, but an inventory, always being consumed and replenished by investment, in new and especially in old fields."

The basic result of the Hotelling analysis is that in the long run the net price of oil (price minus marginal extraction costs) will rise steadily at the rate of interest.

Despite several noteworthy efforts to modify the Hotelling model to capture the reality of the world oil market (e.g., Stiglitz, 1976; Gilbert, 1978; Alsmiller, et al., 1985; Marshalla and Nesbitt, 1986), it remains an unrealistic representation of the nature of oil resources

(Watkins, 1992; Banks, 1986). Mabro (1992, p. 3), has fingered perhaps the most critical issue.

> "The geophysical limits may bite one day, but this day of reckoning is so far ahead as to have, on any conceivable assumption about discount rates, no impact on price."

This view has been echoed most recently by Gordon (1994, p. 4) who points out that in most cases resource exhaustion is not a pressing problem either because the exhaustion costs are too low to matter or because the constraint on resources is nonbinding.

History is very instructive with respect to false fears about resource depletion. Yergin (1991, pp. 51-52) described the situation facing the Standard Oil Trust in the early 1880s.

> "There was always the fear that the oil would run out. ...And who knew when? Could the industry survive even another decade?...Various experts cautioned that the Oil Regions would soon be depleted. In 1885, the State Geologist of Pennsylvania warned that 'the amazing exhibition of oil' was only 'a temporary and vanishing phenomenon--one which young men will live to see come to its natural end."

Adelman (1989, p. 19) made the following acerbic observation about U.S. reserves in the second half of the twentieth century.

> "No area in the world is as drilled-up today as this country was (excluding Alaska) in 1945; 'Remaining recoverable reserves' were 20 billion barrels. In the next 42 years; the 'lower 48' produced not 20 but 100 billion, and had 20 billion left. Equally important, there was no increase in real cost before 1973;"

> "Was this 100-billion barrels-plus, and stable costs, a miracle, like Moses striking the desert rock to get water? Hardly. The lesson is that oil reserves are not a fixed stock to be allocated over time, but an inventory, constantly consumed and replenished by investment."

Considering the reserves of the OPEC countries, one finds that putative "exhaustion dates" are so far in the future that it is hard to conceive how they could be relevant to OPEC pricing policy. At 1992 production rates, the proved reserves of Saudi Arabia would last 85 years, those of Kuwait 250 years, the U.A.E's 115 years, Iraq 135, Iran 75, and Lybia 40 years, according to *Oil and Gas Journal* estimates. Discounted at any reasonable market rate of interest, dollars 100 years from now are not worth much in comparison with dollars today.

Furthermore, Middle East OPEC countries can expand their reserves with little effort. Finding costs which, in non-OPEC areas are usually a significant component of production costs (Adelman, 1986b), in the Middle East are trivially low, as the Deputy Secretary General of OPEC has noted (Al-Chalabi, 1988c, p. 231).

> "Thirdly, the cost of finding a new barrel of oil in the Middle East is so low as to be an economically irrelevant factor, compared with the cost of finding one barrel outside OPEC. It is estimated that the cost of finding one barrel in the non-OPEC area is generally between $5 and $8, whereas in the Middle East is always less than $1 and could be as low as 10-20 cents." (1988 dollars, one assumes)

If oil is not an "exhaustible resource" then a much simpler model of world supply and demand can be used to understand the world oil market. Furthermore, there is no imperative that oil prices rise over time in a competitive market. This point is crucial because if it is not the inexorable economics of exhausting the world's oil resources that causes world oil prices to rise then it must be something else, and that something else turns out to be the exercise of monopoly power.

1.3 THE DISTRIBUTION OF WORLD OIL RESOURCES

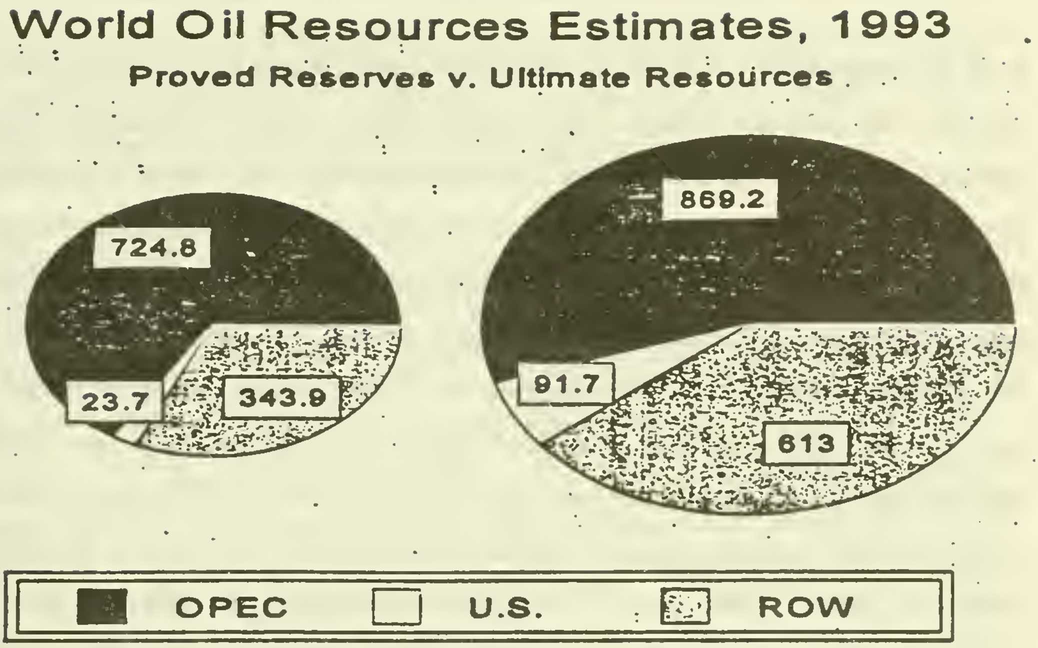
By accident of geological history, the majority of the world's oil reserves are concentrated within the borders of a relatively few nations. The member states of OPEC hold the lion's share of world oil resources by any measure. The *Oil and Gas Journal* estimates that OPEC countries contained 77% of the world's 996 billion barrels of proved reserves of crude oil. *World Oil*, which puts reserves in the former USSR 130 billion barrels higher has OPEC's share at 66% of 1,092 billion barrels (U. S. DOE/EIA, 1994c, table 36). Although there is no standard international definition of proved reserves, these estimates generally reflect crude oil resources that have been discovered and are economically and technically feasible to produce at prices similar to those prevailing in recent history. Certainly there are more petroleum resources in the world than reflected in the proved reserves estimates.[2]

Best estimates of the world's ultimately recoverable petroleum resources, discovered and yet to be discovered, however, also show OPEC dominance. The U. S. Geological Survey's world petroleum assessment puts "World Ultimate Resources" of oil at 2.3 trillion barrels, of which about 0.7 trillion barrels have already been produced. This leaves 1.6 trillion to be recovered, 60% more than reflected in proven reserves (Masters, Attanasi, and Root, 1994). Of the estimated remaining ultimate resources, OPEC countries hold just over 55% and the U.S. just under 6%.[3] At present, OPEC nations are producing at a rate of about 1% of their ultimate resources per year. The rest of the world, however, is drawing down their resources at an average rate of 1.9% per year. The trend is clear: an increasing OPEC share of world oil resources and of world oil production.

[2]Although acknowledging some uncertainty in their estimates, petroleum geologists seem confident in their general level. "We believe that, worldwide, recoverable conventional oil and gas exist in ultimate quantities approximating 2300 billion barrels (370 Gm^3) of oil and 12000 trillion cubic feet (340 Tm^3) of gas. These values are limited by our concepts of world petroleum geology and our understanding of specific basins; nonetheless, continued expansion of exploration activity, around the world, has resulted in only minimal adjustments to our quantitative understanding of ultimate resources." (Masters, Attanasi, and Root, 1994)

[3]The most recent U.S. Geological Survey (1995) assessment of technically recoverable resources puts the total slightly higher, at 112.6 billion barrels up from 91.7 billion barrels. Although a significant change for the U.S., this is only about 1% of the total world estimates.

Figure 2.



Source: U. S. DOE/EIA, 1994 c, Table 36; Masters, Attanasi, and Root, 1994, Table 1

Although world petroleum resources are ultimately finite, the world is not imminently "running out of oil" (Gordon, 1994). At 1992 consumption rates, the 1.6 trillion barrels of ultimate resources would last 65 years. There are, in addition, vast unconventional oil resources in the form of extra heavy oils, tar sands, and oil shale. Extra heavy oil deposits in the Orinoco province of Venezuela and tar sands in Western Canada together are judged to be equivalent to 0.6 trillion barrels of crude oil, roughly the proved reserves of the entire Middle East. These two deposits alone would add another 25 years at current consumption rates. Difficulty of recovery and processing, and adverse environmental impacts will increase the cost of these resources, however. The problem is not one of "running out of oil," it is rather a problem of the costs and environmental impacts of oil use.

1.4 THE INELASTICITY OF WORLD OIL SUPPLY AND DEMAND

After the concentration of resources within the boundaries of a few countries, the most important fact about the world oil market is the inability of supply and demand to respond quickly to shocks. Put another way, the short-run elasticities of oil demand and supply are very small relative to their long-run elasticity. The evidence is very consistent on this point: long-run oil market elasticities are about ten times greater than short-run elasticities (Table 1, below; Huntington, 1991, table 4; 1994, appendix; Greene, 1991, table 1). It is difficult to overemphasize the importance of this for understanding the operations of the oil market and the role of the OPEC cartel in it. It explains why prices can double or triple as a result of very small changes in supply. It explains why monopoly pricing of oil can yield enormous profits for several years, but only at the expense of market share and the erosion of monopoly influence (Adelman, 1986c, p. 325). It explains why the most profitable strategy for the OPEC oil cartel is a series of price shocks sandwiched between years of lower prices (Suranovic, 1994). There is a relatively high degree of consensus on this point in the literature and recent studies show the same magnitudes for price elasticities as older studies.

The most comprehensive assessments of oil market supply and demand elasticities have been conducted by the Energy Modeling Forum (Huntington, 1991; 1993). These provide a consensus that the short-run elasticity of oil demand is less (in absolute value) than -0.1, and that the long-run elasticity is less than -1.0.[4] At an oil price of approximately $30/bbl., short-run price elasticities of demand in Huntington's 1993 study of nine major world oil models, range from -0.027 to -0.115, with a mean and median of -0.075. Long-run price elasticities of demand ranged from -0.157 to -2.544, with a mean of -0.562 and median of -0.437. Gately and Rappoport (1988) estimated a U.S. oil price elasticity of demand of -0.07 for one year and -0.38 over a ten-year period. In a recent simulation study, Huntington (1994) used short- and long-run elasticities of -0.06 and -0.6, respectively to represent both OECD and

[4]Throughout this paper, short-run applies to a period of one year.

non-OECD countries. Suranovic (1994) reports short-run price elasticities of -0.09 for the U.S., -0.06 for Japan and Europe, and -0.02 for the rest of the world outside of OPEC. A more recent study by Gately (1992) produced a short-run U.S. price elasticity of -0.066, while the short-run elasticity in developing economies was -0.01.

Oil supply is also very inelastic in the short-run. In Huntington's (1994) recent simulation analysis he chose supply elasticities of 0.04 and 0.4 for short- and long-run responses to represent both OECD and non-OECD supply. Suranovic (1994) reports values of 0.05 for U.S. short-run supply elasticity, 0.01 for Canada and Europe, and 0.05 for the rest of the world outside of OPEC. A previous assessment by Huntington (1991) of supply elasticities in eleven world oil models found average short-run elasticities of 0.05 for the U.S., 0.05 for the OECD, 0.03 for total non-OPEC world oil supply. The corresponding long-run elasticities were 0.39, 0.43, and 0.40. Again, these were calculated at oil prices in the vicinity of $30 per barrel. Al-Sahlawi (1989) reports an estimated supply elasticity for major non-OPEC producers of 0.03 for the short run and 0.60 for the long run.

These patterns of oil price responsiveness give the OPEC cartel enormous scope to influence oil prices in the short-run, but far more limited monopoly power over the longer term. This fact is crucial to understanding the past and possible future of the world oil market.

1.5 THE MONOPOLY POWER OF OPEC

The fact that OPEC, or at least a core group within OPEC, has acted as a monopolistic cartel in the past is widely accepted by oil market economists. The process by which from OPEC's inception in 1960 the member countries wrested control and ownership of their oil resources from foreign concession holders has been chronicled by Yergin (1991, Chs. 22-29). This together with the tightening of the world oil market in the early 1970s set the stage for the dramatic exercise of OPEC market power in the first oil price shock of 1973-74, when an

Arab OPEC cutback of 5 million barrels per day produced a net supply shortfall of 4.4 million barrels per day (Yergin, 1991, p. 614) and a tripling of the real price of oil.

Although OPEC does not control the entire world oil supply, it still has considerable monopoly power. In reality, absolute monopolies are rare. Even the Standard Oil monopoly at its peak in 1880 controlled 90%, not 100%, of U.S. refinery capacity (Yergin, 1991, p. 95). An additional complication is that OPEC is not a single entity but a cartel of sovereign states.[5] Technically, OPEC is an imperfect monopolistic cartel of the von Stackelberg type (Mabro, 1992). A von Stackelberg monopoly holds a large enough market share to influence prices, but its monopoly influence is limited by a nontrivial amount of competitive supply. Dr. Fadihl J. Al-Chalabi, Deputy Secretary General of OPEC described OPEC's role in just this way (Al-Chalabi, 1988b, p. 115).

> "As the only structured group of sellers in the world energy trade, OPEC can take pricing and production decisions which have a far-reaching impact on the world energy market. Other energy sellers are scattered in separate entities, with no common, coordinated policy action other than the objective of securing and maintaining a market share at a price high enough to allow them to continue investing in the industry."

This is as precise a definition of a von Stackelberg cartel as one could ask for.

OPEC looks like a cartel and talks like a cartel, but does it act like a cartel? Empirical studies by Dahl and Yücel (1991), Jones (1990), and Griffin (1985) have rejected the hypothesis that OPEC's behavior is consistent with that of competitive producers. Griffin clearly and concisely summarized the results of his empirical analysis (1985, p. 962).

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[5]Webster's Ninth New Collegiate Dictionary defines a cartel as, " 2 : a combination of independent commercial or industrial enterprises designed to limit competition or fix prices." Substitute states for commercial or industrial enterprises.

> "Perhaps the most striking aspect of the empirical tests is the clear-cut nature of the results. First, among OPEC countries, the partial market-sharing cartel model could not be rejected for all 11 countries, whereas frequent rejections are observed for the other theories. Second, in terms of the ability of the various models to explain production, the partial market-sharing cartel model dominates the competitive model. Third, in comparisons with 11 non-OPEC countries we observe the opposite tendency--the competitive model could not be rejected for 10 of the 11 non-OPEC producers."

The basis for the conclusions of these formal statistical tests is obvious from an inspection of the oil production data of OPEC core members. When real prices tripled from 1973-1975, Kuwait, Lybia, Iran, and Saudi Arabia all *decreased* rather than *increased* output. Again in the 1979-1982 period, while oil prices skyrocketed as a result of lost supply from Iran and Iraq during their bitter war, all core members consistently cut back production (Figure 3; U. S. DOE/EIA, 1994a, Table 11.5). Competitive producers would have *increased*, not *decreased*, production in response to higher prices. OPEC producers cut production in order to maintain the high price. But by cutting production, OPEC members eventually weakened their own market power, leading to a reduction of revenues.

The gradual erosion of revenues and loss of market power finally led to a collapse of the cooperation among OPEC members necessary to restrict output, and the price "collapse" (to long-run monopoly price levels) in 1986. The head of OPEC's Energy Studies Department described the process as follows.

> "Against such a background, OPEC found it increasingly difficult to stabilize the oil market, maintain strong prices and prevent a large-scale decline in its revenues, from a high of $287 bn in 1980 to $131 bn in 1985. The decrease in revenues occurred in spite of strenuous efforts to maintain prices, by continually scaling down OPEC production and the institution and maintenance of production quotas for Member Countries since April 1982." (Al-Fathi, 1990, pp. 2-3; current $, one assumes.)

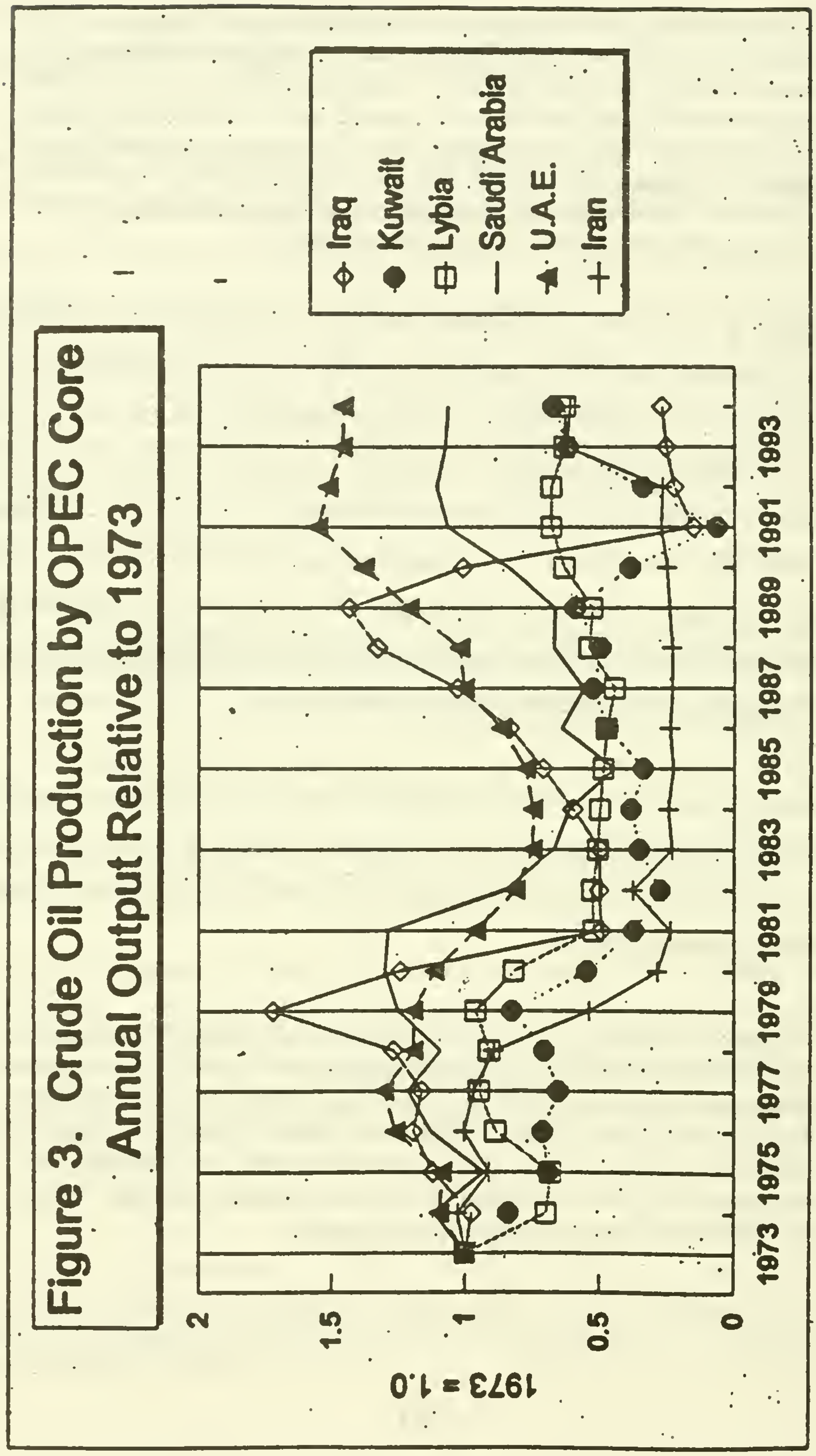

Figure 3. Crude Oil Production by OPEC Core Annual Output Relative to 1973

Dr. Subroto, then Secretary General of OPEC offered the same view of the collapse of oil prices following OPEC's defense of high prices after the 1979-80 shock (Subroto, 1989, p. 7).

> "Since then, we have resorted to a range of agreements aimed at achieving equitable, sustainable levels of price and production in a stable operating environment. This has almost always involved our Member Countries sacrificing market share for the good of all producers and consumers. As mentioned earlier, this ultimately became too much of a burden, most notably in 1986 when the international oil price structure collapsed."

Not only has OPEC acted as a cartel, but it has earned enormous profits by so doing. Dr. Al-Chalabi, Deputy Secretary of OPEC recounted the windfalls produced by the 1979-80 and 1973-74 oil price increases (1988a, p. 5).

> "OPEC's income from oil rose from about $136 billion a year to the staggering figure of about $287 billion during the same period. This must have aggravated the economic impact of the 'first oil shock,' when OPEC's oil revenues rose from about $24 billion in 1972 to about $120 billion in 1974." (Again, one assumes current $.)

Finally, if OPEC producers were competitive, their marginal production costs should at least approximately satisfy the competitive market conditions that marginal costs of production equal the market price. Detailed and careful analyses by Adelman (1986; Adelman and Ward, 1980), have shown that this condition is not close to being satisfied. For example, in 1978 the investment needed to develop an incremental barrel of oil in the U.S. was 69 times what it was in Saudi Arabia (Adelman, 1986, p. 389 and table 1). Updating Adelman and Shahi's (1989) estimates of OPEC's finding and lifting costs for oil, Dahl and Yücel (1991) concluded that in all OPEC countries except Nigeria and Venezuela, costs were $2.20 per barrel or less (1993 $). Venezuela and Nigeria's costs were estimated to be less than $4 and Saudi Arabia's certainly less than $1 per barrel. With prices far above marginal costs, competitive producers would expand output. But OPEC members did not, and are not.

> "But there was obviously massive restraint in Saudi Arabia. The sum of marginal capital and operating cost...was about 1% of the price of $12.70." (Adelman, 1986, p. 391)

Several estimates have been made of what oil prices would be if the world oil market *were* competitive. The most recent estimate by Griffin and Vielhaber (1994) put the competitive market price at $7.25 per barrel ($6.60 per barrel in 1990 $). Other estimates include Adelman's (1989) $6.25 per barrel, Morison's (1987) range of $6.25 to $7.70 and Brown's (1987) range of $8.50 to $11.10 per barrel (all converted to 1993 $). All are obviously well below market prices since 1973.

To summarize, OPEC talks like a monopoly, acts like a monopoly and takes its monopoly profits to the bank. That OPEC has exercised and can exercise monopoly power in world oil markets means there is, *ipso facto*, a massive market failure in the world oil market. Furthermore, to correct the market failure probably requires collective action on the part of consuming nations, since the actions of individual consumers by themselves are not likely to have sufficient impact. This is important, because it implies that neither private conservation in response to higher monopoly prices nor private hedging in anticipation of future price shocks (such as should occur in futures markets) will correct the market failure.

But what of OPEC dissension and disarray? Has not the Persian Gulf War permanently poisoned relations among OPEC members? Perhaps. However, if there are hundreds of billions of dollars to be made, it would be prudent to remember Morris Adelman's admonition.

> "The rewards of monopolizing the world oil industry have been so huge that the OPEC nations will make strenuous violent efforts to maintain it. The Iran-Iraq war was a great help in a difficult decade. So is the Iraqi aggression, which has shut down two major producers. If the cartel collapses, it will reappear, perhaps with a partly different membership. Whenever they settle their differences they can cut production, and raise the price." (Adelman, 1990, p. 12)

That the OPEC cartel has exercised and can exercise monopoly power in world oil markets by cooperating to curtail production is widely accepted (see, e.g. Griffen and Vielhaber, 1994; Jones, 1990; Adelman, 1990b; Griffen, 1992; 1995; MacFadyen, 1993). Instances of cheating are literally exceptions that prove the rule. As owner of two-thirds of the world's proven reserves and supplier of half of the world market, OPEC's potential to use market power is rarely disputed. Those who argue that OPEC has not been effective in using its potential monopoly power in the past (e.g., Bohi and Toman, 1993) have been confused by the dynamics of monopoly power in slowly adjusting markets. Recent studies (Suranovic, 1994; Greene, 1991; Wirl, 1985) have shown that extreme price shocks are inevitably followed by the waning of monopoly influence with the loss of market share, and that loss of market share leads to lower prices. But at lower prices lost market share is recaptured in time, and monopoly influence restored.

Basic economic theory applied to the history of world oil prices proves to be very enlightening. Economic theory demonstrates that in a static market a monopolist maximizes profits by charging a price, P, that exceeds the cost of production, C, (including the normal return to capital).

$$\frac{P}{C} = \frac{1}{\left(1 + \frac{1}{\beta(P)}\right)} \qquad (1)$$

In reality, it is very rare for a monopoly to control 100% of a market. For a monopoly controlling a large share, $0 < s < 1$, of a market, things are a bit more complicated. The profit maximizing price depends on the price elasticity of demand, but it also depends on the monopolist's market share, as well as on the ability of competitors to respond to a reduction in supply by the monopolist (Greene, 1991). In equation (2) which defines the profit maximizing price for such a partial monopolist, μ is defined as the change in quantity supplied by competitors for a one unit increase in supply by the monopolist. Here, it is the negative of the number of barrels supplied by the ROW for a one barrel-per-day reduction in supply by OPEC.

$$\frac{P}{C} = \frac{1}{1 + \left(\frac{1}{\beta(P)} s \; (\mu(P)+1)\right)} \tag{2}$$

This equation has several important features. Like equation (1), the larger β is, the smaller the ratio P/C. Also, the smaller the monopolistic share, s, the smaller P/C. This is very important for understanding the recent history of world oil prices. As OPEC loses market share in defending higher prices, its profit maximizing price *must* fall. Put another way, its monopoly power, defined as the ability to raise prices without loss of profit, declines. Finally, the more responsive the ROW oil supply, μ, the smaller P/C. If the ROW can meet OPEC's supply reductions barrel for barrel, *at the same price*, the cartel has no monopoly influence over prices. Supply responsiveness is a direct function of the price elasticity of supply, as one would expect (Greene, 1991).

The large difference between short-run and long-run oil market price elasticities implies that the cartel can force prices much higher in the short-run than can be maintained in the long-run (Greene, 1991; MacFadyen, 1993). In the short-run, P/C ratios may exceed 5. In the long-run they are probably less than 2. Thus, small supply shortfalls on the order of 10% or less can create enormous price shocks in the short-run, but such price levels cannot be maintained in the long-run. To maintain high prices, the cartel must sacrifice market share. But as it gives up market share it gives up the ability to maintain high prices. Ultimately prices must fall to long-run monopoly levels (or somewhat higher in a growing market).

There is no way out. Maintaining prices at short-run profit-maximizing levels requires loss of market share which eventually requires lowering prices. Retaining market share requires lowering prices. This pattern is clearly evident in the history of oil prices and OPEC market share of the 1970s and 1980s. In Figure 4 oil price is plotted against the market share of the

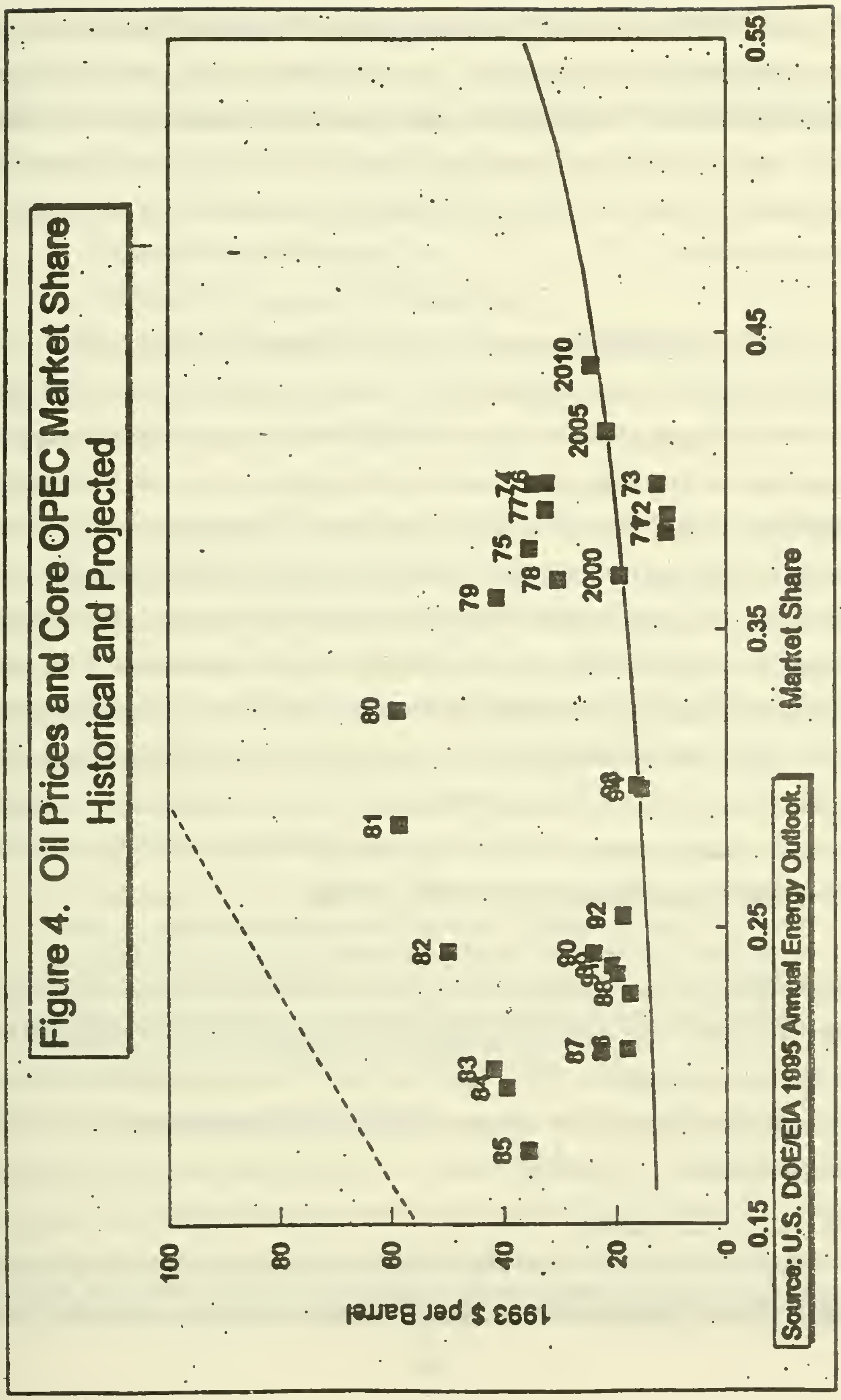

Figure 4. Oil Prices and Core OPEC Market Share
Historical and Projected

OPEC core nations: Saudi Arabia, Kuwait, Iraq, Iran, the United Arab Emirates, and Lybia. Years are identified by their last two digits. Curves representing the long-run and short-run P/C ratios as functions of the core OPEC nations' share of the world market have also been plotted. The curves have been drawn using consensus elasticity estimates based on the energy economics literature.[6] The 1972 world oil price is assumed to be the competitive price (c) for all years.

The 1972 and 1973 oil prices appear to fall below even the long-run monopoly price curve, given OPEC's market share. The price shock of the last quarter of 1973 and 1974 raised prices above the long-run curve but well below OPEC's short-run profit-maximizing price. In a growing world market, prices just above the long-run curve can be maintained indefinitely at a constant market share. This appears to be approximately what was happening from 1974 to 1978. In 1979 and 1980, spurred by the oil supply disruptions due to the Iran-Iraq War, prices rocketed towards short-run profit-maximizing levels. Sustaining these price levels in 1981, 1982, and 1983 cost OPEC dearly in market share. With profits and market share continuing to dwindle in 1984-85, the OPEC resolve cracked. Prices were lowered to approximately the long-run monopoly price level where readjusting economies and economic growth are now building OPEC market share back towards its previous level. Department of Energy forecasts of OPEC market share in 2000, 2005, and 2010 are included to illustrate the expected trends (U.S. DOE/EIA, 1995b).

Studies by Wirl (1990) and Suranovic (1994) have shown that a pricing policy of brief price shocks of two years or so in duration, separated by periods of lower prices may well be a profit maximizing strategy for OPEC. This is bad news for consuming nations since price shocks reduce GNP, tend to increase unemployment and transfer national wealth to oil producing countries.

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[6]Because short-run elasticities are so small, curves cannot be drawn based on the assumption of constant elasticities. Elasticities must be an increasing (in absolute value) function of oil price. We assume linear supply and demand equations, which satisfy this requirement, and the same parameters as Table 1 below.

1.6 IMPACTS OF MONOPOLY BEHAVIOR ON THE U. S. ECONOMY

A sudden increase in the price of oil creates three principal types of economic losses to the U. S. economy:

1. Loss of the potential to produce,
2. Macro-economic adjustment losses, and
3. Transfer of wealth from U. S. oil consumers to foreign oil exporters.

These three effects are separate and additive.

When oil prices rise, they signal the economy that a basic resource has become more scarce. As a result, the economy is able to produce less output with the same resources of capital, labor, materials, and land. The impact of this loss of potential output or GNP, will be greater in the short-run than in the long-run because greater substitution for oil is possible in the long-run. The implications for the economy's long-run potential to produce have been described by Tatom (1993) and many others (e,g, Pindyck, 1980; Burgess, 1984; Pakravan, 1984; etc.).

> "Oil and energy price changes affect the economy because energy resources are used to produce most goods and services. As a result, a rise in their price will (1) raise the total cost of an efficient producer's output, (2) alter the most efficient means for producing output, (3) lower the profit-maximizing level of output, (4) raise the long-run equilibrium price of output, and (5) reduce the capacity output of each firm's existing stock of capital."

In the short-run, the technology embodied in energy using capital cannot be adjusted immediately to the new price regime. It is obvious from the short-run inelasticity of oil demand that the economy's ability to quickly substitute away from oil remains very limited. Even in the long-run, oil demand appears to be inelastic. In the short-run, losses are magnified by the fact that it takes time to optimize the economy is energy-using technology to the new scarcity of oil. How long does it take? Consider the typical life of transportation equipment: 10-15 years for an automobile, much more for a jet aircraft, locomotive, or ship. Additional time is needed to develop designs incorporating more efficient technology and bring these designs to market. Indeed, if prices fall again within a few years, the economy will never fully adjust. This short-run versus long-run potential GNP effect is distinct from macroeconomic adjustment losses.

When prices rise rapidly, additional transitory costs result because wages and prices are not able to adjust sufficiently rapidly to the new oil price regime to permit the economy to operate at full employment. **Macroeconomic adjustment losses** are in addition to the loss of productive capacity that would occur even were the economy at full employment. Because of stickiness in wages and prices, the economy is unable to immediately adjust to a sudden increase in the price of as important a commodity as oil. These cyclical losses are truly transitory, perhaps lasting only about one year (Tatom, 1993, p. 132). Their effect is to temporarily amplify the loss of output capacity.

Third, when prices are increased by monopoly behavior, there is also a **transfer of wealth** from U. S. oil consumers to the owners of foreign oil. This "loss" is a transfer payment. It is not a loss of economic output, which distinguishes it from the two economic losses described above. The wealth still exists, ownership is simply transferred from U. S. citizens to foreign oil producers. A similar transfer of wealth also takes place within the U. S. from oil consumers to owners of U. S. oil resources. Since this is internal to the U. S. we do not count it as a loss to the U. S. economy.[7] The transfer of wealth is exactly equal to the quantity of oil the U. S. imports times the difference between the monopoly price and the competitive market price of oil.

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[7]Nonetheless, it is likely to be perceived as a social problem, as the Windfall Profits Tax on oil imposed during the 1970s attests.

All three effects have been recognized by economists for some time. Pindyck (1980, p. 19) estimated a 0.25% loss of U.S. potential GNP for a 10% increase in the price of oil, based on "back-of-the-envelope" calculations, and also asserted that the indirect, or macroeconomic adjustment effects would be of roughly equal magnitude. He also noted that the cost of an energy price shock depends on the energy cost share of GNP and that, in the short-run at least, it would be reasonable to assume no substitution possibilities as an approximation. Thus he assumed that the short-run elasticity of GNP with respect to an energy price shock would equal the negative of the energy cost share of GNP. Tatom (1994, p. 134) also noted the relationship between the impact of oil prices on output and the oil cost share of GNP as well as the fact that the oil cost share today is about what it was in the 1970s.

> "While energy use per unit of output is lower than earlier, economic theory indicates that the responsiveness of prices or output to a change in a resource's price are proportional to the share of the resource's cost in total cost, not to the share of its quantity in output."

Empirical estimation of the impact of oil price shocks on U.S. GNP was carried out by Mork and Hall (1980a, 1980b). In response to the 70% increase in energy prices in 1974 and additional 30% increase in 1975, they estimated that U.S. GNP fell 2.5% in 1974, about 5% in 1975 and 4.5% in 1976. They concluded that,

> "...the energy price shock appears to explain about three quarters of the recession, in terms of decline in real output in 1974 and 1975, and most of its shortfall thereafter." (Mork and Hall, 1980a, p. 45).

Findings by Mork and Hall (1980b) for the 1979-80 price shock were similar: a 1% decrease in GNP in 1979 and a 4% decrease in 1980.

Hickman (1987) used fourteen major macroeconomic models to estimate the impact of a 50% oil price shock, occurring in 1984, on U.S. GNP. He found short-run responses ranging from -0.010 to -0.047, with an average of -0.028. This would imply an average elasticity of twice that amount, or -0.056, very much in line with both theory and statistical evidence. The oil cost share of U.S. GNP in 1984 was 0.044, which would imply an elasticity for lost output in 1984 of -0.044, leaving -0.012 as the macroeconomic adjustment cost component for that year. Using a small model of the world oil market, Helkie (1991) simulated the impacts of past price disruptions and concluded that an estimate of the elasticity of GNP with respect to oil price of about -0.03 replicated past events well.

Bohi (1989, Ch. 3) claimed to show that a theoretical upper bound on the impact of an energy price shock on potential GNP was so small that the empirical and model-based estimates cited above could not possibly be correct. He obtained a maximum impact of 0.7% in 1974 and 0.36% in 1979-80. Greene and Leiby (1993), however, showed, and Bohi has acknowledged, that these results were due to an error in his calculations, and that the correct answers were 5% for 1974 and 2.5% for 1980. These estimates, of course, are very consistent with all the published estimates from Pindyck (1980) on.

Hamilton (1983; 1985) investigated the historical relationship between oil price shocks and rejected the hypothesis that oil price shocks were statistically uncorrelated with economic recessions. He also rejected the hypothesis that other factors, including monetary policy, could have caused oil prices to rise before recessionary periods. Examining the historical events believed to be responsible for oil price shocks, he concluded that, "...we must give causal interpretation to the correlation between oil prices and output" (Hamilton, 1985, p. 115). More recently, Moosa (1993) concluded that there was a significant relationship in which oil price caused output to decline but not the reverse. He observed,

> "The results are in general hardly surprising: they are in agreement with the basic theory and confirm the conclusion derived from the informal examination of the data." (Moosa, 1993, p. 1151)

Recently, Mork, Olsen and Mysen (1994), estimated macroeconomic responses to oil price increases in seven OECD countries from 1967 to 1992. They found an elasticity of U.S.

GNP with respect to the price of oil of about -0.05 to -0.07, essentially the same as studies using only data from earlier oil price shocks. Only Norway did not show a negative impact of oil price increases on GNP. The authors concluded,

> "Overall, our results seem to leave no doubt that oil-price fluctuations must be reckoned with as a significant force in the shaping of business cycles of the leading market economies. This force must be expected to persist as long as oil remains an important energy source." (Mork, Olsen, and Mysen, 1994, p. 34)

Oil prices doubled from July to October 1990, but declined relatively quickly as Saudi Arabia and the U.A.E. boosted production to eliminate the supply shortfall caused by loss of output from Kuwait and Iraq. Taking into account the shorter length of this price shock, Tatom examined the question of whether its impact on the U.S. economy was disproportionately smaller than previous shocks. He found that it was not.

> "Thus, another lesson from the 1990-91 price changes is that the economy appears to remain exposed to oil price shocks to a nearly equivalent extent as earlier." (Tatom, 1994, p. 148)

The transfer of wealth from oil consumers to owners of foreign oil that occurs when monopoly power is exercised in world oil markets is sometimes neglected because it is not a loss of economic output, but only a transfer of ownership. The output is still produced, it is just a question of who owns what. Oil consumers get poorer, oil producers get richer. If one's concern is with the welfare of the entire world, transfer of wealth is entirely a question of equity, not economic loss. But if one's concern is with the U.S. economy, wealth transfer is a genuine loss. Wealth leaves, and if it comes back, it comes back only in exchange for more U.S. output or property.

> "An international oil shock also reduces the purchasing power of U. S. national income.

> "Even if total U. S. output remains unaltered by the oil shock, the U. S. economy would still be worse off due to the reduction in the purchasing power of its domestic income." (Huntington and Eschbach, 1987, p. 202)

Precisely the same phenomenon has been described by Hogan and Broadman (1988, p. 65). Mork, Olsen, and Mysen (1994, p. 20) also mention the transfer of wealth as a cost of oil price shocks.

That the transfer of wealth is not included in the loss of output (GNP) has been explained by Greene and Leiby (1993) and Huntington and Eschbach (1987, pp. 199-200).

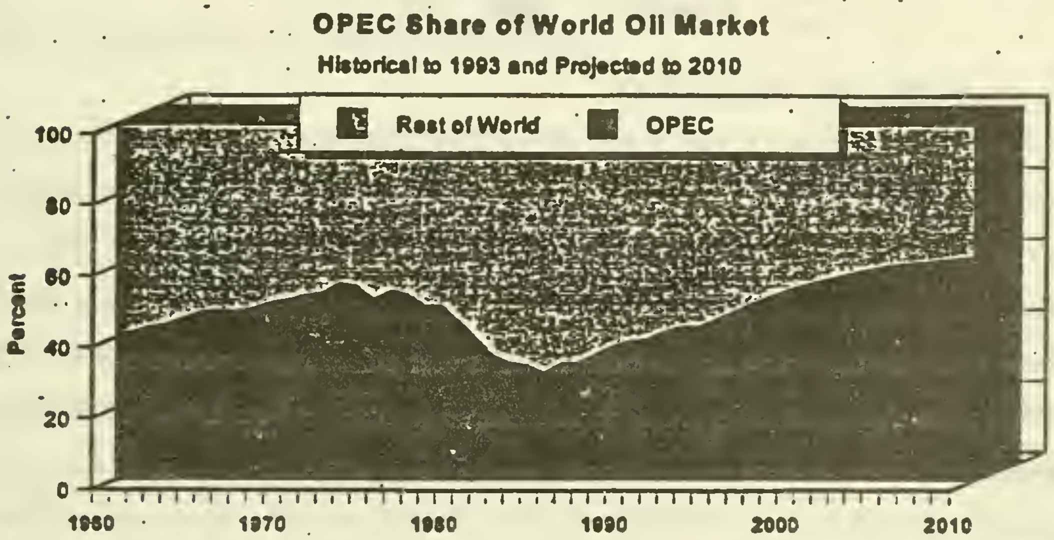
> "In particular, the oil wealth loss that is central to the microeconomic analysis is excluded from real GNP as measured in macroeconomic models. This situation requires a combination of losses estimated from each approach if one wants to measure the full effects of oil price shocks on oil-importing countries."

Finally, the transfer of wealth as a cost of oil dependence derives from the fact that it results from the exercise of monopoly power by oil producers. If there were no monopoly behavior in world oil markets, there would still be some transfer of wealth, in the form of rents, to low-cost oil producers. In a competitive market, this would not be counted as a cost of oil dependence to the U.S. Thus, in estimating the transfer of wealth cost in the monopolized oil market, only the cost over and above a competitive market price is counted.

1.7 THE FUNDAMENTALS HAVE CHANGED LITTLE SINCE 1973

Since 1973, the basic determinants of U.S. vulnerability to monopoly behavior in world oil markets have changed less than one might think: 1) OPEC's market share has fallen but is on the rise; 2) oil demand, now more concentrated than ever in the transport sector, remains price inelastic; 3) the oil cost-share of GNP is about what it was before the first oil price shock; and 4) the level of U.S. imports, key determinant of the transfer of U.S. wealth, is as high as ever. OPEC's monopoly power depends on its share of low-cost world oil resources and its correspondingly large share of the world oil market, as well as from the inelasticity of short- and long-run world oil supply and demand. Market share OPEC lost defending high prices from 1980-85 is being rapidly regained. It appears that reports of OPEC's demise have, in the words of Mark Twain, been greatly exaggerated. Lost market share can and is being regained, and with it comes market power. The Energy Information Administration (U. S. DOE/EIA, 1995b) projects that by 2005, OPEC's market share is likely to exceed the levels of the 1970s (Figure 5).

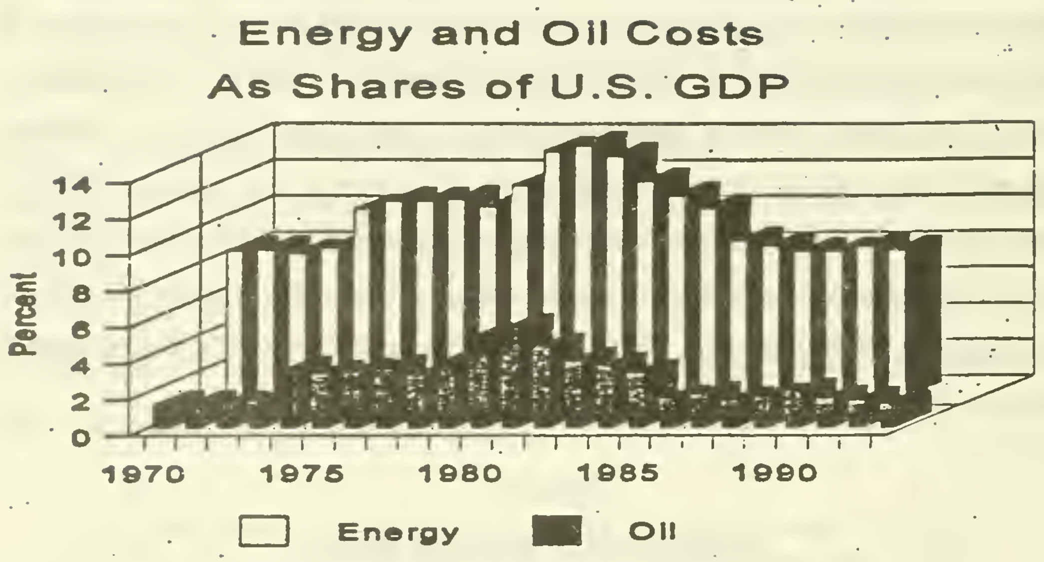
Figure 5.



Source: U. S. DOE/EIA, 1995b, Table C.20, 1994a, Table 11.5

The sensitivity of the economy to oil and energy price shocks depends on the cost shares of oil and energy in GNP. Intuitively, the more one spends on oil, the more a proportional increase in its price will reduce output. Though the economy's dependence on energy and oil since 1981 has been significantly reduced, it is now about the same as it was at the time of the first oil price shock. In 1973 the net cost of oil to the U. S. amounted to 1.5% of GDP. In 1992 oil's cost share was 1.5%, and decreased to 1.3% in 1993 (Figure 6). Energy costs

Figure 6.

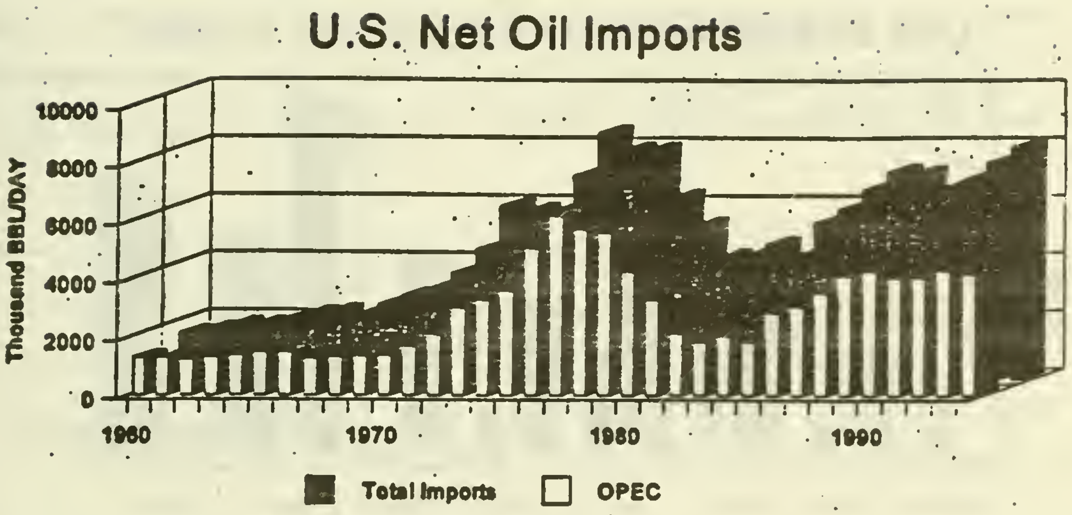


Source: U.S. DOE/EIA, 1994, tables 3.2, 3.5, 3.6.

amounted to 8.3% of GDP in 1973, and in 1992 energy costs comprised 8.2%. To be sure, energy and oil costs rose during the late 1970s and early 1980s with the price of oil. They will rise again with future oil price hikes. The important point is that oil's importance to our economy is about the same as it was twenty years ago, before the Arab OPEC oil embargo of 1973-74. The uses of oil have changed somewhat, increasing the importance of transportation oil use as other sectors moved away from oil.

The transfer of wealth from U. S. consumers to foreign owners of oil depends directly on the level of U. S. imports. Current levels of U. S. oil imports are higher than those preceding the first oil price shock in 1973-74 and almost equal to the highest level on record: 46.5% in 1977. U. S. oil imports have been rising since 1982 and are expected to continue to rise in the future (Figure 7). The EIA predicts that U. S. imports will increase from their current level of 45% of U. S. consumption into the range of 58% to 67% by 2000, and from 58% to 77% by 2010. Greene and Leiby put the transfer of U. S. wealth due to monopolistic oil pricing from 1972-1991 at over $1 trillion. A given OPEC price hike in the future will

Figure 7.



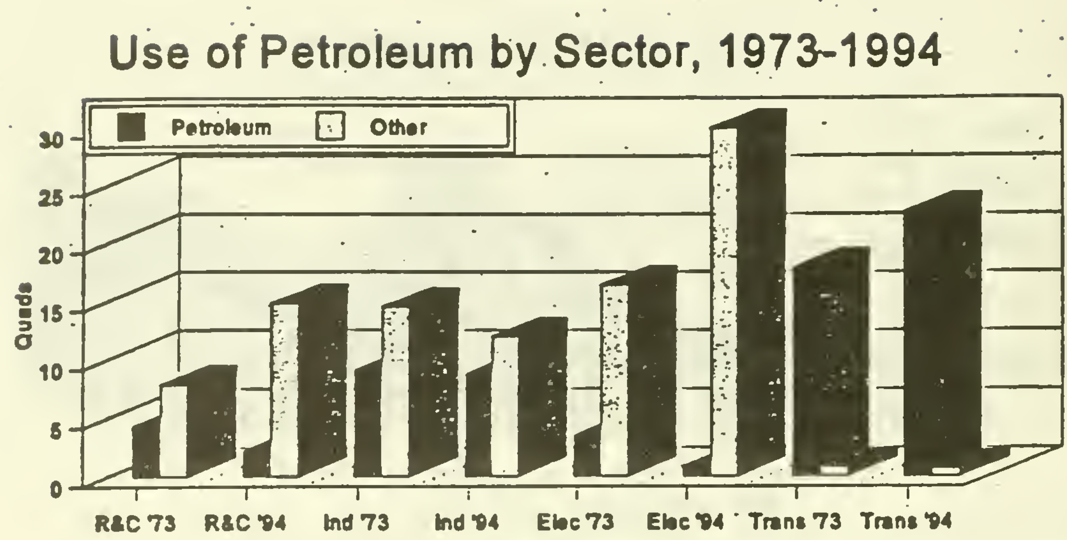
Source : U.S. DOE/EIA, 1994a, table 5.7; 1995a, table 1.8.

almost surely cause a greater loss of U.S. wealth than in the past because the U. S. will be importing more oil.

Oil use is now highly concentrated in the transport sector where fuel demand is known to be price-inelastic. Transportation is at the center of the United States' petroleum problem for three reasons. First, the transportation sector is far and away the dominant consumer of petroleum products, accounting for two-thirds of U. S. oil use in 1993. In terms of the light products that drive the petroleum market, transportation's share is more than three fourths. Second, whereas other sectors over the past twenty years have shown some ability to substitute other energy sources for oil, transportation has not (Figure 8). Third, the transportation sector is all but totally dependent on oil for energy. Pipelines using natural gas or electricity are the only significant nonpetroleum energy users.

Finally, some argue that oil futures markets significantly reduce or even eliminate the costs of monopoly oil pricing and price shocks to the U.S. The purpose of futures markets is to allow oil consumers to hedge, in effect buy insurance, against the possibility of future price

Figure 8.



Source: U.S. DOE/EIA, 1994a, table 2.1; 1995a, table 2.6.

increases (or decreases). Futures markets did not create the possibility of hedging: that always existed in the form of stockpiling, private insurance markets, etc. Futures markets make it easier to hedge, i.e., reduce the transaction costs. Thus, futures markets make it easier for oil consumers to insure themselves against the expected private costs of future price shocks. The key word is private.

Futures markets cannot internalize the public costs of oil use. Given that OPEC wields monopoly power in the world oil market, buying an additional barrel of oil makes a tiny increase in demand, resulting in a tiny increase in the price of oil and a tiny increase in the probability and size of a future oil price shock. All oil consumers experience this infinitesimal increase in cost. The fraction of the total cost that is born as private cost by the marginal consumer is a truly tiny fraction (one over the total number of barrels consumed). The private oil consumer will take no account of the benefits that would accrue to the nation if he reduced his oil consumption or if the price elasticities of oil supply and demand could be increased. Thus, the portion of the marginal social cost of oil that could be internalized by futures markets is negligible in comparison to the total. Futures markets cannot solve problems of public goods and bads. In fact, futures markets do not even try. Nearly all oil futures contracts are very short-term, a few months or less. Clearly this can have nothing to do with oil price shocks that might occur in 2005.

2. THE PRESENT AND FUTURE OIL PROBLEM

2.1 A SIMPLE SIMULATION MODEL

In this section, the likely impact of a future oil price shock on the U. S. economy is simulated. A simple model of world oil supply and demand was constructed in the form of a spreadsheet (see Appendix A for details). World oil demand is represented for two regions: the U. S. and the ROW (including OPEC). World oil supply is represented for three regions: OPEC, the U. S., and the ROW (excluding OPEC). OPEC supply is to be specified (exogenous), while the model solves simultaneously for U. S. and ROW supply and demand. A dynamic adjustment specification is used to represent short- and long-run adjustment to price changes. The EIA's *Annual Energy Outlook 1995*, (AEO) Reference Case provides a "Base Case" forecast. Price shock scenarios are produced by changing OPEC supply and using the model to compute a new market solution for U. S. and ROW oil supply and demand. The cost of monopoly oil pricing to the U. S. economy is then estimated based on techniques developed by Greene and Leiby (1993) to estimate the costs of monopolistic oil pricing from 1972-1991. These are described in detail in Appendix B.

Supply and demand equations are assumed to be linear, which implies that elasticities will be an increasing function of oil price (since both supply and demand are inelastic). Elasticities for the Base Case Simulation Model are shown in Table 1 as a function of world oil price.

Whether and when a future oil price shock will occur will depend on the desire and ability of OPEC nations to cooperate to restrict production. In addition, temporary price shocks can occur even without monopoly behavior if supplies are significantly disrupted by an act of

Table 1. Simulation Model Short-Run Elasticities

	Demand	Supply	
World Oil Price (1993 $/BBL)	U.S. and ROW	U.S.	ROW
$20	-0.037	0.028	0.023
$35	-0.068	0.048	0.032
$50	-0.099	0.067	0.056

war or nature. Because of this, the precise timing and size of a future price shock cannot be predicted. It is conceivable that OPEC nations may be unable to cooperate to restrain production. To say that there is mistrust among OPEC nations today is an understatement. Price shocks, however, are likely to be very profitable for OPEC countries (Suranovic, 1994) and as OPEC's share of the world oil market grows, the economic rewards to restraining production will also grow. If the pay-off is sufficiently large, it is reasonable to expect OPEC countries to search for ways to cooperate and to find a suitable apology for creating yet another oil price shock. Unless meaningful alternatives to petroleum use in transportation are developed, the 2000-2010 period will provide OPEC with both the opportunity and motive to create another oil price shock. The value to OPEC of a brief, two-year supply reduction of 10% the first year and 17% the second is likely to exceed half a trillion dollars.[6]

The consequences for the U. S. economy of another sustained price increase, such as that of 1979-1985, would be grave. The two-year price shock simulated below costs the U. S. economy over half a trillion 1993 dollars, discounted to present value (PV). This single shock nearly doubles the cost of monopoly oil pricing to the U. S. economy through 2010.

[6]The 10% and 17% reductions are relative to the year before the shock. They correspond to 13% and 21% reductions over what OPEC would otherwise have produced under the Base Case projection. Furthermore, OPEC cannot immediately return to previous production levels but must increase slowly from these restricted levels.

2.2 1993-2010 BASELINE FORECAST

The U. S. Department of Energy (DOE), EIA's 1995 *Annual Energy Outlook*, Reference Case Projections are used as the Base Case for analyzing the impacts of future oil supply reductions by OPEC.[9] The Base Case oil price projections call for oil prices to increase from \$16.12/bbl in 1993 to \$19.13 in 2000, \$21.50 in 2005 and \$24.12 in 2010. World oil demand grows at the modest rate of 1.7%/year, from 66.18 MMBD in 1993 to 88.32 MMDB by 2010. U. S. demand grows at a much slower pace, 0.7%/year through 2010. U. S. oil supply declines from 9.53 MMBD in 1993 to a low of 8.22 in 2005, but then begins increasing to 8.58 MMBD in 2010 as oil prices increase. The ROW oil supply increases gradually from 29.63 MMBD in 1993 to 33.07 MMBD in 2010, an average annual rate of 0.6%. The 1995 AEO does not present its assumptions about total oil production by China and former Soviet countries, but only shows the net exports from these countries. The Energy Information Administration's 1994 International Energy Outlook (U.S. DOE/EIA, 1994d, Table 3), however, does show production projections for China, the Former Soviet Union and Eastern Europe through 2010 that are generally consistent with the 1995 AEO Reference Case Projections. These project oil output in China growing from 2.84 MMBD in 1992 to 3.4 in 2010, an average growth rate of 1%, and former Soviet plus Eastern European countries increasing from 9.16 MMBD in 1992 to 11.4 MMBD, according to the 1994 IEO projections, an average rate of 1.2%. We use these growth rates in our simulation analysis. Sensitivity analysis indicates that the results of the simulations are not greatly dependent on this assumption.[10]

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[9] "Oil" production here includes crude oil, natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, alcohols, liquids from coal and other sources, and refinery gains. EIA projections do not include production for internal consumption in Eurasia but only Eurasian exports. An estimate of all Eurasian production is included in the simulation below. As a result, OPEC market share exceeds 50% in 2004 and reaches only 53% by 2010. If former Soviet countries and China become full participants in international trade, this would be more correct.

[10] For example, Griffen and Vielhaber (1994) propose an "aggresstive non-OPEC supply scenario" the "Key assumption" of which is that production by former Soviet Republics and China would increase to 19.2 MBD by 2010. This implies a 3.5%/yr. Rate of production growth for these countries.

With oil prices near the long-run monopoly price level and growing world demand, OPEC's share of the world oil market increases continuously throughout the Base Case forecast. Including Eurasian production for domestic consumption in our ROW Base Case reduces OPEC's market share in comparison with that reported in the 1995 AEO forecast, shown in Figure 8. OPEC's Base Case market share grows from 41% in 1993 to 46% by 2000, 51% in 2005, and reaches 53% by 2010. With growing volume and rising prices OPEC revenues more than double between 1993 and 2010. From $160 billion in 1993, OPEC gross revenues increase to $410 billion by 2010. OPEC grosses a total of $5.0 trillion (1993 $) over the forecast period with a PV of $3.5 trillion discounted at 4%/yr.

2.3 ALTERNATIVE SCENARIOS

Past oil price shocks occurred when wars or the deliberate actions of OPEC nations restricted the supply of OPEC oil to world markets. Following the 1973-74 and 1979-80 price shocks, OPEC nations continued to restrict their supply of oil to world markets in a deliberate effort to maintain high oil prices. As we have seen above, prices following the 1979-80 oil price shock were sufficiently high to result in a continuing erosion of OPEC's market share as oil supply and demand dynamically adjusted to the higher price regime. In 1991, Saudi Arabia and other producers intentionally increased oil production, resulting in a much briefer episode of higher prices. A plausible future oil price shock can be simulated by a similar reduction in OPEC oil supply in the context of an undisrupted, "Base Case" projection. Although it is not clear exactly how a future oil price shock will occur, analysis by Suranovic (1993; 1994) indicates that repeated shocks, each of approximately two years' duration would yield the maximum revenues for OPEC. For our purposes it is sufficient to demonstrate the impacts of a single plausible shock on world oil prices and the U. S. economy.

26-794 97 - 12

The price shock scenario assumes that all OPEC nations reduce their supply in the year 2005 by 10% over the previous year, or 13% over what they would have produced in 2005 according to the AEO projections. In the following year, they further reduce supply by 17% versus 2004, or 21% versus what they would have supplied under the Base Case scenario. OPEC is then assumed to begin gradually increasing supplies until in 2010 the supply reduction is 20.4% versus the Base Case. This pattern was chosen because it produces almost exactly the same revenues for OPEC in the years 2007-2010 as OPEC would have received in the Base Case. This diminishes the need to consider revenue gains or losses in years beyond the 1995 AEO forecast horizon of 2010.

The Energy Information Administration (U.S. DOE/EIA, 1994d, p. 22) recently published the results of the simulation of a shorter supply disruption, assumed to occur earlier, in the year 2000, at a Base Case oil price of $20.70. Three different levels of supply disruption were assumed: 4, 6, and 8 MMBD, corresponding to 11%, 17%, and 23% of OPEC's projected rate of production in 2000. The 4 MMBD disruption was assumed to last for only 6 months, the 8 MMBD for 9 months, and the 6 MMBD disruption was simulated for both 6 and 9 month durations. Because these disruptions last less than a year, their impact on annual prices will be proportionately smaller than our assumed supply cutbacks. In addition, the EIA assumes that 2 MMBD of surge capacity will be available, inside and outside of OPEC, to offset the supply disruption. That is, no monopoly behavior on the part of OPEC is assumed. The EIA simulation also assumes that the U. S. will draw down the SPR at rates of 3.5 MMBD in the first quarter, 1.1 MMDB in the second and 0.5 MMBD in the third (an annual average rate of 1.3 MMBD). Given all of the above, impacts were evaluated for four scenarios defined by use of the SPR, and assumptions about stock inventory responses and price elasticities (Table 2).

Because of the earlier occurrence, shorter duration, and absence of monopoly behavior, the EIA's supply disruption simulations differ from those presented below. On an annual basis, the 8 MMBD supply curtailment with 1 MMBD inventory build-up corresponds to a

Table 2. Oil Prices, EIA Simulation of 8 MMBD, 9-Month Oil Supply Disruption in the Year 2000

Scenario	SPR Not Used	SPR Used
1.0 MMBD inventory build-up + 10% lower elasticity	$54.50	$45.00
1.0 MMBD inventory draw-down + 10% higher elasticity	$37.60	$31.60

5.25 MMBD annual supply shortfall. On this basis, the market response to supply curtailments is comparable to those we present below. Prices rise to $54.50/bbl in EIA's simulation.

Nine additional scenarios are considered (Table 3). Two explore the effect of use of the Strategic Petroleum Reserve (SPR) on this sustained supply curtailment. Three others assess the impact of doubling world price elasticities of supply and demand assuming: 1) Base Case OPEC production, 2) Price shock OPEC production, and 3) OPEC aggressively cuts back on production so as to match OPEC's price shock revenues for as long as possible. These three scenarios are then repeated, assuming that only U.S. oil price elasticities double. Finally, for purpose of comparison, it is assumed that OPEC restricts production to the same levels as in the aggressive scenario with doubled U.S. elasticities, but the lower Base Case elasticities are assumed.

Table 3. OPEC Revenues and U.S. Economic Impacts Under Alternative Scenarios

(Billion 1993 $ Present Value, 1993-2010)

SCENARIO	U.S. GNP IMPACTS				OPEC REVENUES	
	Wealth Transfer	Potential GNP Loss	Macroeconomic Adjustment Costs	TOTAL	1993-2010	2005-2010
Base Case	469	454	51	974	3473	2260
Price Shock	606	710	186	1502	3858	2852
Strategic Petroleum Reserve	592	708	192	1492	3841	2827
Double SPR, Two Years	580	707	162	1449	3833	2814
Double World Elasticities	139	152	43	334	2294	1139
2X World + Price Shock	222	262	108	592	2486	1434
2X World, Aggressive OPEC	374	552	185	1111	2503	785
2X U.S. Elasticities	294	310	15	619	3008	1791
2X U.S. + Price Shock	341	471	109	921	3311	2259
2X U.S., Aggressive OPEC	194	688	234	1116	3337	2045
Base Elasticities, Aggressive	702	1150	413	2265	3870	2580

2.4 SIMULATION RESULTS

2.4.1 A Two-year Price Shock in 2005

The initial supply disruption is about the same size as those that occurred in 1973-74 and 1979-80. In 1980, OPEC crude oil production was 4 MMBD (13%) lower than in 1979. In 1981 OPEC cut output by another 4 MMBD for a 26% reduction over 1979's output level (U.S. DOE/EIA, 1994a). The quantity of oil assumed to be lost in 2005 is somewhat greater, 5.5 MMBD, but the percent reduction is also 13%. As a result of the OPEC cutback, oil prices more than double, from $21/bbl in 2004 to $54/bbl in 2005. To keep prices elevated, OPEC is assumed to cut 2006 output by a total of 21% over what it would otherwise have been. Still, the price of oil declines to $46/bbl as world supply and demand adjust and OPEC's market share falls. After 2006, OPEC is assumed to gradually ease up, allowing prices to drop to $28-30/bbl through 2010. Though past oil price increases lasted longer, this two-year shock is consistent with the types of price shocks Suranovic's (1994) simulation analysis found to be a profit-maximizing strategy for OPEC.

If OPEC were to return to the original Base Case production levels in 2007, prices would fall below the competitive long-run price of $10/bbl and OPEC revenues would plummet. Instead, it is assumed that OPEC expands production just enough to approximate the gross revenues it would have received in the Base Case in the years 2007-2010. The percent cutback is eased to 20.4% in 2010 over the Base Case. Holding revenues in the final years at approximately the same levels as the Base Case minimizes the problem caused by not having forecasts for years beyond 2010.

Responding to the higher prices, world oil supply increases in 2005 by 1.5 MMBD and world demand is 4 MMBD lower than the Base Case scenario. U. S. supply is 0.4 MMBD higher in 2005 and 0.7 MMBD higher in 2006. In comparison with the Base Case, U. S. demand is 1 MMBD lower in 2005 and 1.7 MMBD lower in 2006. Though prices drop to about $3 above the level of the Base Case, supply increases and demand reductions persist after the price shock due to the dynamic adjustment structure of the simulation model. World supply remains 2 MMBD above the Base Case, demand continues to be almost 6 MMBD below it. OPEC's market share falls from 50% in 2004 to 44% in 2006. From there it begins to recover as the cutback is trimmed (Figure 9).

The effect on OPEC revenues is substantial. In simple 1993 dollars discounted to present value (PV) in 2005 at 4%, the supply shock and subsequent strategy nets OPEC an additional $600 billion in gross revenues. This is a 25% increase over the Base Case revenues for the 2005 to 2010 time period (Figure 10). The general picture is little affected by alternative assumptions about oil supply costs and discount rates. Whether $600 billion over five years is sufficient incentive to OPEC members to cooperate on a supply strategy is an interesting question. Of course, profits might be further increased by an additional price shock, but such issues are beyond the scope of this report (Table 3).

2.4.2 Impact of Releases from Strategic Reserves

Use of the SPR is simulated by assuming a maximum drawdown in the first year of the shock. The SPR presently contains 600 million barrels of oil. If all were used over the period of a year, the average production rate would be 1.64 MMBD. Use of SPR is simulated by adding this to world supply for 2005 before recomputing the market equilibrium price. It is assumed that OPEC will not change its planned pattern of cutbacks in response to the SPR release. Perhaps surprisingly, this turns out to be a reasonable assumption.

The SPR release causes oil prices in 2005 to fall by almost $10/bbl versus the scenario without SPR. Thus, SPR mitigates the price shock of 2005. However, in 2006 there is no more SPR and, by assumption, OPEC goes ahead with its original planned cutback of 21%. Because prices were lower and supplies more plentiful in 2005 with the SPR release than

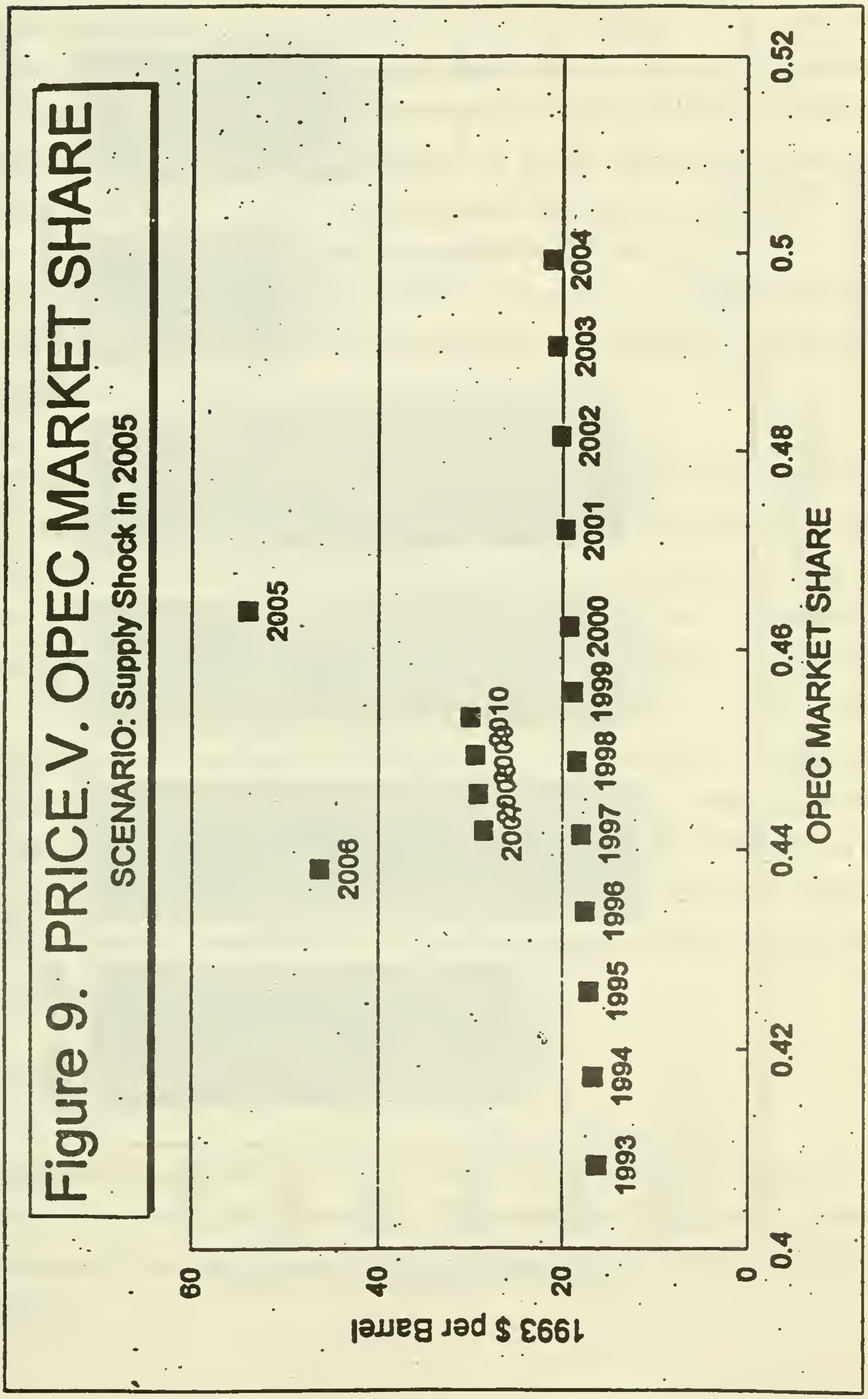
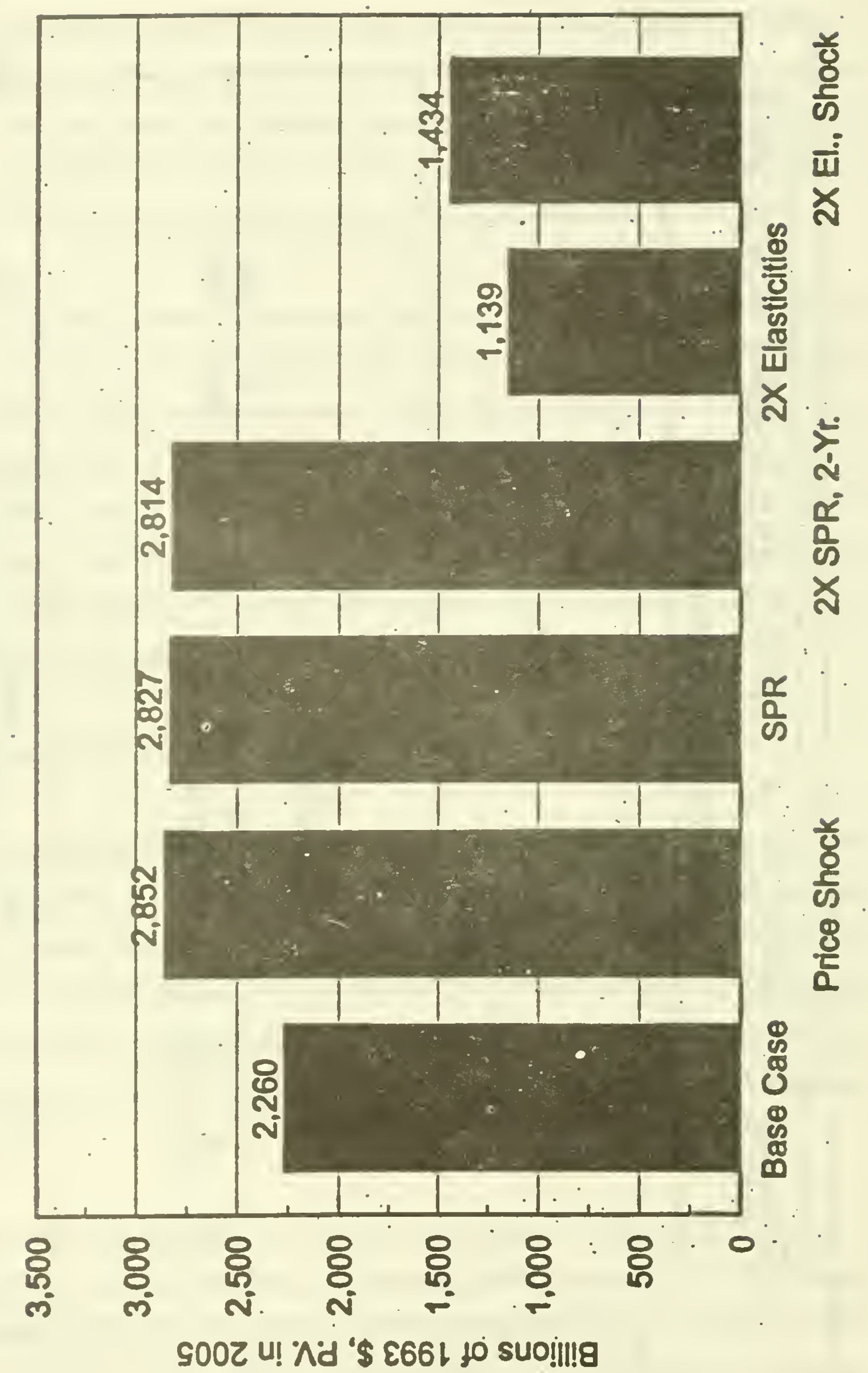


Figure 9. PRICE V. OPEC MARKET SHARE
SCENARIO: Supply Shock in 2005
1993 $ per Barrel
60
40
20
0
OPEC MARKET SHARE
0.4
0.42
0.44
0.46
0.48
0.5
0.52
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

Figure 10. OPEC Gross Revenues: 2005 to 2010
Alternative Scenarios



without it world economies adjust less than in the Price Shock scenario. As a result, the 21% supply reduction in 2006 causes a larger price shock than it would had SPR not been used. Instead of $46/bbl, 2006 prices after the SPR release jump to $55/bbl. After 2006, they are identical to the no-SPR scenario (Figure 11). In effect, the sequence of prices is changed but not the level. As a result, OPEC revenues and profits are little changed by the use of SPR in this way. Estimated gross revenues for the 2005-2010 period are only 1% lower. Used in this way, SPR would have little effect on a determined OPEC strategy to restrain production. On the other hand, during the first year it might have a discouraging effect on a cartel struggling to maintain consensus and discipline.

One could argue that SPR is not the only strategic reserve in the world and that other consuming nations might also release strategic reserves at the same time, magnifying the effect of SPR. Petroleum stocks held by OECD countries increased from 2,588 million barrels in 1973 to 3,665 million barrels in 1993, a net gain of just over 1 billion barrels. Nearly all of the change is accounted for by increased reserves held by the U. S. in the SPR and by Japan in strategic reserves (U. S. DOE/EIA, 1994a, table 11.11). If all of this additional reserve were released in the first year of the shock it would raise supply by an average of 2.95 MMBD. We explore the impact of a larger reserve by assuming that the U.S. has a second 600 million barrel reserve available for use in 2006. The effect of a doubled SPR used over two years is equally disappointing. The price of oil stays at $44/bbl. In 2005, drops to $45/bbl. In 2006, but then jumps to $37/bbl. In 2007 from $29/bbl., without the additional reserve.

2.4.3 Economic Impacts on the United States

Regardless of the assumed use of SPR, the two year supply curtailment costs the U. S. economy in excess of half a trillion dollars PV over the Base Case (Figure 12). Total losses to the U. S. economy in the price shock scenario amount to $1.5 trillion (1993 $) PV (Table 3).

Figure 11. World Oil Prices in
Base Case and Price Shock Scenarios

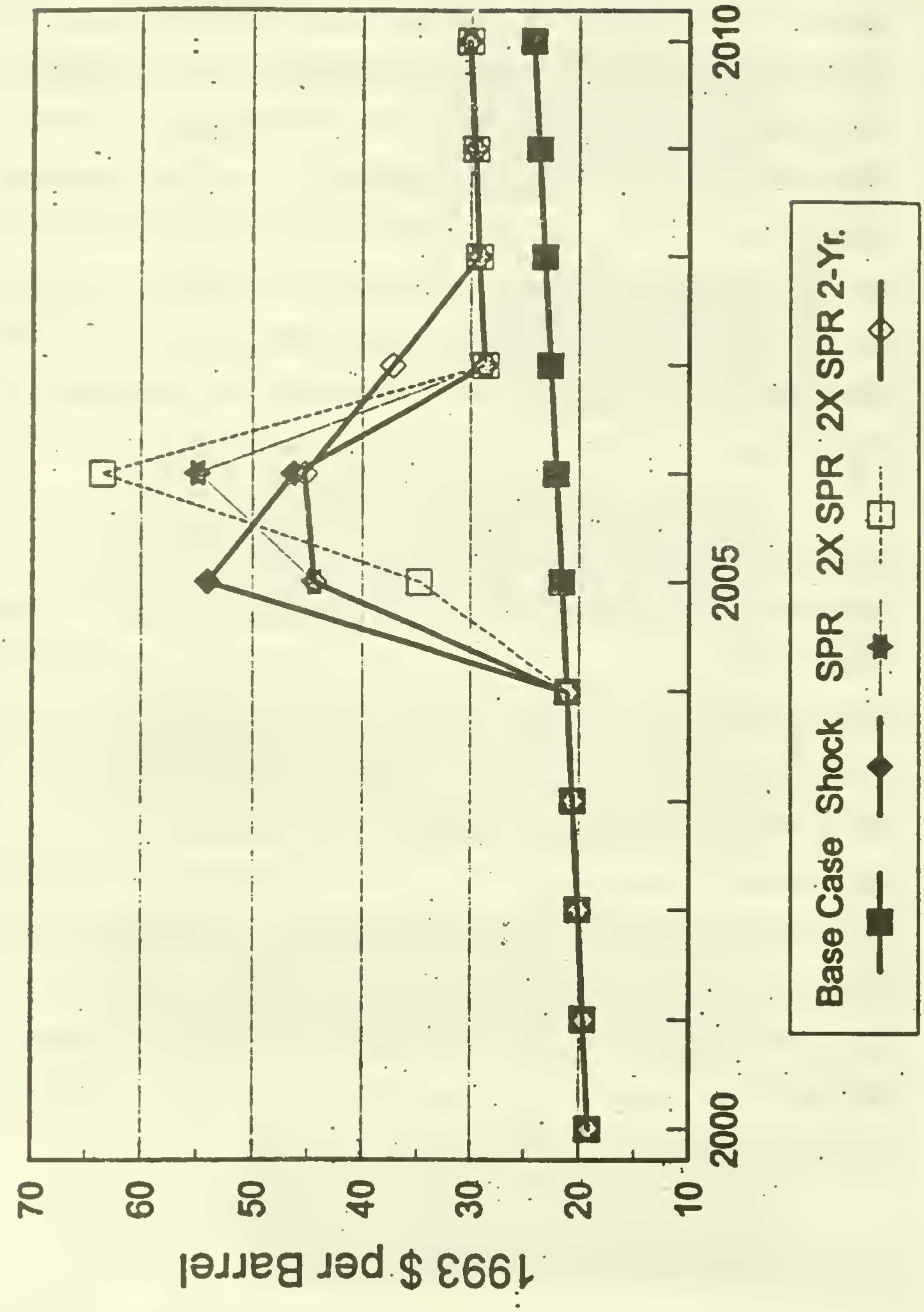
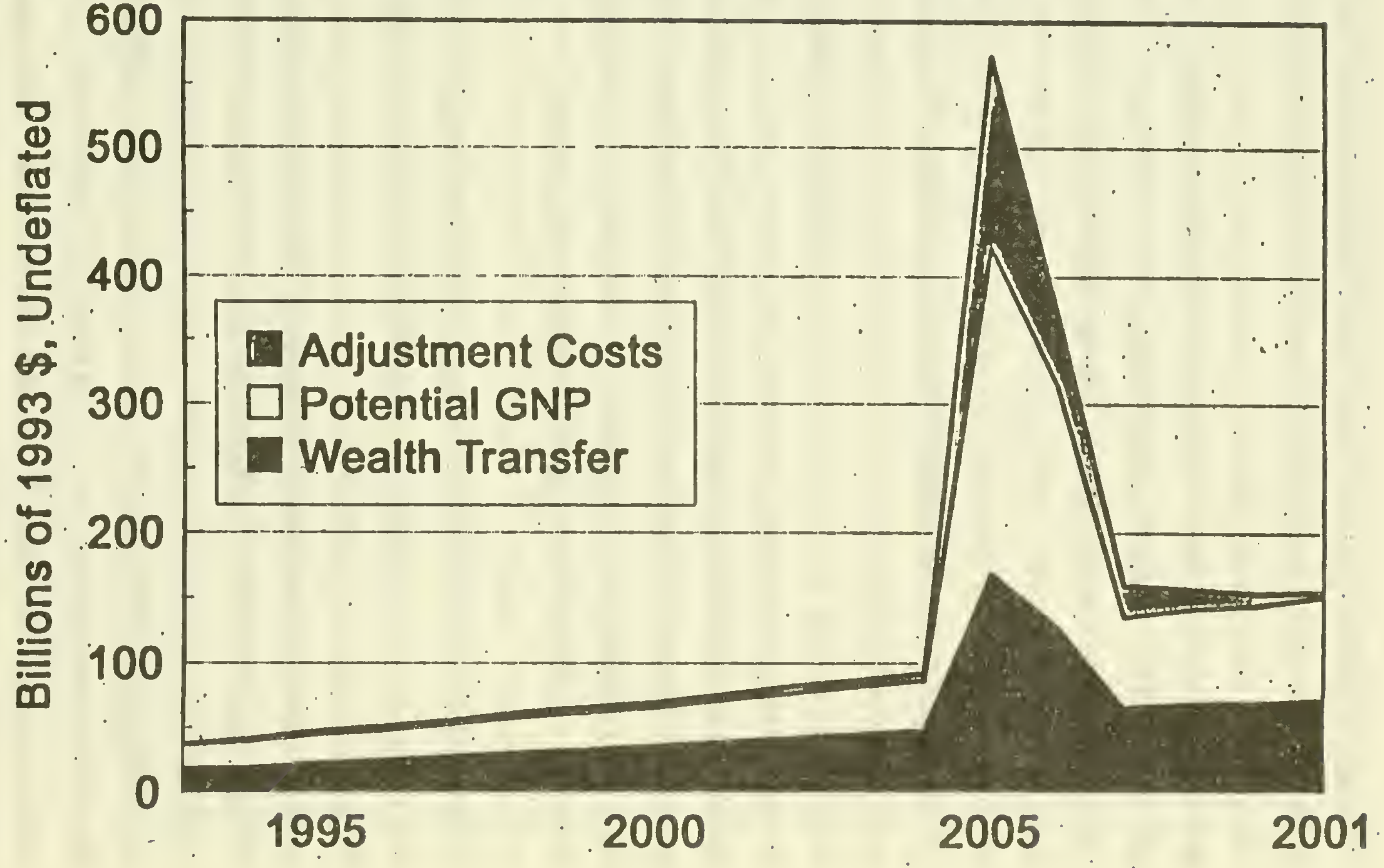


Figure 12. Costs of Oil Dependence to U.S. Economy: Price Shock Scenario



Assuming a hypothetical competitive market price of $10/bbl, the U. S. lost $18 billion in wealth transfer in 1993. By 2010, the U. S. economy would lose $33 billion PV in the form of wealth transfer in the Base Case. Discounted at 4%/yr. the PV of the estimated transfer of wealth in the Base Case through 2010 amounts to $470 billion. The single price shock in 2005-2006 increases this to $610 billion PV. In 2005 alone, $170 billion ($105 billion PV) is lost via wealth transfer. Half of that goes to OPEC, half to other world exporters.

In the Base Case prices increase gradually, but the method used here will always calculate some potential output losses as long as oil prices remain above the assumed competitive market level of $10/bbl. Slow, steady price increases might be accurately anticipated by the market, essentially eliminating all macroeconomic adjustment losses. In the Base Case estimated potential GNP losses amount to $140 billion PV and macroeconomic adjustment losses total $50 billion PV. In the price shock scenario, estimated potential GNP losses hit $160 billion PV in 2005 and $110 billion PV in 2006. Macroeconomic adjustment losses in those two years are $90 billion and $30 billion PV, respectively.

The effect of full use of the SPR in 2005 is estimated to be $10 billion, not counting profit, if any, on the sale of the oil. Estimated wealth transfer declines by $14 billion, potential GNP loss decreases by $2 billion, but macroeconomic adjustment losses increase by $6 billion. The explanation for the SPR's apparently small impact lies primarily in the fact that what is gained in the first year is lost in the second. Without the SPR release, wealth transfer losses are $105 and $75 billion PV in 2005 and 2006 respectively, for a two-year total of $180 billion PV. With the SPR release, estimated transfer losses are $70 and $95 billion PV in the two years for a total of $165 billion PV. If the price shock had lasted only one year, a savings of $35 billion PV would have been realized. As it continued into the second year, an additional $20 billion PV was lost in 2006 due to the use of the SPR in the previous year. The situation is similar for GNP losses. Estimated losses without the SPR total $160 billion PV in 2005 and $115 billion PV in 2006. With the release the estimates are $120 billion PV in 2005 and $150 billion PV in 2006. The sums of the two years differ by only $5 billion PV (numbers rounded to nearest $5 billion).

Doubling the SPR and releasing over two years produces a small additional benefit to the U. S. economy. The implication is that use of strategic reserves in this way against a determined multi-year supply reduction is neither an effective deterrent nor an effective protection for the economy.[11] These discouraging results corroborate the conclusions of an earlier analysis by Suranovic (1994), who found that reserves on the order of 30 billion barrels would be necessary to defeat a strategy of determined supply curtailment.

2.4.4 Increasing Price Elasticities

Given the dependence of OPEC market power on supply and demand elasticities, a logical strategy would be to enhance the ability of oil supply and demand to respond to higher oil prices. Increasing the short- and long-run price elasticities of supply and demand would reduce the impact of the price shock caused by a given supply shortfall, thereby cutting OPEC revenues and reducing the impact on the U. S. economy. Improving price responsiveness should therefore act simultaneously to deter OPEC from initiating a supply cutback and protect the U. S. economy in the event one occurs.

The impact of increasing the oil market's price responsiveness is illustrated by doubling the price elasticities of supply and demand and resimulating the effect of the two-year price shock and its impacts on the U. S. economy. Doubling price elasticites implies that the elasticity of demand at $28/bbl would increase from -0.053 to -0.106. The elasticities of

[11] Of course, in a simulation such as this the model's equations determine the results. We note, for example, that the value of an SPR would probably be greater if constant elasticity supply and demand equations were used instead of linear equations in which elasticities increase with increasing price.

supply at the same price for the U. S. would increase from 0.038 to 0.076.[12] Two scenarios are considered, one in which only U. S. price elasticities are increased and another in which ROW supply and demand elasticities are doubled, as well. The increase in elasticities is assumed to begin in 1996 and increase linearly over a decade until a doubling is achieved in 2005. As a result prices and oil quantities change for all years after 1995, not only those in which supply shortages occur.

Unlike the effect of strategic reserves, the effect of substantially increasing the price-responsiveness of the market is dramatic. Doubling the elasticities of supply and demand for the entire world cuts post 2005 OPEC revenues in half assuming the Base Case OPEC production levels (Figure 10). U. S. economic losses drop to $335 billion PV when world elasticities double, for an estimated benefit to the U. S. economy of $640 billion PV. If the strategy of supply curtailment is tried, OPEC still gets a $300 billion windfall versus no price shock, half the size of the price shock windfall at Base Case elasticities. Total economic losses for the price shock scenario are $1.5 trillion PV at base elasticities and $0.6 trillion PV if elasticities are doubled for a savings of nearly $1 trillion (Figure 13).

But what if OPEC aggressively tries to maintain its Base Case revenues in the face of increasing world elasticity of supply and demand? The answer is that it runs head on into the discipline of the marketplace. With world oil price elasticities at twice their present values, OPEC can maintain its Base Case revenues by cutting back on production only through 2002. By 2003 its market share has dwindled to 23% and it is not capable of raising prices, by cutting production, to a level sufficient to maintain its Base Case revenues (Figure 14). We assume that OPEC ceases cutbacks at this point, and maintains prices at $21/bbl through 2010. This strategy produces only $785 billion PV in revenues,

[12]Of course, this exercise also makes it clear that accurate short-run price elasticity estimates are the most critical element of this analysis. While the estimates used here are consistent with those used by others and produce a pattern of market behavior consistent with past experience, there remains uncertainty both with respect to their values at particular prices and the rate at which they change as price increases.

Figure 13. Costs of Oil Dependence to U.S. Economy: Price Shock & Doubled Elasticities

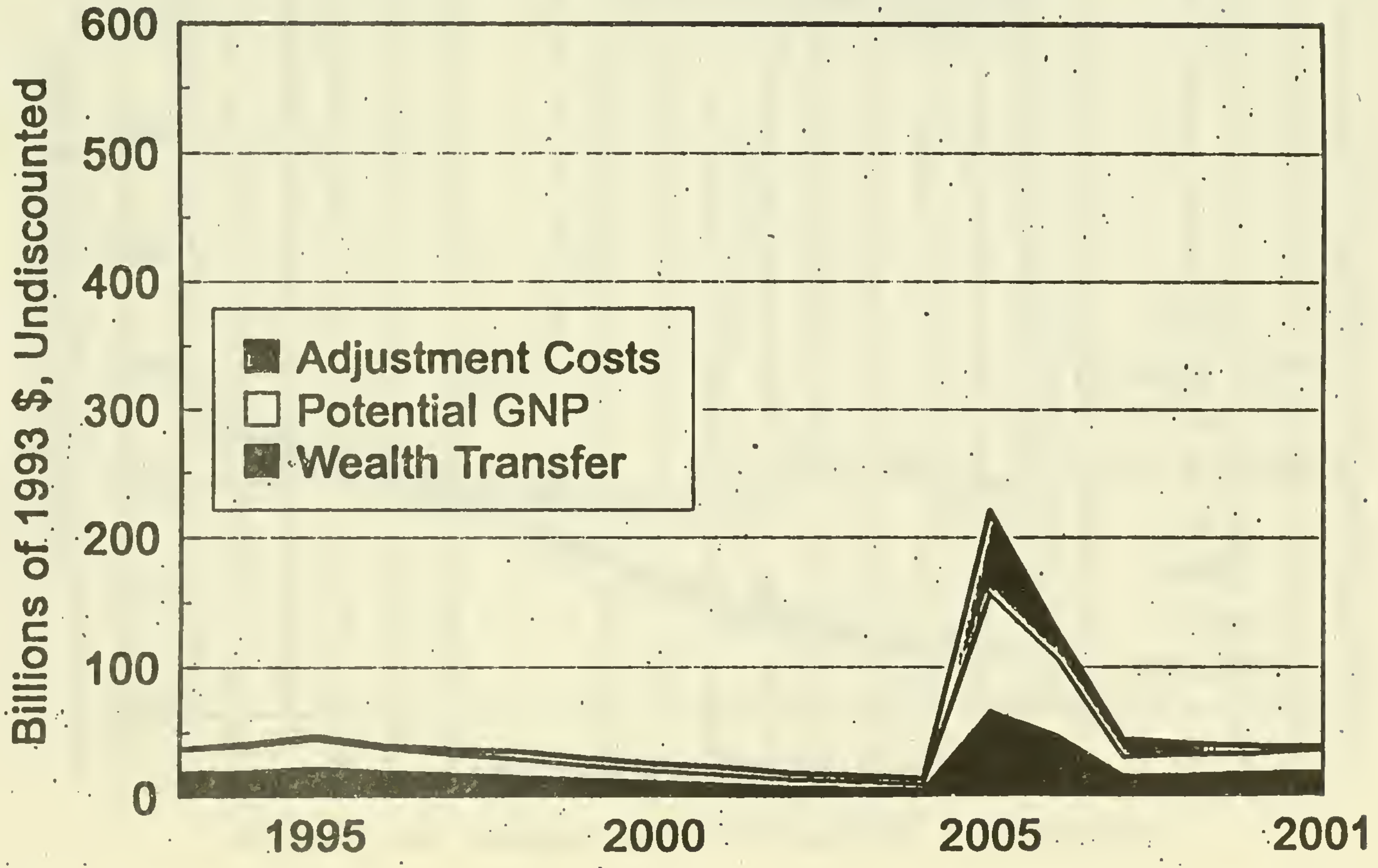
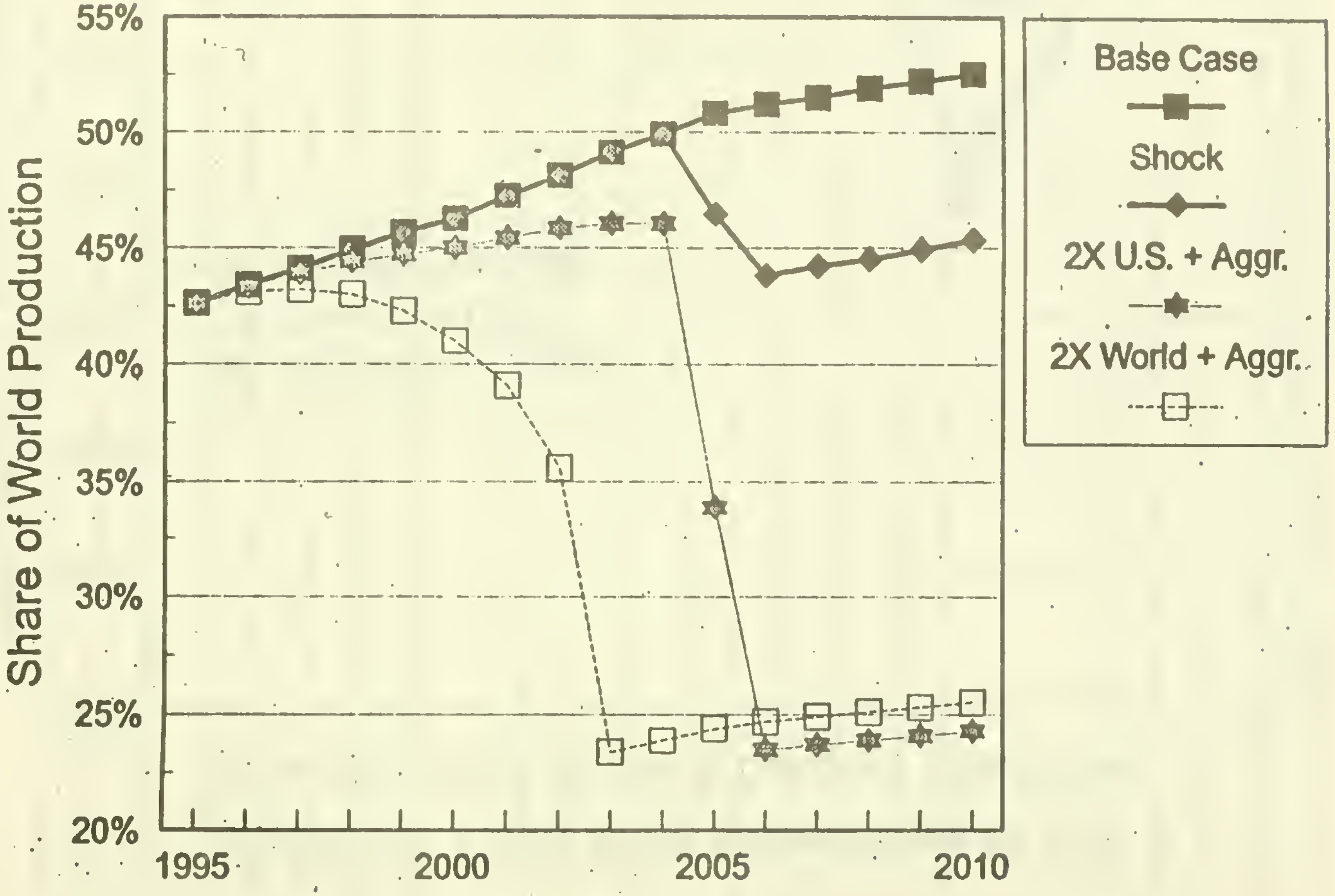


Figure 14. OPEC Market Share, 1995-2010

Alternative Scenarios



$340 billion PV less than the scenario in which Base Case production levels are maintained (Table 3). Costs to the U.S. are significantly higher, but this type of "retaliatory" behavior doesn't pay. The single price shock still works better, raising almost twice as much revenue. Harm to the U.S. economy is also much smaller.

If only U.S. oil price elasticities double, benefits are reduced but are still substantial. At Base Case OPEC production levels, the costs of U.S. oil dependence are reduced 35% or $350 billion PV (Table 3). Assuming the OPEC output levels of the Price Shock scenario raises U.S. costs from $0.6 trillion to $0.9 trillion, but this is still much lower than the $1.5 trillion in Price Shock scenario costs at Base Case Elasticities. If OPEC aggressively cut production, trying to achieve the same revenues as in the Price Shock case at Base Case elasticities, costs to the U.S. economy would increase to $1.1 trillion, slightly higher than the original Base Case with no production cut-backs. However, OPEC revenues are lower than in the Base Case and also lower than in the Price Shock case with doubled U.S. elasticities. If the same aggressive production cuts are made at the lower Base Case elasticities, estimated costs to the U.S. economy double to $2.2 trillion.

Increasing the oil market's price responsiveness is effective against the sustained supply disruption strategy because it simultaneously reduces the incentive for OPEC to create a supply disruption, diminishes the impact of that disruption on world oil prices, and increases the U.S. economy's ability to reduce oil use and oil imports. Increasing the U. S. elasticity of demand is almost equivalent to increasing the price elasticity of transportation oil use. Doubling this elasticity is obviously more easily said than done. Use of alternative fuels, substitute fuels, technology for rapidly increasing energy efficiency, and techniques for quickly improving the operating efficiency of transportation systems would probably all be required.

3. CONCLUSIONS

The United States' oil dependence problem is not one of running out of oil. It is a problem of the use of monopoly power in world oil markets by a few nations that hold the majority of the world's oil resources. In the past, the OPEC cartel has created or capitalized on disruptions in the world oil market, reaping hundreds of billions of dollars in monopoly rents from oil consuming countries. During the past decade, however, the cartel has been less effective. This has led some to conclude that conditions in the world oil market have materially changed and that oil dependence no longer poses the threat it once did (Bohi and Toman, 1993). Unfortunately, the majority of the evidence points to the opposite conclusion. It appears that the only important objective factor that has changed significantly is the market share of the OPEC cartel, a key determinant of OPEC's power in world oil markets. The geographical concentration of world oil reserves, together with trends in world production and consumption, indicate that lost market share will soon be regained. This is corroborated by recent trends and consistent with the best efforts to project the future. The potential for monopoly power in the world oil market remains because oil resources are still concentrated under the control of a few sovereign states.

Monopoly power in world oil markets is limited by the abilities of consumers and other oil suppliers to respond to higher prices and by the OPEC states' own ability to cooperate with one another. Consumers and suppliers have a much greater ability to respond to prices given sufficient time. As a result, a cartel's monopoly power is far greater in the short-run than in the long-run, a fact which has led to considerable confusion about the effects of monopoly behavior in world oil markets. It is very difficult within a single year to discover, develop, and produce new oil supplies or change the fuel economy of an entire fleet of cars. Given a decade or two, however, an entire motor vehicle fleet can be replaced, new technology can be developed, and new energy supplies brought to market. Very high short-run monopoly prices can therefore only be maintained by sacrificing market share and thereby market power.

It is useful to consider what has changed since the oil price shocks of the 1970s and 1980s since some claim that we are not likely to repeat the experience. The key factors are: 1) OPEC share of world oil production, 2) world short- and long-run price elasticities of demand and supply, 3) importance of oil and energy in the U. S. economy, 4) the level of U. S. oil imports, and 5) OPEC's ability and desire to cooperate. OPEC's share of the world oil market is lower today than it was in the 1970s. It is growing steadily, however, and is expected to reach 1970 levels sometime between 2000 and 2005. The current values of elastiticities of supply and demand, because they are usually inferred from historical data, are more difficult to determine. However, the most recent studies do not indicate that elasticities have increased over historical levels (e.g., Dargay and Gately, 1994). In the U. S., the concentration of oil use in the transportation sector as other, more "switchable" sectors have substituted other forms of energy for oil, suggests that demand elasticity has not increased. Finally, oil's cost-share of U. S. GNP, the key determinant of the impact an oil price shock will have on the U. S. economy, is about the same as it was before the first oil price shock in 1973. Recent estimates of the impact on the U. S. of the brief 1990-91 oil price shock indicate that the economy is as vulnerable as ever. As Tatom (1993, p. 148) concluded, "Thus, another lesson from the 1990-91 price changes is that the economy appears to remain exposed to oil price shocks to a nearly equivalent extent as earlier." Today, U. S. oil imports are within 1 percentage point of their highest level ever, and climbing. OPEC's resolve is more difficult to evaluate, especially for a period ten years in the future. The simulations presented here, however, suggest that there will be at least opportunity and motive for collusion.

The SPR does not appear to provide an effective defense against a sustained supply curtailment. For a multi-year episode, the effect of the SPR is to postpone the full impact of a sustained cutback in production, to reduce its benefit to OPEC by about 5% and to mitigate its impact on the U. S. economy possibly by even less. If OPEC is determined to cut production, it can apparently wait out the SPR releases and then reap the benefits of higher oil prices. Although SPR may be very effective against a temporary supply interruption, against a multi-year supply restriction it appears to offer neither a major disincentive to OPEC nor significant protection to the U. S. economy.

Both the benefit to OPEC and the cost to the U. S. of a sustained oil price increase, however, are quite sensitive to the short- and long-run price elasticities of petroleum demand and supply. If world price elasticities of supply and demand could be doubled, the estimated value of a two-year oil price shock to OPEC would be significantly reduced. The estimated cost to the U. S. economy of an OPEC supply curtailment would be cut by almost half. Doubling only the United States' ability to substitute away from petroleum in the event of a price increase, cuts the estimated impact of a price shock on the U. S. economy by one third. Moreover, when price elasticities are increased, benefits accrue continuously. With doubled price elasticities and Base Case production levels, OPEC revenues after 2005 are cut in half, and U. S. economic costs by two-thirds. Attempts by OPEC to maintain revenues in the face of growing price elasticity are likely to be counterproductive for their gross revenues.

Transportation accounts for two-thirds of petroleum use and 80% of high-valued light product use in the U. S., since transportation is 97% dependent on oil. Accordingly, increasing the elasticity of oil demand and supply amounts to increasing the transportation sector's price elasticity of oil demand, and increasing the price elasticity of supply of alternative transportation fuels and domestic petroleum. Increasing transportation's ability to substitute non-petroleum fuels, as well as improve vehicular and system operating efficiencies in the short-run, should be a very effective strategy against the economic costs of oil dependence. How to accomplish this end is beyond the scope of this paper.

If present trends continue, future price shocks appear likely. Price shocks can be very profitable to oil producers and consuming nations appear to have developed no adequate defense against them. It does not appear that strategic oil reserves could be maintained at levels sufficient to defeat a determined supply curtailment. Instead, the ability of the economy, especially the transportation sector, to respond to higher prices must be increased. The ability to substitute nonpetroleum fuels for oil, and the ability to increase vehicle and systems efficiency in the short- and long-run must be enhanced. Even if the U. S. pursues these goals on its own, the benefits are likely to be substantial. If the technology can be diffused to the rest of the world, the benefits will be multiplied.

The challenge for consuming nations is to find an effective strategy for countering monopoly behavior by OPEC, one that can be sustained during periods of low as well as high oil prices. This is not an easy task. When prices are low, there appears to be no oil problem. When price shocks occur, there appears to be a crisis. In fact, the same oil problem in different phases was there all along. There may now be time, while OPEC's market share is growing and while OPEC members are feuding, to prepare for the next oil price shock. If the U. S. can successfully prepare, the benefits may be counted in the hundreds of billions, if not trillions of dollars.

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APPENDIX A

The method for simulating oil supply impacts begins with an assumed state of the world oil market that is perturbed by a reduction of the supply of oil by OPEC countries. This means the model must be able to represent the world oil supply and demand response to an arbitrary reduction in OPEC supply. The world is divided into two demand regions, the U. S. and the ROW, and three supply regions, the U. S., OPEC, and ROW. To create a price shock, OPEC supply is reduced. At this point, demand exceeds supply at the Base Case market price. To achieve a market balance, price must be increased to depress demand and increase U. S. and ROW supply. Critical to this process is specifying the response of supply and demand to a change in oil price.

A.1 PRICE ELASTICITIES OF OIL SUPPLY AND DEMAND

Both oil demand and supply are known to be highly inelastic over a period as short as one year, but much more responsive over a longer period of time. A very commonly used mathematical formulation for representing an increasing response over time is the simple lagged or dynamic adjustment model. This model assumes that the change in demand, ${}_dQ$ (or supply ${}_sQ$), from period t-1 to period t is a fraction (λ) of the difference between the desired, or long-run, demand, ${}_dq_t$ (supply), that would prevail at the current price, P_t, and last year's demand (supply). Because the equations for supply and demand are structurally identical, the supply and demand subscripts are omitted, below.

$$\begin{aligned} Q_t - Q_{t-1} &= \lambda\,(q_t - Q_{t-1}) \\ q_t &= A_t + b\,P_t \end{aligned} \tag{A.1}$$

The constant A_t indicates factors other than price that determine demand (or supply) in year t, and b is the price slope of the supply or demand equation. Equation (A.1) can be readily solved for current demand (or supply) Q_t, as a function of price by substituing for q_t.

$$Q_t = \lambda A_t + \lambda b P_t + (1-\lambda) Q_{t-1} \tag{A.2}$$

From equation (A.2) it is clear that for each of four equations (supply and demand for both the U. S. and the ROW) two parameters are required: b and $0 < \lambda < 1$. The constants, A_t, can be directly computed from the Base Case quantities and prices, given b and λ.[13]

The literature is quite consistent on the point that the adjustment rate for oil demand and supply is very slow. Values of λ on the order of 0.1 are most common. There is also agreement that the short-run price elasticities of supply and demand are quite small, on the order of +0.03 and -0.06, respectively. Values found in the recent literature are shown in Table A.1. Most values given in the literature are specified in terms of price elasticities rather than price slopes, and constant elasticity formulations are common. In the linear dynamic adjustment model (A.2), the short-run and long-run price elasticities (β) depend on price and quantity consumed, as follows.

$$\beta_{SR} = b\lambda \frac{P_t}{Q_t} \quad ; \quad \beta_{LR} = b \frac{P_t}{Q_t} \tag{A.3}$$

The implication of equation (A.3) is that if price doubles, short-run price responsiveness will approximately double. It is virtually certain that the price elasticity of oil demand, if not oil supply, increases with increasing price in the short-run. Suranovic (1994, p. 126)

[13]This procedure does not explicitly represent the effect of oil prices on demand via the other variables that determine the constant terms. As long as the price responses are reasonably accurate, this should not be an important concern.

Table A.1 Recent Estimated Short- and Long-Run Price Elasticities of Oil Demand

Model/Source	S.R. Price	L.R. Price	λ	Midpoint Price (1993$)
BP America - OECD	-0.048	-0.548	0.09	$30.30
IPE - OECD	-0.027	-0.772	0.03	$30.30
CERI - OECD	-0.099	-0.425	0.23	$30.30
OMS - OECD	-0.062	-0.448	0.14	$30.30
Gately - OECD	-0.067	-0.157	0.42	$30.30
WOMS - OECD	-0.029	-2.544	0.01	$30.30
Penn-BU -OECD	-0.056	-0.247	0.23	$30.30
FRB - OECD	-0.115	-0.538	0.21	$30.30
HOMS - OECD	-0.083	-0.319	0.26	$32.28
HOMS1 - OECD	-0.116	-0.769	0.15	$30.30
OMS92 - U.S. / Suranovic (1994)	-0.090	-0.700	0.13	--
OMS92 - Europe	-0.060	-0.380	0.16	--
WOM-World/Huntington (1994)	-0.060	-0.60	0.10	$35.20

Sources: Huntington (1994), (1993) and (1991), Suranovic (1994).

model in which price elasticity increases but at a slower rate than it would if the oil demand equation were linear. In Suranovic's model, for example, an increase in oil price from $24 to $48 (1990 dollars), would increase the price elasticity of demand by only about 30%. Compared to those studies, the linear formulation will predict smaller price shocks for a given reduction in OPEC demand, and thus a greater loss of OPEC market share over time for any given monopolistic supply strategy.

uses a formula based on the Energy Information Administration's Oil Market Simulation (1983) Huntington (1991) calculated price elasticities of demand based on a comparison of eleven world oil market models for a scenario of world oil prices increasing from $21.50 to $43.00 (1993 $) per barrel from 1989 to 2010. He found that short-run price elasticities clustered near -0.1 and long-run elasticities were in the vicinity of -0.4. In a more recent study, Huntington (1993) used more rigorous econometric methods to estimate short-and long-run price elasticities of demand for nine of the world oil models. The range of world oil prices was similar to his previous study. The average short-run elasticity was -0.075 and the average long-run elasticity -0.562, implying an adjustment parameter of 0.13. In a recent article Huntington chose representative values of -0.6 for the long-run price elasticity of world demand and used an adjustment factor of 0.1, implying a short-run elasticity of -0.06 associated with an oil price level of $35.20 (1993 $/bbl).

For supply outside of OPEC, Huntington's (1991) study found that short-run price elasticities were well below +0.1, averaging +0.03 for total non-OPEC supply and about +0.05 for the U. S. and other OECD countries (Table A.2). In his 1994 analysis, Huntington used parameters of +0.4 for the long-run price elasticity of supply and and adjustment parameter of 0.1, implying a short-run elasticity of +0.04.

Translating the point or constant elasticity estimates found in the literature into equivalent parameters for linear supply and demand equations requires associating an oil price with each estimate because in the linear model elasticity is a function of fuel price. At the 1995 AEO forecast price for 1993 of $16.12 (1993 $/bbl) and quantities consumed (17.24 MMBD for the U. S., 48.94 MMBD for ROW), the short-run price elasticities of demand for both the U. S. and ROW are assumed to be -0.03, with an adjustment parameter of 0.1. At $28/bbl, roughly the average price of oil since 1967, the short- and long-run price elasticities of demand would be -0.053 and -0.53, respectively. At $35/bbl, the short-run price elasticity becomes -0.068. Short-run supply elasticities at 1993 prices and quantities are assumed to be 0.0225 for the U. S. and 0.0187 for the ROW. These imply U. S. and

Table A.2 Price Elasticities of World Oil Supply

Model/Source	S.R. Price	L.R.Price
United States		
OMS (EIA)	0.117	0.340
Gately	0.045	0.577
IPE	0.000	
ETA-MACRO		0.215
Penn-BU	0.000	0.162
CERI	0.137	0.195
HOMS	0.012	0.522
FRB Dallas	0.013	0.475
DFI-CEC		0.500
HOMS-I	0.0859	0.662
Average	0.052	0.394
Rest of the World		
OMS (EIA)	0.000	0.170
Gately	0.052	0.553
IPE	0.000	
Penn-BU	0.000	0.200
CERI:WOMM	0.000	0.144
HOMS	0.000	0.510
FRB Dallas	0.013	0.480
DFI-CEC		0.980
HOMS-I	0.076	0.633
Average	0.018	0.384

Source: Huntington (1991), table A.3

ROW supply elasticities of 0.038 and 0.032 at $28/bbl, and 0.048 and 0.04 at $35/bbl. An adjustment rate parameter of 0.1 is again assumed so that long-run elasticities are ten times as large.

Although there can be no exact correspondence between parameters of constant and variable elasticity models, these parameters are generally consistent with other models over the range of prices mentioned above. Most importantly, as prices rise during a supply curtailment, elasticities in the linear model will increase, mitigating against very large price shocks. Thus, relative to constant elasticity models, the simulation model used here will tend to predict smaller price increases for a significant oil supply reduction.

Given the short-run price elasticity estimates at 1993 prices and quantities, slope coefficients (b in equation A.3 above) are calculated. These are assumed to remain constant throughout the 1995 AEO forecast, and to apply at the Base Case prices and quantities supplied and demanded. Next, for each forecast year and for each supply and demand equation, a constant term (A_t, in equation A.2 above) is computed. With the year-specific constant terms and the price slopes, we have demand and supply equations for each year. Given a reduction in supply from the Base Case, these can be used to solve for a new world price that equates oil supply and demand.[14]

In some scenarios, we assume that price elasticities increse over the Base Case levels. This is simulated by multiplying the initial elasticity estimates by a constant factor (say, 2, to double price elasticity) and recomputing new price slopes (using equation A.3) at the same initial price and quantities. The Base Case calendar year constant terms (A_t) are not changed. It is assumed that price slopes begin to increase in 1996 and increase linearly to reach the new higher value in the year 2005, remaining constant thereafter. This is intended to reflect the fact that price elasticities cannot be changed immediately.

[14]A very simple algorithm, implemented as a macro in the market simulation spreadsheet, is used to equate supply and demand. Given an initial supply shortfall, the change in price that would equate demand to the lower level of supply is computed. One fourth of the difference between the "hypothetical" price and the initial price is then added to the initial price to create a new price estimate. World supply and demand are recomputed at the new price and a new supply shortfall estimate is calculated. The process is repeated until the supply shortfall becomes sufficiently small to be negligible. The dynamic adjustment specification of demand equations causes the previous year's demand to affect the current year's, and so on. Still, the process usually converges in less than 20 iterations.

APPENDIX B

B.1 METHODS OF ESTIMATING ECONOMIC IMPACTS

Each of the three principal types of economic losses to the U. S. economy is estimated:

1. Loss of the potential to produce,
2. Macro-economic adjustment losses, and
3. Transfer of wealth from U. S. oil consumers to foreign oil exporters.

The loss of potential GNP is related to oil's cost share of GNP, as the following demonstrates (Bohi, 1989). Let Q be the gross output of the economy, including final consumption of goods and services plus the intermediate consumption of oil used to produce them. Net output, or true GNP, is therefore,

$$GNP = Q - P_{oil} X \tag{B.1}$$

where P_{oil} and X are the price and quantity of oil consumed by the economy, respectively. Q is a function of capital (K), labor (L), other energy (E), and oil X, Q(K,L,E,X). If we assume that marginal products (dQ/dK, etc.) are equal to factor prices, as they would be at equilibrium in a full employment economy, then a change in GNP can be related to changes in factor inputs as follows.

$$dGNP = P_K dK + P_L dL + P_E dE - X dP_O \tag{B.2}$$

If we divide equation (B.2) through by dP_O , then multiply through by (P_O /GNP) and rearrange terms, we derive the following expression in terms of the cost shares of GNP of each factor,

$$\eta_{GNP,P_O} = \sigma_K \eta_{K,P_O} + \sigma_L \eta_{L,P_O} + \sigma_E \eta_{E,P_O} - \sigma_O \qquad \text{(B.3)}$$

where σ_i is the cost share of GNP for factor i (price of i times quantity of i divided by GNP), and η_i is the elasticity of substitution of i with respect to the price of oil (percent change in the use of i with a percent change in the price of oil). If the elasticities of substitution were all zero, then the elasticity of GNP with respect to the price of oil would equal the negative of oil's cost share of GNP.

While capital, labor, and other energy sources can certainly be substituted for oil in the long-run, the short-run substitution possibilities are more limited. For the period of a year or two, it seems quite reasonable to assert that the products of the substitution elasticities for capital and labor and their respective cost shares are essentially zero. Also in the short-run, experience indicates that the effect of an oil price shock on nonpetroleum energy use may even be negative. Thus, the negative value of the oil cost share of GNP should be a reasonable, if very approximate, estimate of the short-run elasticity of GNP with respect to the price of oil. The long-run elasticity of GNP with respect to the price of oil should be smaller. It is assumed to be zero in this analysis.

Macroeconomic adjustment losses occur due to the inability to maintain full employment of the factors of production throughout the adjustment to the new price regime. Fortunately there have been numerous assessments of the impact of oil price changes on the U. S. economy, some based on model simulations, others using econometric methods to analyze historical data. Unfortunately, these studies generally do not distinguish between the two causes of loss of GNP.

In terms of the size of the impacts, all the estimates of which we are aware are of the same general magnitude as the oil cost share of GNP. The earliest estimates by Mork and Hall (1980) and Pindyck (1980) based on the 1973-74 price shock were -0.03 and -0.02, respectively. In 1973 the oil cost share of GNP was 0.015 and in 1974 it jumped to 0.032. More recently, Mork, Olsen and Mysen (1994) estimated oil price elasticities for U. S. GNP of -0.054 and -0.068, depending on model formulation, using data covering the period 1967-1992. In the most extensive simulation of the impacts of oil price shocks, the Energy Modeling Forum (Hickman, 1987) tested fourteen macroeconomic models with a simulated 50% oil price increase beginning in 1983 (Table B.1). They tracked the impact on GNP for four consecutive years, ending in 1986. If one takes the simple average of all four years and all fourteen models, an estimate of -0.047 is obtained. Elasticities for individual models ranged from -0.02 to -0.095.

> "Thus the average finding is that real output is reduced by about 0.5 percent and the price level increased by about the same amount for each permanent increase in the price of oil, with a range for each response of about 0.2 to 1.0." (Hickman, 1987, p. 164)

In the years 1982 and 1983, the oil cost share of GNP was .045 and .037, respectively, having been as high as 0.056 in 1981. Helkie (1991) cites an elasticity of GNP with respect to oil price of -0.03, based on simulations of the Federal Reserve Board staff's MCM model, which he uses in his analysis of the impact of supply shortfalls on oil prices. The apparent correlation of GNP impact and the oil cost share of GNP is to be expected based on the simple theoretical discussion above, and has been previously pointed out by Tatom (1993, p. 131) and earlier by Pindyck (1980, p. 19).

> "The percentage decline in capacity output and the rise in the price level associated with each one percent rise in the relative price of energy generally are equal and proportional to the share of energy in the cost of output." (Tatom, 1993, p. 131)

We assume that in the short-run, the elasticity of potential GNP with respect to oil price is equal to the oil cost share of GNP. We further assume that in the long-run, substitution

Table B.1 Estimates of the Impact of Oil Price Shocks on GNP

Elasticities of GNP with Respect to Oil Price			
Source	Potential GNP Loss	Adjustment Costs	Total Effect
Pindyck (1980)	-0.01	-0.009	-0.02
Helkie (1991)			
Federal Reserve MCM			-0.03
Federal Reserve MPS			-0.04
Mork and Hall (1980)[a]			-0.03
Hickman (1987) EMF 7 Study			
LINK			-0.05
Wharton			-0.059
MACE			-0.043
Hubbard-Fry			-0.022
Chase			-0.051
Claremont			-0.072
MPS			-0.063
FRB MCM			-0.02
BEA			-0.069
DRI			-0.046
Hickman-Coen			-0.044
St. Louis			-0.057
Mork			-0.095
Michigan			-0.067
Average			-0.055
U. S. DOE Interagency Working Group (1990)			
LOW		-0.020	
MID		-0.025	
HIGH		-0.040	
Mork, Olsen and Mysen (1994)			-0.054 -0.068

[a]Based on a predicted -2.8% decline in 1980 GNP for a 93% increase in oil prices in 1980 over 1978.

effects will offset half of the short-run loss of output potential. Since we are measuring costs relative to a competitive oil price level, and since that competitive price is much lower than the forecasted oil prices, we do not use the instantaneous oil cost share. Instead we use the midpoint between the oil cost share at the competitive price and that at the current price. Thus, if the current oil cost share is 3% and the competitive price oil cost share is 1%, the short-run potential GNP elasticity would be -0.02 and the long-run elasticity would be -0.01, for that year. The mechanism of adjustment is described below.

There is little in the literature concerning the relative sizes of the macroeconomic and potential GNP effects, however, Pindyck (1980) suggests a 50/50 split. In the calculations done here, it is assumed that the macroeconomic adjustment effect is 75% as large as the short-run potential GNP effect.

In the case of both the potential GNP and macroeconomic adjustment losses, one may expect the economy to adjust over time to the higher price of oil, reducing its impact on GNP. This is represented here by estimating a hypothetical price to which the economy has adjusted in any given year, and computing GNP losses as a function of the difference between the actual market price and the hypothetical price to which the economy has already adjusted. This method is motivated as follows. Consider the lagged adjustment model of oil demand and supply presented in the Appendix in equations (A.1) and (A.2). At any particular time, t, the quantity demanded (supplied) will be the long-run equilibrium quantity for some price of oil, P^*_t. Substituting this price into equation (A.1) and letting the equilibrium quantity, $q_t = Q_t$, and then setting equation (A.2) equal to the resulting expression, we get the following intuitive formula for the hypothetical price.

$$P^*_t = \lambda P_t + (1-\lambda) P_{t-1} \qquad \text{(B.4)}$$

For macroeconomic adjustment costs, the rate used is (λ=0.33). This rate implies near complete adjustment within three years. This is faster than the adjustment rats for most of the models studied by Hickman (1987). Macroeconomic losses occur whether prices rise or fall.

The elasticity of potential output with respect to oil price is defined as

$$\eta_{GNP,P_o} = \frac{\frac{\Delta GNP}{GNP}}{\frac{\Delta P_o}{P_o}} = -\sigma_o \ \textit{short run,} \ \frac{-\sigma_o}{k} \ \textit{long run.} \tag{B.5}$$

Where σ_o is the oil cost share of output (GNP) and P_o is the price of oil. As noted above, we assume k=2. The GNP loss is computed relative to the assumed competitive market price, P_c. Thus in the short run,

$$-\sigma_o \frac{\Delta P}{P} = -\sigma_o \frac{P_t - P_c}{P_c} \tag{B.6}$$

and in the long run,

$$\frac{-\sigma_o}{k} \frac{P_t - P_c}{P_c} = -\sigma_o \frac{P_t - p_t}{P_c} \tag{B.7}$$

The price variable p_t is a weighted average of the current and competitive price that depends on k.

$$p_t = \left(1 - \frac{1}{k}\right) P_t + \frac{1}{k} P_c \tag{B.8}$$

Equation (B.8) is defined so that equation (B.7) is always satisfied. We now assume that the economy gradually adjusts towards the long-run potential GNP elasticity by substituting an adjusted price, p_t', for p_t in equation (B.7).

$$P_t = \lambda p_t + (1-\lambda) p_{t-1} \tag{B.9}$$

In the event that the current price of oil is less than the competitive price, we estimate the potential GNP *gain* by assuming that the short-run elasticity applies. When the current price is above the competitive market price, the GNP loss is estimated by two different formulas, depending on whether the adjusted price is converging on the weighted average price from below ($p_t < p_t$) or from above. If $p_t < p_t$, then the elasticity is given by,

$$\eta_{GNP,P_o} = -\sigma_o \left(\frac{P_t - p_t}{P_c} \right) \tag{B.10}$$

When $p_t > p_t$, the adjusted price is converging on the long-run price from above, so the long-run elasticity is used.

$$\eta_{GNP,P_o} = -\sigma_o \left(\frac{P_t - P_c}{P_c} \right) \tag{B.11}$$

Because P_t is often many times as large as P_c, a better approximation for the denominator than P_c is the midpoint of the competitive and current price of oil. Thus, we substitute $P_{mid} = (P_t - P_c)/2$. in the denomenator of (B.10) and (B.11) in calculating the oil price elasticities of potential GNP.

When oil prices rise due to the exercise of monopoly power by OPEC, there is also a transfer of wealth from U. S. oil consumers to the owners of foreign oil. Not all exporters are monopoly producers who will receive the transfer of wealth in the form of pure monopoly rents. Some will have to spend money on exploration and development to produce oil. These costs will be deadweight losses to the world economy, resulting from the monopoly pricing of oil. Thus, they are true economic losses. However, since they occur outside the U. S., they are not included in the loss of U. S. GNP due to higher oil prices. Therefore, it is not double counting to consider the entire amount that the U. S. pays for imports over and above the competitive market price as a loss of wealth to the United States, and count this as an economic cost in addition to the deadweight losses that make up the loss of potential GNP within the U. S. economy. Whether oil exporters waste the additional money we pay them or put it to productive use does not change the fact that it is lost to us.

A key problem, of course, is determining what the price of oil would be in a competitive world oil market without monopoly influence. In 1972, the year before the Arab OPEC oil embargo, the average cost of imported oil to U. S. refiners, which had been declining for two decades, was \$10.30/bbl in 1993 dollars. In this analysis, we assume a competitive market price of \$10/bbl in 1993 dollars. Costs may be computed either holding this price constant through 2010, or increasing it at an assumed real discount rate. The latter is consistent with the theory that oil is treated by markets as a finite exhaustible resource, a view that is rejected by several renowned energy economists because of the historically demonstrated ability of technology to discover new reserves, increase recovery from known reserves, and generally expand the definition of economically exploitable resources (e.g., Gordon, 1994; Adelman, 1990; Mabro, 1992).

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Q2. **On page 5 of your prepared testimony, you also state that "if current energy forecasts prove out, the Persian Gulf nations' oil revenues may triple from $80 billion a year today to nearly $250 billion a year in 2010."**

Please document this statement.

A2. The sources of this information are two publications of the Energy Information Administration: the Annual Energy Outlook 1995 and the International Energy Outlook 1995. Since this testimony was prepared, the 1996 versions of these documents have been released. The calculations below use the more current data. According to these documents, the Persian Gulf oil production for 1996 is 17.110 million barrels per day (MMBD)–slightly higher than 1995. The projected 2010 production is 35.8 MMBD. The world oil price for 1996 is estimated to be $16.98 per barrel–again, slightly higher than 1995. The projected 2010 price is $23.70 per barrel–slightly lower than the 1995 projection. These data translate to 1996 Persian Gulf revenue of $106 billion in 1996 and $310 billion in 2010. While both these figures are higher than those from the 1995 data, it still represents a tripling of revenue for oil producers in the Persian Gulf–one of the most politically unstable regions of the world.

Q3. **On page 6 of your prepared testimony, you state: "The final piece in the geopolitical puzzle is that during the first oil crisis in the early 1970s, the countries that were competing with us for oil were our NATO allies, but during the next oil crisis, a new important complication will arise: the competition for oil will increasingly come from the rapidly growing countries of Asia. Indeed, in the early 1970s, East Asia consumed well under half of the oil used by the United States; by the time of the next crisis, however, East Asian nations will probably be consuming more oil than we do."**

Please document this statement.

A3. The source for this information is Table A3, *"World Total Oil Consumption by Region, 1990-2010,"* International Energy Outlook, June 1995, page 81. Even by 2000, the combined use of Japan and non-OECD Asia will be 20 million barrels per day (MMBD), compared to the U.S. demand of 18.9 MMBD (reference case).

[*Note: These pages are attached.*]

DOE/EIA-0484(95)
Distribution Category UC-950

International Energy Outlook 1995

May 1995

Energy Information Administration
Office of Integrated Analysis and Forecasting
U.S. Department of Energy
Washington, DC 20585

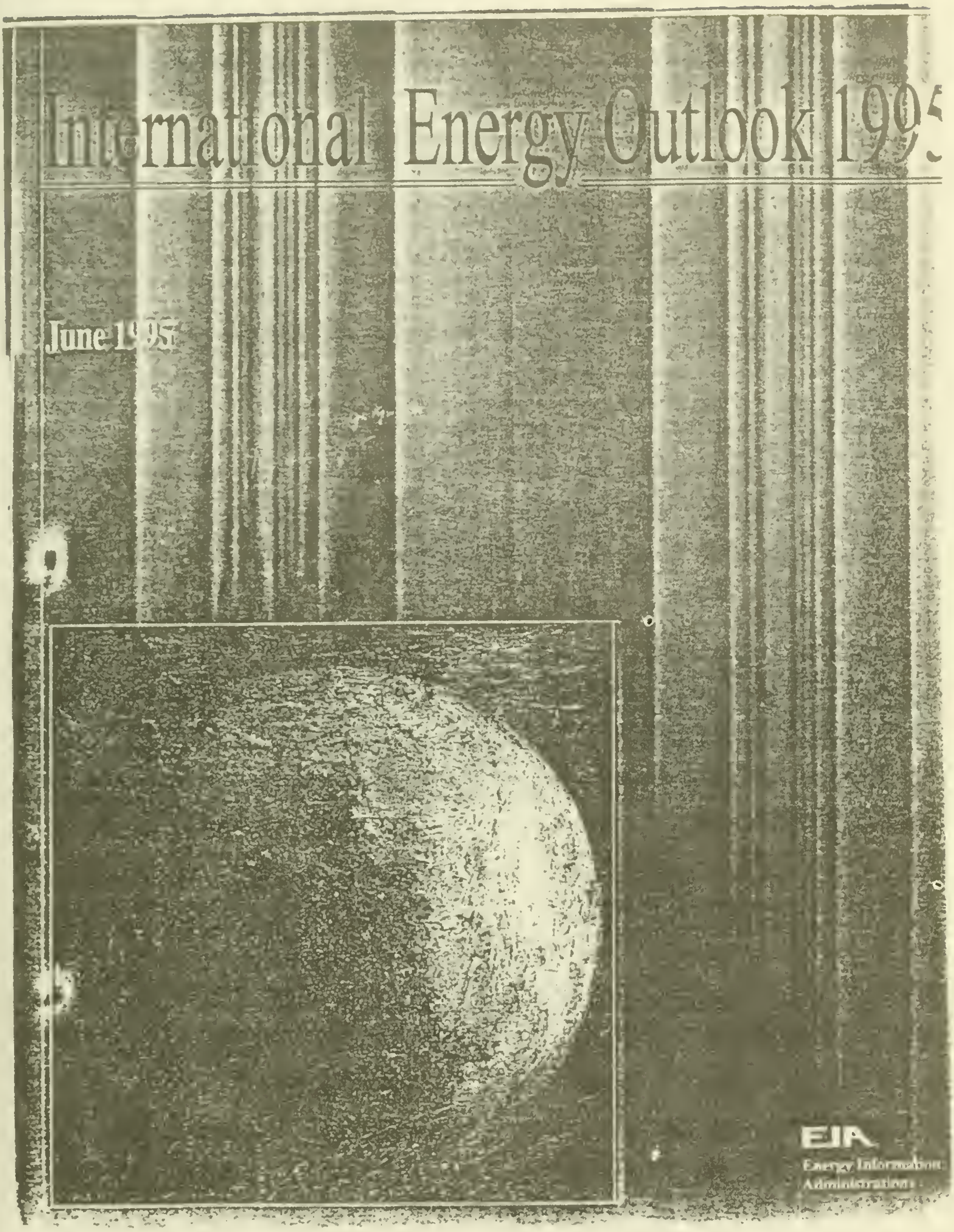
International Energy Outlook 1995
June 1995
EIA
Energy Information Administration

Table A2. World Total Energy Consumption by Region, 1990-2010
(Quadrillion Btu)

Region/Country	History 1990	History 1992	Projections 2000 Reference Case	2000 Sensitivity Range		2005 Reference Case	2005 Sensitivity Range		2010 Reference Case	2010 Sensitivity Range	
OECD	183.8	190.2	214.4	*206.1*	*223.2*	227.4	*214.7*	*241.0*	239.0	*222.3*	*257.2*
United States[a]	84.3	85.8	94.8	*92.8*	*96.4*	99.4	*96.5*	*102.4*	103.9	*99.4*	*108.5*
Canada	10.7	11.0	13.2	*12.2*	*14.4*	14.2	*12.6*	*16.1*	15.1	*12.9*	*17.5*
Mexico	4.8	5.2	8.3	*5.8*	*6.9*	7.0	*6.1*	*7.9*	7.5	*6.4*	*8.6*
Japan	18.2	19.0	23.2	*20.7*	*25.8*	25.0	*21.6*	*28.6*	26.4	*22.2*	*31.1*
OECD Europe	60.9	64.3	71.5	*67.8*	*75.6*	75.6	*69.5*	*82.5*	79.8	*71.3*	*88.9*
United Kingdom	9.0	9.7	11.5	*10.8*	*12.6*	12.3	*10.9*	*13.7*	12.8	*11.1*	*14.7*
France	8.9	9.7	10.8	*10.2*	*11.4*	11.4	*10.4*	*12.4*	12.0	*10.7*	*13.4*
Germany	14.4	14.1	15.8	*14.8*	*16.7*	16.8	*15.3*	*18.4*	17.8	*15.7*	*19.6*
Italy	8.6	7.0	7.8	*7.3*	*8.3*	8.2	*7.5*	*9.0*	8.8	*7.7*	*9.6*
Netherlands	3.3	3.5	3.9	*3.7*	*4.1*	4.1	*3.8*	*4.5*	4.3	*3.9*	*4.8*
Other Europe	18.8	20.3	21.8	*21.0*	*22.6*	23.0	*21.6*	*24.5*	24.4	*22.3*	*26.6*
Other OECD	4.8	4.9	5.6	*5.3*	*5.9*	5.9	*5.5*	*6.4*	6.3	*5.6*	*7.0*
EE/FSU	74.3	63.2	63.7	*61.3*	*66.2*	69.4	*65.1*	*74.0*	74.7	*68.1*	*81.7*
Former Soviet Union	58.0	51.2	49.7	*47.9*	*51.5*	54.3	*51.2*	*57.5*	58.4	*53.7*	*63.4*
Eastern Europe	16.3	12.0	14.1	*13.1*	*15.0*	15.1	*13.7*	*16.7*	16.2	*14.3*	*18.4*
Non-OECD Asia	52.5	56.8	79.4	*71.1*	*88.4*	92.1	*78.3*	*107.8*	104.2	*84.7*	*126.8*
China	27.9	29.2	41.6	*37.3*	*46.7*	48.4	*41.0*	*56.6*	55.6	*44.9*	*68.1*
Other Asia	24.7	27.5	37.6	*33.8*	*41.7*	43.7	*37.2*	*51.0*	48.6	*39.6*	*58.9*
Middle East	11.3	12.2	15.2	*14.0*	*16.5*	16.9	*14.9*	*19.1*	18.4	*16.7*	*21.5*
Africa	9.8	10.8	12.6	*11.8*	*13.4*	13.6	*12.3*	*15.0*	14.8	*12.7*	*16.6*
Central and South America	13.9	14.4	17.2	*15.9*	*18.5*	19.1	*17.0*	*21.5*	20.8	*17.8*	*24.2*
Total World	345.6	347.6	402.8	*381.5*	*424.9*	438.6	*403.3*	*477.0*	471.7	*422.4*	*526.6*

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

Notes: OECD = Organization for Economic Cooperation and Development. EE/FSU = Eastern Europe/Former Soviet Union. Energy totals include consumption of biofuels in the United States. All sensitivity ranges are derived independently and do not necessarily add to totals. Other totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: History: Energy Information Administration (EIA), *International Energy Annual 1992*, DOE/EIA-0219(92) (Washington, DC, January 1994). Projections: EIA, *Annual Energy Outlook 1995*, DOE/EIA-0383(95) (Washington, DC, January 1995), Table B1; and World Energy Projection System (1995).

Table A3. World Total Oil Consumption by Region, 1990-2010
(Million Barrels per Day)

Region/Country	History		Projections								
			2000			2005			2010		
	1990	1992	Reference Case	Sensitivity Range		Reference Case	Sensitivity Range		Reference Case	Sensitivity Range	
OECD	39.5	40.6	44.7	*43.9*	*47.1*	47.2	*46.0*	*51.5*	48.9	*47.2*	*54.6*
United States[a]	17.0	17.0	18.8	*18.7*	*19.5*	20.1	*19.8*	*21.3*	20.9	*20.4*	*22.5*
Canada	1.7	1.8	1.8	*1.8*	*2.0*	1.9	*1.8*	*2.1*	1.9	*1.9*	*2.2*
Mexico	1.7	1.8	2.4	*2.4*	*2.6*	2.6	*2.5*	*2.9*	2.7	*2.6*	*3.3*
Japan	8.1	5.5	6.0	*5.8*	*6.5*	6.3	*6.0*	*7.2*	6.6	*6.2*	*7.9*
OECD Europe	12.9	13.6	14.3	*14.1*	*15.3*	15.0	*14.5*	*16.4*	15.4	*14.8*	*17.2*
United Kingdom	1.8	1.8	1.9	*1.9*	*2.0*	2.0	*1.9*	*2.2*	2.0	*2.0*	*2.3*
France	1.8	1.9	2.0	*2.0*	*2.2*	2.1	*2.1*	*2.3*	2.2	*2.1*	*2.4*
Germany	2.7	2.8	3.0	*2.9*	*3.2*	3.1	*3.0*	*3.4*	3.2	*3.1*	*3.6*
Italy	1.9	1.9	2.0	*2.0*	*2.2*	2.1	*2.1*	*2.3*	2.2	*2.1*	*2.4*
Netherlands	0.7	0.8	0.8	*0.8*	*0.9*	0.8	*0.8*	*0.9*	0.9	*0.8*	*1.0*
Other Europe	4.1	4.3	4.6	*4.5*	*4.9*	4.8	*4.6*	*5.2*	4.9	*4.7*	*5.5*
Other OECD	1.0	1.0	1.3	*1.2*	*1.3*	1.3	*1.3*	*1.5*	1.4	*1.4*	*1.6*
EE/FSU	10.0	7.8	6.1	*6.0*	*6.2*	7.5	*7.2*	*7.8*	9.2	*8.6*	*9.8*
Former Soviet Union	8.4	6.7	4.7	*4.6*	*4.7*	5.9	*5.8*	*6.2*	7.5	*7.1*	*8.0*
Eastern Europe	1.6	1.1	1.4	*1.4*	*1.5*	1.6	*1.5*	*1.6*	1.7	*1.5*	*1.8*
Non-OECD Asia	7.6	8.8	14.0	*13.8*	*14.3*	15.5	*15.2*	*16.1*	16.4	*16.0*	*17.3*
China	2.3	2.6	3.7	*3.6*	*3.8*	3.9	*3.6*	*4.1*	4.0	*3.7*	*4.3*
Other Asia	5.3	6.2	10.3	*10.2*	*10.6*	11.6	*11.4*	*12.2*	12.4	*12.2*	*13.2*
Middle East	3.5	3.7	4.5	*4.5*	*4.5*	5.0	*4.9*	*5.0*	5.4	*5.4*	*5.6*
Africa	2.1	2.2	2.8	*2.7*	*2.9*	3.1	*3.0*	*3.2*	3.3	*3.2*	*3.6*
Central and South America	3.5	3.5	4.6	*4.5*	*4.7*	5.0	*4.9*	*5.2*	5.3	*5.2*	*5.6*
Total World	65.2	66.7	76.6	*75.9*	*79.4*	83.2	*82.2*	*88.0*	88.7	*87.4*	*94.9*

[a]Includes the 50 States and the District of Columbia. U.S. Territories are included in "Other OECD."

Notes: OECD = Organization for Economic Cooperation and Development. EE/FSU = Eastern Europe/Former Soviet Union. All sensitivity ranges are derived independently and do not necessarily add to totals. Other totals may not equal sum of components due to independent rounding. The electricity portion of the national fuel consumption values consists of generation for domestic use plus an adjustment for electricity trade based on a fuel's share of total generation in the exporting country.

Sources: History: Energy Information Administration (EIA), *International Energy Annual 1992*, DOE/EIA-0219(92) (Washington, DC, January 1994). Projections: EIA, *Annual Energy Outlook 1995*, DOE/EIA-0383(95) (Washington, DC, January 1995), Table C20; and World Energy Projection System (1995).

Q4. **On page 10 of your prepared testimony, you state that "[i]f biofuels R&D continues to be funded at current levels, ethanol from fast-growing dedicated crops, crop waste, and wastepaper could be produced for as little as sixty to seventy cents a gallon by 2005."**

Please document this statement.

A4. Process economic analyses are being used to guide the biofuels R&D activities that could lead to ethanol production costs for as little as sixty to seventy cents a gallon by 2005. These analyses identified three process steps that would lead to major cost reductions. The steps are: (1) physical and chemical pretreatment to make the biomass materials more amenable to enzymatic attack, (2) production and use of efficient, low-cost enzymes which convert the material to fermentable sugars, and (3) fermentation of the sugars to ethanol. Performance parameters have been established for each of these process steps and are being pursued through research and development projects at the National Renewable Energy Laboratory and with universities and industrial partners. One of our primary customers, Swan Biomass Company, believes it can produce ethanol for about seventy cents a gallon in niche markets now, using waste feedstock and a process technology package funded in part by DOE. Cost reductions in both feedstocks and production systems, i.e., fast growing dedicated crops and improved conversion processes, should bring the costs within the sixty to seventy cents range.

Q5. **On page 10 of your prepared testimony, you also refer to the Partnership for a New Generation of Vehicles (PNGV) goal which is to design and construct a prototype clean car by the year 2004 that has three times the fuel efficiency of existing cars and very low emissions, but comparable or improved performance, safety, and cost.**

Q5a. **Aren't the "Big Three" automakers–GM, Ford and Chrysler–involved in the PNGV?**

A5a. Chrysler, General Motors, and Ford are all active in the Partnership for a New Generation of Vehicles.

Q5b. **Haven't all of the "Big Three" automakers–GM, Ford and Chrysler–been making considerable profits in recent years?**

A5b. While none of the "Big Three" were profitable in 1992, Ford, Chrysler, and General Motors have each reported profits in 1993 through 1995. Profit trends are far from clear, however. Ford and Chrysler reported 1995 per-share earnings that were sharply lower (off 28 and 45 percent respectively) than in 1994. In contrast, General Motors per-share profits rose by 17 percent in 1995.

Q5c. **If indeed all of the "Big Three" automakers–GM, Ford and Chrysler–have been making considerable profits in recent years, what is the rationale for subsidizing them to develop a near-term prototype "clean car"?**

A5c. Absent government support, these companies have little or no incentive in spending their scarce research and development funds on high-risk technologies needed to achieve radical improvements in fuel economy. This question gets right to the heart of the proper role of government in the conduct of research and development. We believe government has a critical role to play as a catalyst and a facilitator of technology research and development--as distinct from product research and development which is and should be funded by industry.

Current market forces (particularly historically low motor fuel prices) are antithetical to industry funding of technologies to reduce fuel use. However, developing and commercializing more fuel efficient vehicles has considerable energy security, environmental, and economic competitiveness benefits for the nation that are external to market pricing. Key to the achievement of the national interest objectives is government support of long-term, high-risk research and development that is not linked to market pull. These technologies include hybrid propulsion systems, hydrogen fuel cells, lightweight materials and structures, energy storage components, supercomputer models, vehicle recycling. and alternative fuels. The government contribution includes not only cost-shared funding, but also the unique research and development capabilities of the Federal laboratories in enabling technologies such as materials engineering, supercomputing, and manufacturing technologies.

The majority (about 75 percent) of the government cost-shared funding provided to Chrysler, Ford, and General Motors for research and development is not spent by them, but passed on to suppliers and universities who perform the work. The proportion of Federal funding will be higher for high-risk projects where the outcome is uncertain, and that of industry funding will be higher for technologies with a clear, more, definite, and nearer term market. Beyond the technology development phase of PNGV, the industry has committed to apply, as they become commercially viable, those technologies resulting from the research program that would be expected to significantly increase fuel efficiency.

The leveraging of government research and development capabilities by the private sector enables U.S. companies to better compete with foreign companies, which often obtain significant assistance from their governments (e.g., Japan/Ministry of International Trade and Industry and Europe/EUROCAR). As the recent (3/18/96) National Research Council Peer Review of the PNGV program pointed out, the U.S. is already behind in the crucial areas of compression ignition engines and ultracapacitors. We currently enjoy a leadership position in such technologies as energy storage, gas turbines, and hydrogen fuel cells; to reduce our effort at this point would result in surrendering these leads to our foreign competitors.

Q6. At the bottom of page 10 and the top of page 11 of your prepared testimony, you refer to advanced battery research, and highlight the nickel metal-hydride battery.

Is it not true that nickel metal-hydride batteries are already commercially available, and if so, what is the rationale for continued taxpayer subsidies of this technology rather than concentrating scarce resources on long-term battery R&D?

A6. Nickel metal hydride batteries are only commercially available today as small cells and batteries for consumer electronics applications. In FY 1997, approximately 75 percent of the advanced battery research and development funding will be for long-term technologies. A portion of the remaining 25 percent will be used for projects which will reduce the cost of large nickel metal-hydride batteries to a threshold that will render them viable for electric vehicles.

Q7. On page 11 of your prepared testimony, you say that the Department is "seeking to expand natural gas as a transportation fuel."

Is it not true that natural gas has been used as a transportation fuel for decades, and if so, why should scarce Federal resources be used to further demonstrate what is already a reality?

A7. Although natural gas has been used in vehicles for many years, and is a popular transportation fuel worldwide, many technical and market barriers exist to increased use of natural gas in the U.S. transportation market. DOE is working to address these barriers, as provided for in the Alternative Motor Fuel Act of 1988 and the Energy Policy Act of 1992. DOE R&D efforts are focused on key technological advancements that will dramatically increase the range of natural gas vehicles, reduce the costs of manufacture, and capture the improved emissions performance these vehicles are capable of. Industry investment in light duty and heavy duty engine development for natural gas vehicles has grown dramatically during the last five years, with DOE support, but still pales in comparison to industry investments in gasoline and diesel engine development. Simultaneous with critical R&D, DOE works in partnership with industry, and State and local governments, to identify infrastructure needs, such as refueling, service, training, and information to fleets and consumers on the availability and use of natural gas vehicles. For example, our Office of Heavy Vehicle Technologies is working with major manufacturers, such as Cummins Engine Company and Caterpillar, to improve the efficiency of direct injection engines with liquefied natural gas (LNG). Engines have been optimized to operate on gasoline and diesel, and the same research and testing must be accomplished to optimize operation using alternative fuels.

Q8. On page 11 of your prepared testimony, you also say that the Department is developing gas turbine engines for light duty vehicles.

What specific development is underway?

A8. DOE's PNGV/Hybrid Propulsion System Program, which is being implemented through 50-50 cost-shared contracts with each of the three major U.S. automakers, includes gas turbines as one of the major candidate engine technologies. Gas turbines offer noise, vibration, packaging, multi-fuel, and emissions advantages relative to many other options. The automakers and turbine developers (AlliedSignal, Teledyne Ryan, and Allison) are developing advanced turbine engines designed for hybrid propulsion systems that will double the fuel efficiency of current 4-door, mid-size sedans (i.e., Concorde, Lumina, and Taurus). Additionally, DOE is conducting supporting R&D to address the major technical challenges: low-cost, high-temperature structural ceramic components, ceramic waste heat recovery devices, ultra-low emission combustion systems, and thermal insulation.

Q9. On page 11 of your prepared testimony, you say "probably the one technology that experts would agree has the best chance over the long term of significantly reducing petroleum use in the transportation sector is fuel cells."

If this is the case, and given that Federal resources are and will continue to be constrained for the foreseeable future, why doesn't the Department allocate relatively more resources to this promising technology rather than continuing to spend money on technologies, such as natural-gas vehicles that are already commercially available?

A9. Allocation of limited Federal funds is a matter of balancing the risk of achieving success in a specific technology with the need for a high probability of achieving our mission of reducing petroleum use in the transportation sector, preferably within a few years. Increasing the use of alternative fuel vehicles, such as natural gas vehicles, ensures that near-term displacement of petroleum is achieved while the risks associated with longer term technologies, such as fuel cells, are being reduced. Since fuel cells are fuel flexible and therefore can operate on various alternative fuels, they will benefit by the fuel infrastructure which is established by nearer term alternative fuel vehicles. Over the last five years, there has been rapid progress in proton exchange membrane fuel cell technology, such as dramatic increases in power density and decreases in precious metal catalyst loadings. These technology advances have resulted in the Department requesting major increases in the fuel cell budget allocation even though the over-all budget has been constrained. For example, since the fuel cell program for transportation was established in FY 1987, the funding has steadily increased to about 10 times the initial funding. We regularly reevaluate these allocations as the state of the technology continues to change and advance. This reevaluation process occurs through internal processes, through external peer review, and through close consultation with industry.

Q10. Finally, on page 11 of your prepared testimony, you state: "Over the past two decades the DOE has invested considerable resources to develop several types of fuel cells that will soon be used to power cars, trucks, utilities, commercial buildings, and industries. The Japanese government has been increasing its fuel cell R&D budget at 20% per year for the past five years, and Japanese companies are less than five years behind U.S. companies in this technology."

Q10a. Please provide, by fiscal year, the DOE funding for fuel cells over the past twenty years.

A10a. DOE Office of Fossil Energy (DOE/FE) fuel cell appropriations in million $ are listed below. The DOE/FE total for the 20 years, 1977 through 1996, is $778.1 million.

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
21	35.2	40.5	35.5	32.0	34.5	32.0	46.6	42.7	35.3

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
29.4	34.2	26.5	38.0	42.9	50.8	50.4	51.1	47.0	52.5

Source: DOE appropriations records.

. DOE Office of Energy Efficiency and Renewable Energy (DOE/EE) funding for fuel cells in the transportation sector is presented below:

FISCAL YEAR	FUNDING $ MILLIONS	COMMENTS
1987	1.0	No funding before 1987. The fuel cell bus program was initiated during this period.
1988	2.6	
1989	3.7	
1990	5.1	During this period the fuel cell bus program continued at approximately $2.0M/YR until tapering off and successful conclusion in FY 1996 (no FY 1996 funding). Research and development programs in fuel processing and PEM fuel cells were initiated
1991	7.8	
1992	9.5	
1993	12.0	
1994	19.5	
1995	23.1	
1996	22.0	PEM fuel cell system development and fuel processing programs.
TOTAL	106.30	

Q10b. Please provide the Japanese government funding over the same two decades.

A10b. Values for the amount of fuel cell funding by the Japanese government, as reported in literature and estimated by visitors to Japan sometimes vary over a fairly wide range. In addition to variations in the rates assumed for conversion from Japanese yen to U.S. dollars, it appears that sometimes the values attributed to government spending have included the total costs of some government programs which are 1/2 to 2/3 cost-shared by the private sector. These are separate from the totally private sector funded programs. Published reports of the government funding over the past 20 years for R&D and for demonstrations are listed below in million $ (converted from Yen at rates indicated). No funding before 1981 is reported in the literature.

	1978	1979	1980	1981	1982	1983	1984	1985	1986
(Y/$)				235	235	235	232	240	160
R&D				1.1	2.5	8.5	15.9	19.9	19.9
Demo									
Tot.				1.1	2.5	8.5	15.9	19.9	19.9

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
150	124	126	146	134	126	110	100	94	
22.4	28.3	28.6	19.4	25.1	30.8	43.3	50.5	54.6	
				4.8	14.7	11.9	8.3	NA	
22.4	28.3	28.6	19.4	29.9	45.5	55.2	58.8	NA	

Sources: N. Asada, MITI Fuel Cells Program, U.S. DOE/Japan AIST Fuel Cell Technical Meeting, Tucson, Dec. 3, 1992; M. Nishikawa, Government Budget for Fuel Cell Development Information Center, Oct., 1994; U.S. DOE/Japan AIST Fuel Cell Development Meeting, San Diego, Dec. 2, 1994.

Q10c. Please document the statement that "Japanese companies are less than five years behind U.S. companies in this technology."

A10c. A recent assessment regarding stationary fuel cells appears in the outside witnesses testimony on fuel cells for the House Appropriations Subcommittee on Interior and Related Agencies, March 7, 1996, Statement of Donald R. Glenn, Energy Research Corporation: "ERC believes the U.S. has a tenuous three-four year lead in this field with Japan close behind."

With respect to transportation fuel cells, the Japanese position in fuel cell technology is well documented in the scientific literature. For example, there were five Japanese Proton Exchange Membrane (PEM) fuel cell papers presented at the fall 1995 meeting of the Electrochemical Society. All were directly relevant to transportation technologies, but perhaps the most interesting was that presented by scientists from Toyota ("Optimized CO Tolerant Electrocatalysts for Polymer Electrolyte Fuel Cells," Masayoshi Iwase and Shigeyuki Kawatsu, Toyota Motor Company, Extended Abstracts Volume 95-2 of the Electrochemical Society). In this paper they demonstrate their complete grasp of the issues involved in PEM fuel cell catalyst loading and poisoning; a major issue in commercialization of this technology. In comparing the data presented there with our own studies it is evident that they are very close to achieving our present state-of-the-art. We should note that information presented in scientific journals typically lags the true competitive position of the researchers.

Besides information which is directly available to us in the scientific literature, there is anecdotal evidence that a major Japanese automotive company is close to unveiling a hybrid electric concept car with an integrated fuel cell power source.

Also, in an unclassified review of the status of fuel cells: "Fuel Cells: Foreign Development Efforts to Catch Up in an Emerging Technology," the efforts of Japan, Europe, South Korea, Canada, and Russia are examined. A graphic within the document lists the following countries and companies as "less than 5 years behind the United States" by type of fuel cell:

Phosphoric acid cells:
Japan - Toshiba
Japan - Fuji Electric
Japan - Mitsubishi Electric Corporation
Japan- Sanyo

Molten Carbonate cells:
Japan - Ishikawajimi-Harima Heavy Industries
Japan - Mitsubishi Electric Corporation
Japan - Hitachi

Polymer electrolyte cells:
Japan - Fuji Electric
Germany - Siemens
Germany - Daimler-Benz

Q11. On page 12 of your prepared testimony, you state that "domestic jobs are created when money that would have gone overseas to purchase foreign oil goes instead to U.S. workers manufacturing technologies for highly-efficient cars and trucks, or for growing domestic biofuels."

Mr. Schleede says in his prepared testimony, however, that a large share of the outflow of dollars for our oil imports comes back to the U.S., directly or indirectly, as payments for the merchandise and services that we export and that DOE seems uninterested in the relationship of oil import dollars to our export markets.

How would you respond to Mr. Schleede?

A11. Mr. Schleede's assertion that "DOE seems uninterested in the relationship of oil import dollars to our export markets" is incorrect. The Department is very much interested in this relationship. We believe that we have a responsibility to the taxpayers to consider the national interest, which includes the trade deficit. Mr. Schleede doesn't seem to share our concern.

Q12. On page 13 of your prepared testimony, you state that "[w]e already spend a hundred times as much money on military forces in and around the Gulf than we do on technologies to minimize dependence on Gulf oil."

Please document this statement.

A12. The current fiscal year expenditures on research and development of energy efficiency technologies that can reduce dependence on imported oil total about $220 million.

According to the CATO Institute, annual expenditures for the defense of the Middle East equal about $50 billion (Ravenal, Earl C., Designing the New World Order, 1991). This is more than 120 times the amount spent on the DOE energy efficiency technology research and development activities(not including state grants, such as weatherization assistance), and over 70 times the amount spent on RD&D for Energy Efficiency and Renewable Energy.

Q13. On page 13 of your prepared testimony, you refer to the "independent commission headed by Daniel Yergin".

Please explain why the Secretary of Energy Advisory Board (SEAB) Task Force on Energy Research and Development, chaired by Daniel Yergin, was truly an "independent commission."

A13. The Secretary of Energy Advisory Board's Task Force on Strategic Energy Research and Development, chaired by Dr. Daniel Yergin, was constituted under the Federal Advisory Committee Act and operated entirely independently from Department of Energy's management and influence.

The Task Force was composed of 31 members, none of whom had any direct affiliation with the Department. These members represented one of the most impressive collections of seasoned energy experts ever to advise the Secretary of Energy on its energy R&D programs. Dr. Daniel Yergin, is a renowned expert on energy issues and a Pulitzer Prize author of *The Prize*.

Dr. Yergin made all final decisions about Task Force membership. He sought competence in the field and broad representation from industry, academia, and non-Federal public sector interests. The Task Force deliberated extensively in full public view at nine open meetings in order to achieve consensus before issuing its final report.

In July 1995, at the request of Chairman Rohrabacher, the Department conducted a review of all contractual arrangements over the previous five years, from FY 1991 through FY 1995, which, may have existed between the Department, its laboratories and subcontractors, and the organizational entities with whom the Task Force members were employed or otherwise affiliated. Our final report was submitted to the Chairman on August 17, 1995. The results of our review showed that 15 of 31 entities had no contractual arrangements whatsoever with the Department over the entire five-year period. Four other entities had minor funding relationships, totaling from $ 10,000 to less than $ 100,000, over the five-year period. Hence, 19 of 31 entities, or nearly two-thirds of all entities affiliated with the Task Force's membership, had little or no R&D business with the Department. Of the remaining 12 entities, six were major research universities, from whom any Federal sponsor of R&D would be expected to seek R&D expertise.

These Task Force members provided a valuable public service to the Department and the Nation by sharing the wisdom and advice of their experience virtually free of charge. They made a considerable commitment of their personal time and effort. Their sole purpose was to render a collective view-based on their professional knowledge and expertise–on how the Nation might best address its long-term energy R&D needs. They did this as a public trust, independently, without conflict of personal or organizational interest.

[*Note: Chairman's Rohrabacher's letter to Secretary of Energy Hazel R. O'Leary dated June 30, 1995, Secretary O'Leary's response dated August 2, 1995, and Acting Deputy Assistant Secretary for House Liaison, Robert S. Kripowicz response dated August 17, 1995 are attached.*]

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE

SUITE 2320 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6371
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June 30, 1995

Honorable Hazel R. O'Leary
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary O'Leary:

The House Science Subcommittee on Energy and Environment has received copies of the Final Report of the Secretary of Energy Advisory Board (SEAB) Task Force on Strategic Energy Research and Development, and an accompanying press release dated June 13, 1995, entitled "Independent Task Force Says Energy R&D Essential to U.S. Economy *Cutbacks in R&D Could Put Nation at Risk*".

According to the attached June 13, 1995, press release, "[t]he report cautioned that proposed cuts in federal energy R&D programs 'would not be prudent, given the strategic importance of energy to the Nation' and that energy R&D is needed 'to help mitigate the severe economic risks of possible disruptions in the Nation's future energy supplies.'"

In addition, the press release states that "[t]he Task Force recommends 'that the Federal Government continue to provide leadership, focus, and substantial financial support for energy R&D to ensure that the national goals of U.S. energy security, economic growth, environmental quality, and national leadership in science and technology are effectively achieved. Such support is essential to our Nation's future well-being."

Basically, the Task Force endorses the status quo, but bemoans the fact that even more taxpayers' dollars are not being spent on energy R&D. While this result is hardly surprising, I find it disturbing the many of the members of this "independent" task force are employed by or affiliated with entities that receive funding from the Department of Energy.

June 30, 1995
Page Two

Specifically, I request that you provide me details of all direct and indirect Department of Energy funding (including type of funding instrument and purpose of funding) for each of Fiscal Years 1991 through Fiscal Year 1995 to date for each of the following entities: (1) Cambridge Energy Research Associates; (2) AlliedSignal Inc., (3) PG&E Enterprises, (4) American Gas Association, (5) State of Iowa Department of Natural Resources, (6) Honeywell Incorporated, (7) Clark-Atlanta University, (8) CONSOL Incorporated, (9) Gas Research Institute, (10) Natural Resources Defense Council, (11) Fusion Power Associates, (12) Massachusetts Institute of Technology, (13) American Electric Power, (14) Oregon Public Utilities Commission, (15) Baker, Hughes, Incorporated, (16) Pacific International Center for High Technology Research, (17) Electric Power Research Institute, (18) Amoco/Enron Solar, (19) ABB Combustion Engineering, (20) Strata Production Company, (21) AES Corporation, (22) Stanford University, (23) Bechtel Group, Inc., (24) University of Michigan at Ann Arbor, (25) The University of Massachusetts, (26) Pennsylvania State University, (27) U.S. Export Council for Renewable Energy, (28) Shell Oil Company, (29) Unocal Corporation, (30) National Power Company, and (31) The Alliance to Save Energy.

I further request that this information be provided no later than the close of business on Monday, July 10, 1995.

If you or your staff have further questions regarding this request, please contact Dr. Harlan Watson, Staff Director of the Subcommittee on Energy and Environment at 225-9816.

Thank you for your cooperation.

Sincerely,

Dana Rohrabacher
Chairman
Subcommittee on Energy and Environment

Attachment

SEAB

Task Force on Strategic Energy Research and Development

Daniel Yergin, Chairman
Maxine Savitz, Vice Chair
Mason Willrich, Vice Chair

EMBARGOED FOR RELEASE UNTIL:
Tuesday, June 13, 1995
12 Noon, E.T.

CONTACT: Maria Rodriguez
Vanguard Communications
(202) 331-4323

Independent Task Force Says Energy R&D Essential to U.S. Economy
Cutbacks in R&D Could Put Nation at Risk

Federal support for energy R&D is "essential to our Nation's future well-being," contributing to economic growth, security, environmental quality, and competitiveness in the international marketplace, according to an independent Task Force chaired by energy expert and Pulitzer Prize-winning author Daniel Yergin. Noting that Department of Energy research and development "has had its flaws," the Task Force added that recent investments "are generating billions of dollars worth of annual consumer energy savings and new business opportunities, and playing an important role in job creation."

The report cautioned that proposed deep cuts in federal energy R&D programs "would not be prudent, given the strategic importance of energy to the Nation" and that energy R&D is needed "to help mitigate the severe economic risks of possible disruptions in the Nation's future energy supplies."

"DOE's R&D programs can be made more efficient," said Yergin, president of Cambridge Energy Research Associates. "But the wholesale demolition of those programs would not only hurt America's energy position but also contribute to a 'brewing R&D crisis' in the United States—the result of simultaneous cutbacks in federal R&D programs, and retrenchment and refocusing of private sector R&D."

Energy R&D: Shaping Our Nation's Future in a Competitive World, is the product of a nine-month study by a 30-member Task Force of leading energy experts from industry, academia, and research, under the chairmanship of Yergin, the author of *The Prize: The Epic Quest for Oil, Money, and Power* and co-author of *Russia 2010.* The Task Force was appointed by Secretary of Energy Hazel R. O'Leary in October 1994, and today presented its report to the Secretary of Energy Advisory Board. The group was charged with reviewing and assessing the Department's energy research and development programs.

According to the Task Force, energy R&D funding by the Department of Energy has already been "substantially reduced"—by 75 percent in constant dollars—from $9.7 billion in 1978 to today's

[MORE]

level of $2.5 billion ($1.75 billion in applied energy R&D, and $750 million in basic energy R&D). Federal energy R&D currently is only about one-half of one percent of the Nation's annual energy expenditures.

Energy Security Margin Eroding

World energy demand is expected to grow by 40 percent over the next 15 years; and by the year 2010, the United States will be importing a minimum of 60 percent of its oil, says the Task Force. Although noting that the energy situation has become much more favorable in recent years—"helped by the movement to market principles around the world"—the report observes that "current trends point to stress and tension as the Nation's hard-won `energy security margin' erodes into the next century."

"Technological advances emerging out of R&D will be critical to meeting future energy and environmental needs, reducing stress on the supply and consumption systems, diversifying risk, and avoiding or at least minimizing any future crises that might develop in an uncertain world," says the Task Force.

"The world oil market is tightening again," continues the report, pointing to the "critical capacity utilization indicator." Utilization of global crude oil production capacity, which was well over 90 percent in the early 1970s, before the first oil crisis, and then fell to 85 percent before the 1986 price collapse, is now back to 96 percent.

The report notes that, despite the global movement away from regulation and state control, there is still a "continuing and critical security component to energy, especially oil." More than 450,000 American troops went to the Persian Gulf during the 1990–91 Gulf Crisis, and 20,000 American troops remain in Kuwait today. "But, unlike the Allied Coalition in the Gulf Crisis, innovation and technological creativity cannot be summoned into service on short notice," says the report. "Energy R&D is a long-term investment—a modest investment by comparison to the costs of disruption—that is made to assure a more secure and productive future."

Commenting on the Task Force's efforts, Yergin said: "Given the importance of energy to our economy and our national security, and considering the major cuts that already have hit energy R&D, this is not a time to be abruptly cashing in our energy R&D stocks. The dividends from these investments will be critical to our future standard of living and are part of the inheritance for the next generations."

Energy R&D on the Decline

The Yergin Task Force says that private sector energy R&D amounts to about $3 billion, but is falling, reflecting the overall trend of private sector R&D in the United States. "The `R&D headlights' are being lowered in the private sector, where `long-term' is now only five years—and sometimes only three," says the report.

[MORE]

Noting that public and private sector R&D has been one of the most important "drivers" of U.S. economic growth in the five decades since World War II, the report adds that the shrinking of U.S. R&D will "reduce economic growth, damage the U.S. standard of living and America's international competitiveness—and erode American leadership."

"Today, it is hard for American companies, energy and non-energy alike, to invest in R&D beyond a three- to five-year time horizon, in significant part because companies are being judged on quarterly performance by financial markets," said Dr. Maxine Savitz, vice chair of the Task Force and General Manager of AlliedSignal Ceramic Components. "But it takes more than five years to develop new energy technologies."

Opportunities for Savings

In December 1995, several months into its study, the Task Force was asked by Secretary O'Leary to help the Department identify $1.2 billion in savings over five years from DOE's $1.75 billion annual applied energy R&D programs. The Task Force concluded that deep cuts should not be made in funding that reaches scientists and engineers but that significant savings reductions, as much as 15 percent per year, in energy R&D costs can be achieved primarily through a major overhaul in the way the programs are directed and managed.

"DOE can strengthen energy R&D, while achieving significant savings for American taxpayers, by reducing bureaucracy and cutting reams of red tape," said Mason Willrich, vice chair of the Task Force and former CEO of PG&E Enterprises. "But Congress must cooperate to make this possible by reducing its own micromanagement, the costly 'over-compliance burden,' and the chronic instability in funding."

The Task Force expressed particular concern about excessive overhead and administrative expenses that "drive up costs, divert energy and attention, constrain creativity, and waste resources." Adds the report, "undoing the unnecessary compliance burden is a matter of urgency if the R&D programs are to be efficient."

The Task Force recommends "that the Federal Government continue to provide leadership, focus, and substantial financial support for energy R&D to ensure that the national goals of U.S. energy security, economic growth, environmental quality, and national leadership in science and technology are effectively achieved. Such support is essential to our Nation's future well-being."

"Our Nation's scientific and technical base is one of the country's most valuable resources," concludes the report. "But, without investment, it cannot be maintained."

The Task Force reviewed DOE's energy research and development activities, which include programs in fossil energy, energy efficiency and renewable energy, nuclear energy, fusion, and basic energy research. The Task Force received testimony from dozens of experts from the private sector, research organizations, universities, the Office of Technology Assessment, and the National Academy of Sciences, as well as the Department of Energy.

[END]

The Secretary of Energy
Washington, DC 20585

August 2, 1995

The Honorable Dana Rohrabacher
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Rohrabacher:

Thank you for your letter of June 30, 1995, concerning the Final Report of the Secretary of Energy Advisory Board (SEAB) Task Force on Strategic Energy Research and Development (R&D). Your letter requested details on direct and indirect Department of Energy funding during fiscal years 1991 through 1995 for 31 entities that were listed for affiliation purposes for the Members of the Task Force. Please find enclosed the data you requested.

The data presented in the enclosure covers funding relationships between the Department of Energy and the entities listed in your letter, including grants, contracts and cooperative agreements. In addition, subcontracting relationships were included for those Department of Energy national laboratories with significant energy R&D programs. The data are presented in the two categories of applied energy R&D and energy-related basic research. These two categories constitute the full scope of the SEAB Task Force. Additional notes are provided in the table to describe other funding relationships outside of these categories, for example, with weapons research, laboratory management, or joint planning of R&D.

Your letter expressed the view that the Task Force "endorses the status quo, but bemoans the fact that even more taxpayers' dollars are not being spent on energy R&D." You also found it "disturbing" that many members of the Task Force are employed by or affiliated with entities that receive funding from the Department of Energy. I feel the need to address each of these issues directly.

On the first matter, I simply cannot agree with your assessment that the Yergin Task Force produced a status quo document recommending increased federal funding for energy R&D. To the contrary, the Task Force provided a broad range of recommendations on how the Department should change its energy R&D programs. Through implementation of these recommendations--particularly in the area of management efficiencies--the Task Force concluded that the Department could "reduce total energy R&D costs by 15 percent." This translates into a reduction of approximately $1.2 billion over five years. The Task Force did not recommend increased funding.

Your second concern is more troubling, since it challenges the integrity of the individuals who agreed to serve as members of this Task Force.

Your inference is that the Task Force presented a biased report due to possible financial relationships between the affiliated organizations of the Task Force members and the Department of Energy. This is not supported by the facts. As you will note from the enclosed table, 17 of 31 entities--a clear majority of the Task Force--received no direct funding for energy R&D over the past five-year period. Five more entities had funding relationships totaling less than $100,000. Thus, 22 of 31 members were affiliated with entities having no or relatively minor funding relationships with the Department.

Beyond these statistics, however, I feel compelled to defend both the membership of the Task Force and the process used to determine its composition.

By almost any measure, this Task Force represented one of the most impressive collections of seasoned energy experts that has ever advised the Department on its energy R&D programs. Members of the Task Force are internationally recognized leaders who hold a broad diversity of views. Daniel Yergin made the principal decisions about membership, based on recommendations from sources including representatives in the private sector, relevant staff directors of the National Academy of Sciences and Office of Technology Assessment, and our own experiences in the energy field. Financial relationships between the Department and organizations affiliated with candidate Task Force members were never a consideration and all Task Force members were informed of the conflict of interest rules governing Federal Advisory Committee activities.

The Federal Government gains essential advice from external experts who assist with the peer review processes of R&D agencies and serve on advisory bodies throughout the government. These advisory functions would be severely crippled and the administration of the nation's R&D programs would suffer if one were to summarily disqualify from these processes all individuals with an organizational relationship with the agency being advised. The SEAB Task Force members performed a service to the Department and to the Nation through the commitment of their time and effort. Their guiding purpose was to render a collective judgement--based upon deep professional experiences--on how the nation might best address its long-term energy needs.

I am sorry that we disagree on the value of the SEAB Task Force report, but I look forward to continuing to work with you as Congress further deliberates on issues affecting the Department of Energy.

Sincerely,

Hazel R. O'Leary

Hazel R. O'Leary

Enclosure

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
ABB Combustion Engineering	0	0	Funding from DOE to ABB Combustion Engineering totalled $56K; activities performed with these funds were outside the Yergin Task Force charter of applied energy R&D and related basic research, and are related to other DOE missions.
AES Corporation	0	0	Funds from DOE to the AES Corporation from 1991 to 1995 totalled $2.2 million. These funds were for technical analyses and support services for the Office of Policy, and not for R&D related to the charter of the Yergin Task Force.
Alliance to Save Energy	0	0	DOE funds to the Alliance to Save Energy totalled $749K. One project funded falls within the R&D scope of the Yergin Task Force charter. This project was funded through a subcontract with PNL.
Allied-Signal	7,160	0	Allied Signal has several energy R&D contracts with DOE and its national laboratories. In addition, Allied Signal is the management and operation contractor for the Department's Kansas City Plant. The Kansas City Plant is a DOE/Defense Programs' facility that produces non-nuclear components for nuclear weapons.
American Gas Association	0	0	DOE had no contracts with the American Gas Association between 1991 and 1995.
American Electric Corporation	0	0	DOE had no contracts with the American Electric Corporation between 1991 and 1995.
Amoco/Enron Solar	0	0	DOE had no contracts with Amoco/Enron Solar from 1991 to 1995.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
Baker Hughes, Inc.	0	0	DOE had no contracts with Baker Hughes, Inc. between 1991 and 1995.
Bechtel Corp.	13,215	0	Bechtel performs energy R&D for DOE. Total shown does not include funding to Bechtel Petroleum Operations, Inc. for management and operation of the Department's Naval Petroleum Reserves in California. In addition, total does not include funding to Bechtel Hanford for Environmental Restoration efforts at Hanford, Washington.
Cambridge Energy Research Associates	0	0	DOE has one contract for $298K with Cambridge Energy Research Associates for policy studies and economic analysis. CERA performs no R&D for DOE.
CONSOL Inc.	0	0	DOE had no contracts with CONSOL Inc. between 1991 and 1995.
Electric Power Research Institute (EPRI)	0	0	EPRI received no direct funding from the Department, but the Department jointly planned and cost-shared 10 contracts with EPRI R&D performers from FY 1991 to FY 1995, with a total DOE investment of $6.8 million. Of this, $3.9 million was for energy R&D consistent with the Yergin charter.
Fusion Power Associates	27	0	DOE had no contracts with Fusion Power Associates from 1991 to 1995; one subcontract was awarded by ANL in 1995.
Gas Research Institute	0	0	DOE had no contracts with the Gas Research Institute between 1991 and 1995. DOE and GRI jointly plan natural gas-related R&D of about $100 million per year. Part of this R&D is cost-shared with GRI.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
Honeywell Inc.	1,899	0	DOE funding to Honeywell Inc. from 1991 to 1995 was largely for one contract and one project: Emissions Reduction through District Heating Improvements.
National Power Company	0	0	DOE had no contracts with the National Power Company between 1991 and 1995.
Natural Resources Defense Council	77	0	DOE funding to the Natural Resources Defense Council from 1991 to 1995 totaled $77K. These funds were for two projects: a Pollution Prevention Pilot Program and development of an Energy Efficient Technologies Handbook.
Pacific International Center for High Tech. Research	4,735	0	The $4.7 million represents all DOE contracts and subcontracts with the Pacific International Center for High Tech. Research from 1991 to 1995. Of this, $4.6 million was for an Open-Cycle OTEC Net-Power Producing Experiment.
Pacific Gas & Electric Enterprises	0	0	DOE had no contracts with PG&E Enterprises from 1991 to 1995.
Shell Oil Company	10	0	DOE had no contracts with Shell Oil Company, Inc. PNL had one subcontract for development of Hethom & Pneupe computer codes.
Strata Production Company	0	0	DOE had no contracts with the Strata Production Company between 1991 and 1995.
U.S. Export Council for Renewable Energy	0	0	DOE Funding to the U.S. Export Council for Renewable Energy totalled $369K. This funding was for development of an IMAX film, miscellaneous federal assistance action, and other non R&D activities.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
Unocal Corporation	0	0	DOE had no contracts with the Unocal Corporation between 1991 and 1995.
Clark Atlanta University	510	0	Universities are significant R&D performers for DOE. DOE funding to Clark-Atlanta University is largely through grants. Total shown does not include $22 million in funding from FY 1986 to FY 1994 for the design and construction of a graduate research center for science and technology. The total also does not include $44 million from FY 1990 to FY 1995 for an environmental technology and waste management consortium and academic partnership program.
University of Massachusetts (Boston)	48	420	DOE funded an additional $600K for research projects outside the energy R&D scope of the Yergin Task Force charter.
Massachusetts Institute of Technology	191,147	8,052	Total shown does not include funding to MIT for management and operation of the Bates Linear Accelerator. Funding to MIT for Bates in FY 1994 was $20.7 million.
University of Michigan (Ann Arbor)	7,840	235	Additional DOE funding to the University of Michigan at Ann Arbor is about $92 million. This amount was for activities outside the scope of the Yergin Task Force, and included funding for construction projects, workshops, pharmaceutical research, and educational programs.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
Pennsylvania State University	34,022	1,727	Additional DOE funding to Pennsylvania State University is about $14 million. This amount was for activities outside the scope of the Yergin Task Force, and includes funding for construction projects, policy studies, and educational programs.
Stanford University	18,097	5,663	Total shown does not include funds to Stanford for management and operation of the Stanford Linear Accelerator Center.
State of Iowa Department of Natural Resources	0	0	DOE had no applied R&D or basic research contracts with the State of Iowa.
Oregon Public Utilities Commission	0	0	DOE had no contracts with the Oregon Public Utilities Commission between 1991 and 1995.

Department of Energy
Washington, DC 20585

AUG 1 7 1995

Mr. Harlan Watson, Staff Director
Subcommittee on Energy and Environment
Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Harlan:

This letter provides supplemental information concerning your request of June 30, 1995, regarding the Final Report of the Secretary of Energy Advisory Board Task Force on Strategic Energy Research and Development. Your letter requested details on direct and indirect Department of Energy funding during Fiscal Years 1991 through 1995 for 31 entities that were listed for affiliation purposes for the Members of the Task Force.

In the Department's response of August 2, 1995, a table was enclosed providing the information you requested. Since then, the Department has explored two additional lines of inquiry. The first was to search our data bases for names of entities that were not on your list, but were corporately related to those on your list. This search revealed a contract with Garret Ceramics Components, Inc., a subsidiary of Allied Signal. It also revealed a number of contracts with Combustion Engineering, Inc., which is now part of ABB Combustion Engineering, Inc.

A second line of inquiry was to have the Department's program offices review more completely any indirect funding relationships, through our national laboratory contracting systems, that might exist with the entities of interest. As a result, two additional entities, initially reported to have received no funding from the Department over the last five years, were found to have indirect funding through laboratory subcontracting. Some additions to earlier reported totals for six other entities also were made.

A revised table reflecting this additional information is enclosed. These revisions do not affect the thrust of our initial response of August 2, 1995, nor our view of the value and independence of the SEAB Task Force Final Report.

Sincerely,

Robert S. Kripowicz
Acting Deputy Assistant Secretary for
House Liaison

Enclosure

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 (*thousand dollars*) Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
ABB Combustion Engineering and Combustion Engineering, Inc.	224,401	0	DOE had no contracts with ABB Combustion Engineering for research activities within the scope of the Yergin Task Force on Energy R&D. DOE had $224 million in contracts with Combustion Engineering, Inc. Of this, $54 million was for an IGCC repowering project, $35 million was for MHTGR support, and $49 million was related to advanced light water reactor System 80 development and certification.
AES Corporation	0	0	Funds from DOE to the AES Corporation from 1991 to 1995 totalled $2.2 million. These funds were for technical analyses and support services for the Office of Policy, and not for R&D related to the charter of the Yergin Task Force.
Alliance to Save Energy	140	0	DOE funded four projects with the Alliance to Save Energy that fall within the R&D scope of the Yergin Task Force charter. These project were funded through subcontracts with PNL and NREL.
Allied-Signal and Garrett Ceramic Components	7,160	890	Allied Signal had several energy R&D contracts with DOE and its national laboratories. Total also includes one contract with Garrett Ceramic Components, a subsidiary of Allied Signal. In addition, Allied Signal is the management and operation contractor for the Department's Kansas City Plant. The Kansas City Plant is a DOE/Defense Programs' facility that produces non-nuclear components for nuclear weapons.
American Gas Association	30	0	DOE had no direct contracts with the American Gas Association between 1991 and 1995. NREL had two subcontracts with AGA totalling $30K.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
American Electric Corporation	0	0	DOE had no contracts with the American Electric Corporation between 1991 and 1995.
Amoco/Enron Solar	0	0	DOE had no contracts with Amoco/Enron Solar from 1991 to 1995.
Baker Hughes, Inc.	0	0	DOE had no contracts with Baker Hughes, Inc. between 1991 and 1995.
Bechtel Corp.	20,348	0	DOE funded five contracts for energy R&D with Bechtel. In addition, Bechtel had 7 subcontracts with DOE labs. Total shown does not include funding to Bechtel Petroleum Operations, Inc. for management and operation of the Department's Naval Petroleum Reserves in California. In addition, total does not include funding to Bechtel Hanford for Environmental Restoration efforts at Hanford, Washington.
Cambridge Energy Research Associates	0	0	DOE has one contract for $298K with Cambridge Energy Research Associates for policy studies and economic analysis. CERA performs no R&D for DOE.
CONSOL Inc.	0	0	DOE had no contracts with CONSOL Inc. between 1991 and 1995.
Electric Power Research Institute (EPRI)	0	0	EPRI received no direct funding from the Department, but the Department jointly planned and cost-shared 10 contracts with EPRI R&D performers from FY 1991 to FY 1995, with a total DOE investment of $6.8 million. Of this, $3.9 million was for energy R&D consistent with the Yergin charter.
Fusion Power Associates	27	0	DOE had no direct contracts with Fusion Power Associates. ANL had one subcontract with FPA in 1995.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
Gas Research Institute	0	0	DOE had no contracts with the Gas Research Institute between 1991 and 1995. DOE and GRI jointly plan natural gas-related R&D of about $100 million per year. Part of this R&D is cost-shared with GRI.
Honeywell Inc.	1,899	0	DOE funding to Honeywell Inc. from 1991 to 1995 was largely for one contract and one project: Emissions Reduction through District Heating Improvements.
National Power Company	0	0	DOE had no contracts with the National Power Company between 1991 and 1995.
Natural Resources Defense Council	77	0	DOE funding to the Natural Resources Defense Council from 1991 to 1995 totaled $77K. These funds were for two projects: a Pollution Prevention Pilot Program and development of an Energy Efficient Technologies Handbook.
Pacific International Center for High Tech. Research	5,287	0	DOE funded $5.3 million in energy-related contracts and subcontracts with the Pacific International Center for High Tech. Research from 1991 to 1995. Of this, $4.6 million was for an Open-Cycle OTEC Net-Power Producing Experiment.
Pacific Gas & Electric Enterprises	0	0	DOE had no contracts with PG&E Enterprises from 1991 to 1995.
Shell Oil Company	10	0	DOE had no direct contracts with Shell Oil Company, Inc. PNL had one subcontract for development of Hethom & Pneupe computer codes.
Strata Production Company	0	0	DOE had no contracts with the Strata Production Company between 1991 and 1995.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
U.S. Export Council for Renewable Energy	0	0	DOE Funding to the U.S. Export Council for Renewable Energy totalled $369K. This funding was for development of an IMAX film, miscellaneous federal assistance action, and other non R&D activities.
Unocal Corporation	0	0	DOE had no contracts with the Unocal Corporation between 1991 and 1995.
Clark Atlanta University	510	0	Over five years, DOE awarded a number of grants and contracts for research to Clark-Atlanta University. Total shown does not include $22 million in funding from FY 1986 to FY 1994 for the design and construction of a graduate science and technology. The total also does not include $44 million from FY 1990 to FY 1995 for an environmental technology and waste management consortium and academic partnership program.
University of Massachusetts (Boston)	48	420	Over five years, DOE awarded a number of grants and contracts for research to U Mass. DOE funded an additional $600K for research projects outside the energy R&D scope of the Yergin Task Force charter.
Massachusetts Institute of Technology	191,709	8,052	Over five years, DOE awarded a number of grants and contracts for research to MIT. Total shown does not include funding to MIT for management and operation of the Bates Linear Accelerator. Funding to MIT for Bates in FY 1994 was $20.7 million.

Contractor, University, or State Agency	Estimated 5-Year Total FY 1991-1995 *(thousand dollars)* Applied Energy R&D	Energy-Related Basic Research	Notes for 5-Year Period
University of Michigan (Ann Arbor)	7,843	235	Over five years, DOE awarded a number of grants and contracts for research to U Michigan. Other DOE funding to the University of Michigan at Ann Arbor is about $92 million, for activities outside the scope of the Yergin Task Force, and funding for construction projects, workshops, pharmaceutical research, and educational programs.
Pennsylvania State University	34,397	1,727	Over five years, DOE awarded a number of grants and contracts for research to Penn State U. Other DOE funding to Penn State U. is about $14 million. This amount was for activities outside the scope of the Yergin Task Force, and funding for construction projects, policy studies, and educational programs.
Stanford University	18,390	5,663	Over five years, DOE awarded a number of grants and contracts for research to Stanford. Total shown does not include funds to Stanford for management and operation of the Stanford Linear Accelerator Center.
State of Iowa Department of Natural Resources	0	0	DOE had no applied R&D or basic research contracts with the State of Iowa.
Oregon Public Utilities Commission	0	0	DOE had no contracts with the Oregon Public Utilities Commission between 1991 and 1995.

Q14. On page 14 of your prepared testimony, you state: "Energy R&D has helped keep energy prices low, and can do so in the future."

Please document how "[e]nergy R&D has helped to keep prices low."

A14. Examples of research and development that have helped keep energy prices low include: (1) Sandia National Laboratories' polycrystalline diamond drill bit that lowers the cost of drilling by as much as $1 million per well, reduces lost-time accidents and fatalities, has annual sales in excess of $200 million, and has delivered a total national benefit in excess of $1 billion; (2) four building technologies–fluorescent lamp electronic ballasts, advanced energy-efficient windows, analytical software for energy-efficient building design, and a high-efficiency refrigerator/freezer compressor–developed with DOE support of about twenty-five million dollars, have already saved consumers and businesses a net of more than $5 billion in lower energy bills.

Q15. On page 14 of your prepared testimony, you also state: " . . . Sandia National Laboratory in New Mexico solved a drill-bit problem that industry scientists had tried for two decades to solve. The resulting polycrystalline diamond drill bit lowers the cost of drilling by as much as $1 million per well, reduces lost-time accidents and fatalities, has annual sales in excess of $200 million, and has delivered a total national benefit in excess of $1 billion."

Q15a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A15a. [*Note: DOE sent two different answers to this question. Both responses are included below.*]

Answer 1: The total R&D investment at Sandia National Laboratories by the DOE Geothermal Division and the Fossil Energy Office over the years 1974-86 is estimated to have been $5,262,000, distributed as follows:

YEAR	INVESTMENT
1974	$207,000
1975	$227,000
1976	$248,000
1977	$308,000
1978	$331,000
1979	$525,000
1980	$559,000
1981	$505,000
1982	$424,000
1983	$447,000
1984	$470,000
1985	$494,000
1986	$517,000
TOTAL	$5,262,000

Of this total, approximately $750,000 covered contract work with General Electric ($520,000), Brigham Young University ($25,000), Drilling Research Laboratory ($90,000), and Tulsa University ($115,000). These data are extrapolated from pp. 67-68 of "Technology Transfer Impact Profiles," S. Falcone, University of New Mexico, November, 1995. (The annual distribution of funds is estimated based on the total cost and the annual labor distribution given in the report.)

Answer 2: DOE funding for this technology was through Sandia National Laboratories, and totaled approximately $7.5 million. Although precise year-by-year funding figures are not available, contractor funding was during the FY 1976 to FY 1984 period, and totaled about $0.75 million. General Electric received about 40% of this funding, and the rest was split among Brigham Young University, Drilling Research Laboratory, and Tulsa University. Sandia expenses during this period accounted for the remaining $6.75 million, mostly for labor.

Q15b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A15b. Private sector investment figures are not available, but it is likely that General Electric (GE) invested a considerable sum. GE produced the first synthetic diamonds on prototype drill bits in 1973, and marketed the first commercial bit in 1977. See question 15g for information on how DOE-funded activities complemented GE's efforts and contributed to the overall success of this technology.

Q15c. Please provide detailed documentation of the total national benefit in excess of $1 billion.

A15c. The benefits for this technology are documented in detail in "Technology Transfer Impact Profiles," by Santa Falcone, University of New Mexico School of Public Administration, November 1995. The two major sources of benefits are $ 1.1 billion for regional economic impacts, and $0.7 billion for drilling cost savings. Regional economic impacts were derived by estimating total sales and using a Department of Commerce output multiplier. Drilling cost savings were developed by estimating the number of wells drilled with diamond bits (currently about 14% of domestic wells, including most of the expensive ones), and multiplying by estimated cost savings per well. There are many articles on savings for particular wells using diamond bits, so the estimates used are considered very credible.

Q15d. Does DOE hold the patents for this technology, and if not, why not?

A15d. DOE does not hold the patents for this invention. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights of any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which Department's energy R&D was undertaken. Conveying patent and other rights to the contractor or inventor furthers this objective.

Q15e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A15e. DOE does not hold the patent for this technology.

Q15f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A15f. DOE does not hold the patent for this technology.

Q15g. Please provide evidence that the polycrystalline diamond drill bit technology would not have been developed and commercialized without the DOE funding.

A15g. In the late 1970's GE was marketing a diamond drill bit. However, because of high bit failure rates, and a reluctance by larger bit manufacturers to embrace the new technology, GE began to disband its program. Small specialty bit companies stepped in to fill the void, but failure rates due to a host of technical reasons, combined with inconsistent results, threatened the commercial viability of the diamond drill bits. In the Department's view, DOE funding sustained research during this period, where competition for drilling contracts was fierce, profit margins were not high enough to support R&D, and the expertise did not exist among the drilling and service companies (which were small and numerous) to substantially advance drilling technology. Sandia research findings and computer models on mechanics, hydraulics, thermal properties, force and wear provided the needed foundation for technology advancement. In an industry article summarizing bit advances and breakthroughs from 1981 to 1986, almost half of the citations are to DOE-funded work at Sandia.

Q16. At the bottom of page 14 and top of page 15 of your prepared testimony, you state: ". . . four building technologies–fluorescent lamp electronic ballasts, advanced energy-efficient windows, analytical software for energy-efficient building design, and a high-efficiency refrigerator/freezer compressor–developed with DOE support of about twenty-five million dollars, have already saved consumers and businesses a net of more than $5 billion in lower energy bills."

Q16a. Please document this claim, and provide supporting documentation.

A16a. The estimate of $5 billion is conservative. Consumer energy savings for the four innovations listed above total over $ 10 billion, as described below.

Advanced Energy-Efficient Windows: Cumulative consumer energy savings were developed by combining industry sales information with computer simulations of energy savings per unit of low-E glazing installed in residential and commercial buildings. Glazing industry market sources were used to establish yearly sales of low-E glazing (in billion square feet) for the time period of 1984 to 1995. Computer simulations were used to estimate the annual energy savings per square foot of window, for several different climates and then averaged over climates, and account for HVAC system efficiency and fuel/electricity costs. The computer simulations were validated by comparison to results from outdoor test cells and measurements in buildings. The table on the following page provides the specific calculations supporting the development of the $1.8 billion estimate of cumulative savings.

Estimated Consumer Energy Savings–Low Emissivity Window Coatings

YEAR	RESIDENTIAL SALES (BILLION SQ. FT.)	COMMERCIAL SALES (BILLION SQ. FT.)	RESIDENTIAL SAVINGS/ YEAR ($/SQ. FT.)	COMMERCIAL SAVINGS/ YEAR ($/SQ. FT.)	ANNUAL SAVINGS BY VINTAGE ($ BILLION)	SAVINGS BY STOCK IN A GIVEN YEAR ($ BILLION)
1985	0.006	0.001	0.200	0.410	0.002	0.002
1986	0.059	0.012	0.200	0.400	0.017	0.018
1987	0.120	0.024	0.190	0.390	0.032	0.050
1988	0.170	0.034	0.190	0.380	0.045	0.096
1989	0.180	0.036	0.180	0.360	0.045	0.141
1990	0.160	0.032	0.180	0.350	0.040	0.181
1991	0.170	0.034	0.170	0.340	0.040	0.221
1992	0.190	0.038	0.170	0.330	0.045	0.266
1993	0.210	0.042	0.160	0.320	0.047	0.313
1994	0.230	0.046	0.152	0.282	0.048	0.361
1995	0.230	0.046	0.154	0.284	0.048	0.410
Total	1.725	0.345			0.409	2.059

Cumulative Savings (1988-1995) --> $2.1 Billion
Cumulative Savings as of April 1995 --> 1.8 Billion

("Success Stories" was published on May 22, 1995. Interpolating the annual data to find the estimated savings through the end of April 1995 yields the $1.8 billion figure.)

Analytical Software for Energy-Efficient Building Design: The $1.9 billion in energy savings for buildings constructed through 1993 is based on a 1994 survey of users of the DOE-2 building energy simulation program. The savings estimates are documented on pages 17-20 of *From the Lab to the Marketplace*, January 1995, Lawrence Berkeley Laboratory, Berkeley, California. A copy is being provided. [Attached at the end of this question.] Fluorescent Lamp Electronic Ballasts Savings of $750 million for the florescent lamp electronic ballasts are documented in the following spreadsheet:

Estimated Consumer Energy Savings–Fluorescent Lamp Electronic Ballasts

YEAR	1988	1989	1990	1991	1992	1993	1994	1995
Magnetic Ballasts Shipped (1,000s)	74,609	76,285	78,363	80,386	83,710	82,730	76,184	69,246
Total Ballast Market (1,000s)	75,673	77,711	81,364	88,729	96,860	107,130	110,344	113,654
Electronic Ballast Market Share	1%	2%	4%	9%	14%	23%	31%	39%
Total Stock of Electronic Ballasts (1,000s) [assumes 12-year life/retirement	1,064	2,490	5,491	13,834	26,984	51,384	85,544	129,952
Electronic Ballasts Replacing Original Magnetic Ballasts (1000s)	1,064	2,490	2,490	2,490	2,490	2,490	2,490	2,490
Electronic Ballasts Replacing Efficient Magnetic Ballasts Shown (1000s)	0	0	3,001	11,344	24,494	48,894	83,054	127,462
Electricity Savings for Stock in Year (GWh)	112	261	387	738	1,290	2,315	3,750	5,615
Value of Electricity Savings in Year Shown ($1993 million)	8	18	27	52	90	162	262	393

Engineering Assumptions
Annual operating hours: 3500 hours
Assume ballast powers: Two 32 watt lamps

Cumulative Savings (1988-1995) --> 1,012
Cumulative Savings as of April 1995 --> 749

("Success Stories" was published on May 22, 1995. Interpolating the annual data to find the estimated savings through the end of April 1995 yields the $750 million figure.)

Annual Energy Savings vs Base Case

Basecase for years 1988-1989	90 watts	105 kWh
Basecase for 1990-1995	72 watts	42 kWh
Electronic ballast	60 watts	0

Note: 1 GWh = 1 billion watt-hours=1 million kilowatt-hours

High-Efficiency Refrigerator/Freezer Compressor. From 1978 through 1980, ORNL sponsored a research subcontract for DOE with Columbus Products Company to develop a high-efficiency (energy efficiency ratio, or EER, of 5.0) compressor for household refrigerators. By making design changes to the motor, suction muffler, and compressor valve assembly and piston Columbus Product achieved a 44% improvement over the compressor technology used in refrigerators at the time (EER 3.5).

The resulting technology was incorporated into a compressor product line manufactured by Greenville Products Co. (Kelvinator) of Grand Rapids, Michigan, which produced and sold them through the mid-1980's. The technology was then transferred to Americold Compressor Co. of Cullman, Alabama. Americold continued improving compressor designs on their own through the 80's and 90's and have exceeded the performance standards set by the DOE-supported development. They are now marketing refrigerator compressor with EERs of 5.2-5.5 for use with R-134a (replacement for CFC-12) and are developing a new line of R-134a compressors for refrigerators and freezers, manufacturing over 4 million per year.

The availability of high efficiency compressors was a major reason refrigerator energy use (on a shipment-weighted-average basis) dropped from about 1500 kWh/yr in the late 1970's to about 900 kWh/yr in 1990. Availability of improved compressors pioneered by DOE's research effort is responsible for approximately half of this improvement

The shipment-weighted average energy use of new refrigerators in the late 70's (when DOE-sponsored research started) was about 1500 kWh/yr. New refrigerators were produced at an average rate of about 6.25 million units/yr between 1980 and 1990. By incorporating energy efficiency improvements into the refrigerator, 150 billion kWh or 1.7 quads of cumulative energy have been saved with energy efficient compressor accounting for 75 billion kWh. At an average utility cost for electricity of $0.08/kWh this results in $6 billion in energy cost savings.

Q16b. Please document the private sector investment in these technologies.

A16b. *Advanced Energy-Efficient Windows*: Private sector investment is very difficult to estimate since this type of information is generally considered as confidential by industry. Southwall (formerly Suntek) initially raised more than $10 million in venture capital in the early 1980's after successfully demonstrating the potential for low-E technology. These funds were used to complete product development, perform engineering design of the equipment required to produce low-E coatings and set up the initial production facility.

The success of Southwall producing and marketing low-E technology subsequently stimulated other companies to make even larger investments over time to provide competitive low-E window products. The industry appears to have made a $150 million investment in low-E production capability over the last 15 years, based on the following assessment:

Current low-E production is about 300 million sq. ft. per year which is the output of about 10 sputtering machines at 20 million sq. ft /machine and five on-line coaters at 20-50 million sq. ft. Each sputtering machine or on-line coater represents a direct manufacturing investment of about $10 million, or a total of about $150 million.

In addition, substantial R&D investments were made by industry to bring low-E technology to high-rate, cost-effective production. This investment is estimated at approximately 10 percent of the production investment, or $15 million. Additional investment was made by glass producers in testing and marketing the coatings, and by the window manufacturers who had to make R&D and marketing investments in the transition from use of standard insulating glass to low-E insulating glass.

Analytical Software for Energy-Efficient Building Design: The private sector funding in the DOE-2 building energy simulation program, is shown below (in thousands of dollars), along with ratio of private to government funding.

YEAR	PRIVATE SECTOR INVESTMENT IN DOE-2	RATIO OF PRIVATE SECTOR TO GOVERNMENT FUNDING
FY76-89	1,500	15%
FY90	170	60%
FY91	180	53%
FY92	230	61%
FY93	998	333%
FY94	1,125	205%
FY95	1,150	209%
FY96	750	136%
Total	6,103	47%

Fluorescent Lamp Electronic Ballasts: It is extremely difficult to estimate private sector cost since manufacturer investment data is generally considered as confidential. To estimate this value, we note that there were approximately 12 small ballast manufacturers, other than Iota and Stevens, that began to manufacture electronic ballasts starting in 1977 (see attached Figure 1.6). If each of these 12 companies invested only $100K annually over the five years from 1980-1984 (a very conservative number), the total industry investment would be $6 million (12 companies x $100,000/yr x 5 yrs = $6 million). This provides a lower bound on the private sector investment in this technology for the five year period 1980-1984. The actual investment was probably much larger.

High-Efficiency Refrigerator/Freezer Compressor: The private sector cost share was $276,000 by Columbus Products Company in the DOE sponsored research and development effort.

Q16c. Please provide evidence that these four building technologies would not have been developed and commercialized without the DOE funding.

A16c. *Advanced Energy-Efficient Windows*: Low-E coating technology would probably have been developed eventually by industry. However, its initial introduction would have been much later and resulting market penetration would have been slower.

Two key events, both directly influenced by DOE investments, moved low-E commercialization forward in the late 1970s and early 1980s:

1) DOE funding directly resulted in the first firm (Suntek, later renamed Southwall) offering low-E windows for sale. The company came to DOE for R&D funds when it was unable to obtain private sector investment for its R&D because it was a small company and its technology was seen as unproved and too risky. After 3 years of federal support for R&D the company was able to raise the venture capital needed to complete production engineering and, ultimately, to procure its first low-E coating machine.

2) The first major window manufacturer to adopt low-E was Andersen Windows, who utilized low-E coated glass produced by Cardinal IG, a major U.S. glass manufacturer. Both Anderson and Cardinal stated that DOE-funded efforts in the late 1970s and early 1980s were important factors in the critical decisions that led them to make major-capital investments in these new coating technologies.

Analytical Software for Energy-Efficient Building Design: The private sector and other agencies have developed building energy simulation models, but none approach the level of capability of DOE-2, and since many opportunities occurred without the development of such capability, it is reasonable that it would not likely have occurred without the DOE program.

In a 1995 survey of users of the DOE-2 building energy simulation program, the reasons respondents gave for selecting DOE-2 over other, public and private sector building energy simulation programs include: "flexibility, range of modeling options, equipment configurations, and ability to compare complex energy systems", "recognition", "peer acceptance", "accuracy", "best available", "speed", continuously improving", "industry standard", "international credibility", "other programs considered self-serving", "unbiased", "validated", "client preference", "support", "reliability", "completeness", "hourly", "detailed hourly reports", "whole building", and "parametric run capability".

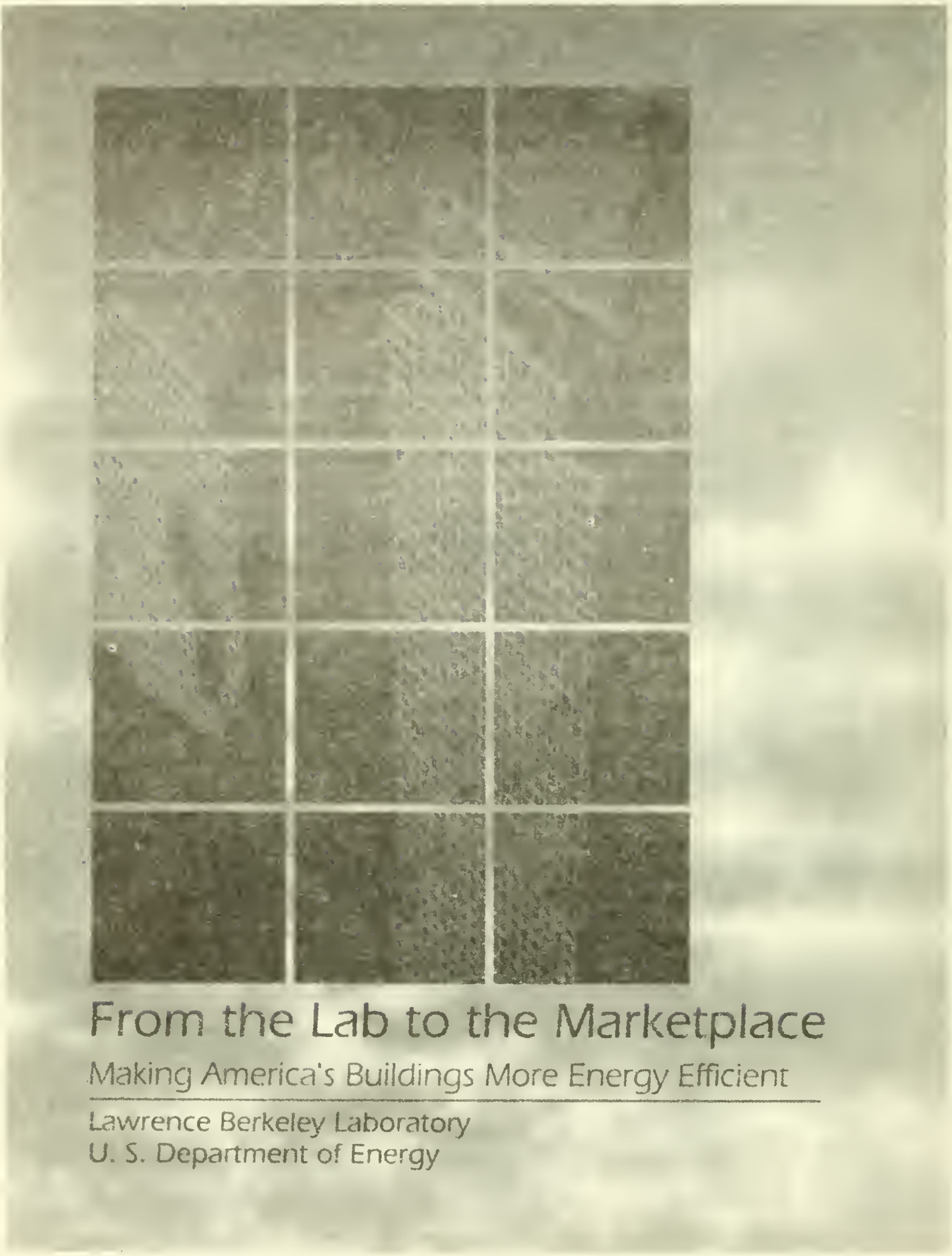
DOE-2 has the largest user base of any public or private sector building energy simulation program–more than 1200 users. Most private sector building energy simulation program have fewer than 100 users. The only other major public sector building energy simulation programs, BLAST (developed by the Department of Defense and no longer under development) and TRNSYS (developed by the University of Wisconsin with support from federal agencies) both have fewer than 400 users.

In 1992, the Electric Power Research Institute decided to develop a new building energy simulation program. They first reviewed all the available public and private sector tools, concluding that none of them except the DOE-2 building energy simulation program would meet their needs. They then started a joint effort with the Department of Energy's Lawrence Berkeley National Laboratory to develop a new version of DOE-2. Since 1992, the Electric Power Research Institute and its member have expended approximately $3 million in this development effort. The new version of DOE-2, PowerDOE, will be released in early FY 1997.

Fluorescent Lamp Electronic Ballasts: The electronic ballast would probably have been eventually developed by the ballast industry, but market introduction would have been delayed (perhaps as long as 5 years) and market penetration would have been slower. Indirect evidence of the above statement is as follows:

Large ballast manufacturers produce most of the electronic ballasts shipped today. But when LB/DOE released RFPs for electronic ballasts in 1976, no large manufacturers responded, even though 90% of conventional magnetic ballasts at that time were produced by only two large manufacturers. The small companies who won the RFP had been unable to attract the capital to commercialize the electronic ballast technology. It was not until the injection of DOE funding for the production of manufacturer prototypes and LBL/DOE's testing at the Pacific Gas and Electric Company demonstration site (and other sites) that the larger ballast manufacturers started to take notice and invest in the technology. In 1983, Magnetek entered the electronic ballast market–the first major manufacturer to do so. Universal (another large ballast company) acquired Stevens Luminoptics in 1981 with the intent of commercializing the electronic ballast technology. The other major ballast manufacturer, Advance Transformer, did not enter the electronic ballast market until 1987.

High Efficiency Refrigerator-Freezer Compressor. There is no firm evidence that advanced refrigerator/freezer compressors would not have eventually been developed without DOE funding. However, prior to the issuance of the DOE competitive solicitation for advanced compressor development, there was negligible energy performance-related R&D being carried out by the major U.S. refrigeration systems manufacturers. The technology developed by DOE led to a compressor which was 44% more efficient than any available at that time, and this technology dominated the market until 1990 when efficiency standards and other influences began to propel compressor development forward again.



From the Lab to the Marketplace

Making America's Buildings More Energy Efficient

Lawrence Berkeley Laboratory
U. S. Department of Energy

For further information about the programs described in this report, contact Dr. Evan Mills:

510/486-6784
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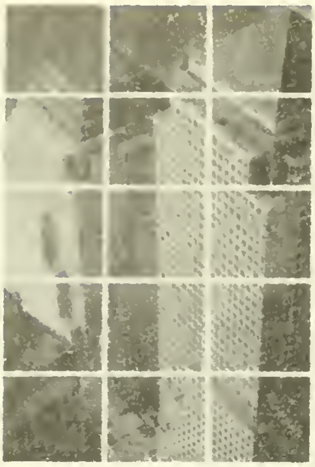

From the Lab to the Marketplace

Making America's Buildings More Energy Efficient

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Revised March 1995

SUMMARY

Since the mid 1970s, DOE has invested some $70 million in research and development at Lawrence Berkeley Laboratory (LBL) for development of advanced energy-efficient building technologies, software, and standards. That investment has helped spawn a $2.4-billion U.S. market for key products—energy-efficient lighting and advanced window coatings—and efficiency standards for residential equipment and computerized tools for more efficient building design. By 1993 DOE's initial investment had reduced consumers' energy bills by an estimated $5 billion ($1.3 billion in 1993 alone). By 2015 we estimate that the products of that investment will save consumers $16 billion annually.

LBL research partnerships address a host of other building technology issues as well—building technology issues whose economic benefits are less easy to quantify but whose overall worth is equally important. We analyze public policy issues such as the role of efficiency options as a mitigation strategy for global climate change. We develop planning and demand-management methodologies for electric and gas utilities. We identify technologies and analytical methods for improving human comfort and the quality of indoor air. We contribute to the information superhighway. We focus on the special problems and opportunities presented by energy use in the public sector. And we do all these things at the local, national, and international levels.

At LBL, we are part of the multi-laboratory, interdisciplinary approach to building technology research supported by DOE's Office of Energy Efficiency and Renewable Energy. We also participate in buildings-related research supported by DOE's Office of Health and Environmental Research, other federal agencies, and industry. This document describes LBL's role within this wider effort.

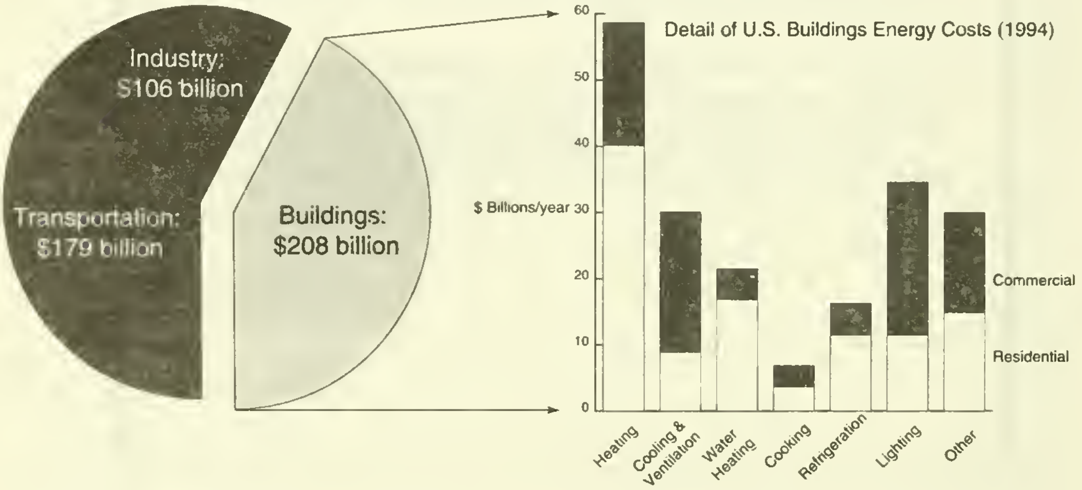
BRINGING NEW TECHNOLOGIES TO MARKET

As part of the DOE national laboratory system, Lawrence Berkeley Laboratory has acted as a catalyst in the energy-efficiency marketplace for two decades, providing an extraordinary rate of return on the federal research investment. From the outset, our approach was not one of belt-tightening, but rather a coordinated technological and deployment-oriented strategy for doing more with less energy and, at the same time, saving money. Partnerships with industry, utilities, government agencies, universities, and others are an integral part of that strategy. LBL's accomplishments in the building sector provide an example of how the national laboratories can serve the nation today and into the next century.

With a $500 billion per year national energy bill and more than half of our oil supplied by foreign sources, U.S. energy use has become a matter of strategic importance. There is little disagreement that wise management of our energy consumption is a national priority, and we are making substantial progress toward that goal. Thanks in part to new technologies and policies focusing on the efficient use of energy, leveraged by research and development (R&D) at the DOE national labs, the national energy bill is about $100 billion lower today than it would otherwise have been.

Programs addressing energy and the environment promise relief for some of the most pressing issues of our time: the rising national energy bill, industrial competitiveness, international security, urban and indoor air pollution,

Components of the $500-Billion U.S. Annual Energy Bill



and the specter of global climate change. At the same time, it is recognized that energy-saving objectives must be coupled with goals of enhanced comfort, quality, productivity, and safety in the built environment.

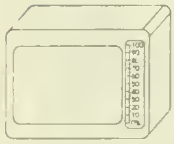
LBL's interdisciplinary research programs are positioned to guide new technologies from the lab to the marketplace. Research and development plays an important leveraging role in the marketplace by accelerating the commercialization and consumer acceptance of new technologies, while ensuring the quality of the indoor environment. This work is rooted in collaborations with equipment manufacturers, building professionals, utilities, and other national laboratories active in the energy sector. New technologies nurtured at LBL with multimillion-dollar research programs are yielding multi*billion*-dollar savings nationally as they successfully capture market share.

Four Highlights

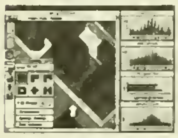
In the following pages, we present four case studies along with a discussion of future directions in each area:

- **The electronic ballast**, a technology that improves the efficiency of fluorescent lighting systems by up to 30% and enhances their quality and flexibility. The current market share of electronic ballasts is 23% of all ballasts sold. Other LBL efficient lighting breakthroughs are also entering the marketplace.

- **Advanced energy-efficient window coatings**—largely invisible to the human eye—thatoffer a one-third efficiency advantage over ordinary double-glazed windows by selectively blocking unwanted heat gain or loss. The current market share is 36% of all windows sold.



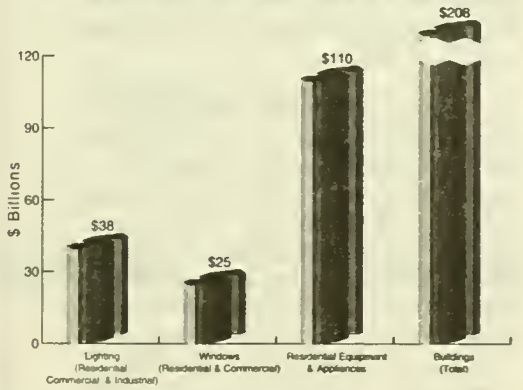
- **Residential equipment and appliance standards development**, in which LBL provides the technical and economic analyses used by the government to set mandatory efficiency levels for household appliances and heating and cooling equipment. The current market share is virtually all major appliances, air-conditioners, and furnaces sold.



- **DOE-2, a powerful computer-based design tool for reducing energy use in buildings.** Thanks to this computer software, building designers can now evaluate the energy implications of complex design alternatives. DOE-2 is currently used in the design of about 5% of all commercial buildings by floorspace. Users report that DOE-2 enables them to routinely identify an extra 20% energy-savings opportunity.

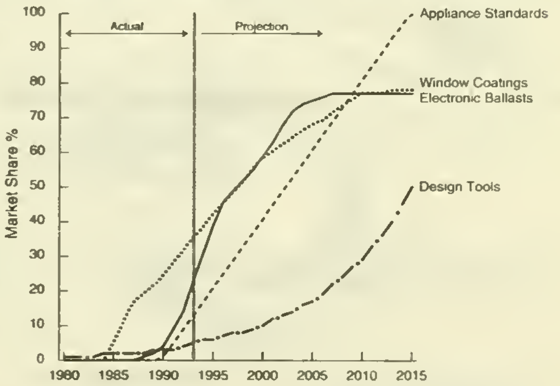
Each of the preceding four examples documents a different path to energy savings—with, in each case, a different role for LBL in capturing these savings. This report assembles the best available data and provides the framework for understanding how DOE's investment ultimately serves the U.S. consumer.

Annual U.S. Buildings Energy Costs Targeted by LBL Research



Note: "Buildings" includes windows, equipment, lighting, and all other end uses.

Market Penetration of New Technologies and Tools



Note: Market shares for windows, ballasts, and tools represent percentage application in new buildings; for appliance standards, the share represents the rate at which new appliances meeting the standard replace existing stock.

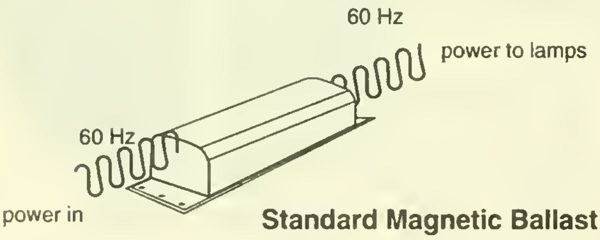
ACCELERATING THE MARKET FOR EFFICIENT LIGHTING

Lighting costs U.S. businesses and consumers nearly $40 billion each year. The strategic use of research dollars can trim billions from this annual bill. LBL's early work on the electronic ballast illustrates the potential payoff from lighting research and working with industry. Virtually unknown in the mid 1970s when the $3-million LBL research effort began, the electronic ballast today has captured a nearly 25% market share, with annual U.S. sales of about 24 million units ($200 million incremental retail value). It has already saved $400 million in consumer energy bills. Net savings will grow to $13 billion by the year 2015. In current research efforts, LBL has transferred new light fixture design strategies to all major U.S. manufacturers and is fostering the development and commercialization of the world's most efficient white light sources. Other work on the effect of various types of light sources on humans may revolutionize the way efficiency and lighting are measured and thereby improve productivity in the workplace.

The Electronic Ballast—An Early Success

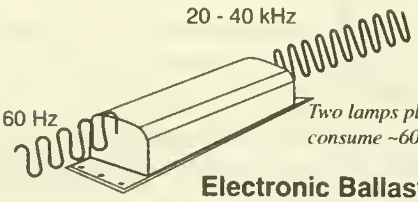
Fluorescent lights require ballasts, which help start and then control the current flowing through the lamp. An annoying flicker, hum, and energy loss are infamous hallmarks of the magnetic ballast, the industry standard for decades. More than ten years ago, LBL played a catalytic role in developing the high-frequency electronic ballast and in encouraging its market growth. Electronic ballasts not only eliminate flicker and hum, they also save energy by reducing electrical losses in both the ballast and the lamps. Electronic ballasts can also be designed for dimming, and can be made smaller and lighter than standard ballasts.

When our research on the electronic ballast was just beginning in the late 1970s, LBL contracted with three small companies to produce commercial models of high-frequency electronic ballasts for conventional fluorescent lamps. (At that time, no electronic ballasts were commercially available—even though the high-frequency operation of fluorescent lamps was known to improve energy efficiency.) The intent of this early effort was to accelerate the availability of electronic ballasts by demonstrating the energy efficiency and reliability of these new, energy-saving products in typical building environments. After the ballasts were tested by LBL to assure compliance with specifications, they were installed at a demonstration site in a utility office (PG&E) in San Francisco. The results of these early demonstrations were widely publicized at technical and trade conferences and showed that electronic ballasts could operate satisfactorily in a typical building environment and reduce lighting energy use by up to 30%.



Standard Magnetic Ballast

Two lamps plus ballast consume ~90 watts



Two lamps plus ballast consume ~60 watts

Electronic Ballast

As a result of research efforts and continued quality improvements, the electronic ballast has developed from a laboratory curiosity to a proven and successful energy-efficient lighting technology. By 1993 electronic ballasts represented 23% of total ballast sales, and the electronic ballast is now an accepted mainstream product. They will likely replace magnetic ballasts in more than 75% of applications by 2015 as a consequence of utility and other incentive programs, and federal programs and standards.

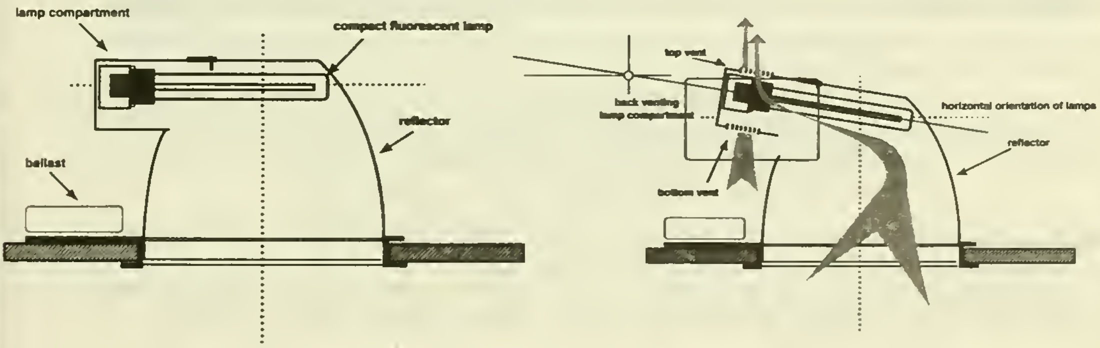
The federal investment in electronic ballast R&D is about $3 million, leveraging a cumulative energy savings attributable to electronic ballasts from 1988 to 1993 of $400 million. Based on energy savings "in the pipeline," i.e., for technologies installed as of 1993, businesses and consumers will ultimately save $700 million (*net* of their extra capital investment), which will grow to $13 billion for technologies installed through the year 2015. In 2015, environmental emissions of approximately 73 million tons of CO_2, 157,000 tons of SO_2, and 144,000 tons of NO_x will be avoided through the use of electronic ballasts.

Beyond Ballasts

Current research focuses on LBL-industry collaborations to improve other lighting systems through advanced lamps, luminaires, controls, and daylighting strategies. One major area of emphasis is the search for near-term improvements to the traditional incandescent lamp. Although incandescent lamps are the most inefficient light source currently available, nearly two billion such lamps are manufactured annually in the U.S. LBL is working to optimize the performance of one alternative—compact fluorescent lamps (CFLs), which are four times as efficient as today's incandescent light sources. Lamp manufacturers have shown keen interest in the LBL design concepts. Osram, one of the world's largest lighting manufacturers, included the LBL work in its widely used *Compact Fluorescent Handbook.*

In 1989, lighting researchers began work with major manufacturers of compact fluorescent lamp fixtures. Early on, LBL researchers specifically targeted the recessed "can" fixture industry, which has annual sales of about 20 million units in the U.S. and has the fastest sales growth of any type of fixture. LBL pioneered a series of optimized low-cost fixture improvements that use conductive cooling or convective venting designs to eliminate excess heat buildup, thereby allowing up to 25% greater light output. Manufacturers such as Cooper Lighting, Delray, Edison Price, Indy Lighting, Kurt Versen, Lightolier, Lithonia, Microflect, Mitor, Prescolite, Reggiani, Staff, and Zumtobel have already incorporated LBL's efficiency-enhancing strategies into their product lines. Manufacturers see these improvements as enhancing their position in markets where many consumers are dissatisfied with the amount of light produced by conventional compact fluorescent fixtures. From the standpoint of national energy use, these improvements widen the market niche for CFLs and appreciably increase potential savings.

Standard Recessed Fixture Without Venting **Vented Fixture With Tilted Lamp Compartment**



Allowing for passive ventilation and tilting the lamp to keep excess mercury away from hot lamp electronics increase fixture light output up to 25%.

In another effort, LBL researchers are working with Fusion Lighting to create a novel light source that is about 50% more efficient (~130 lumens/watt) than the best-available fluorescent systems and yet provides a far superior spectrum, similar to that of true sunlight. The so-called "sulfur lamp" contains no environmentally troublesome mercury, offers an extremely long service life, and has "tunable" color properties. It is dimmable and delivers efficiency unmatched by any currently available white light source.

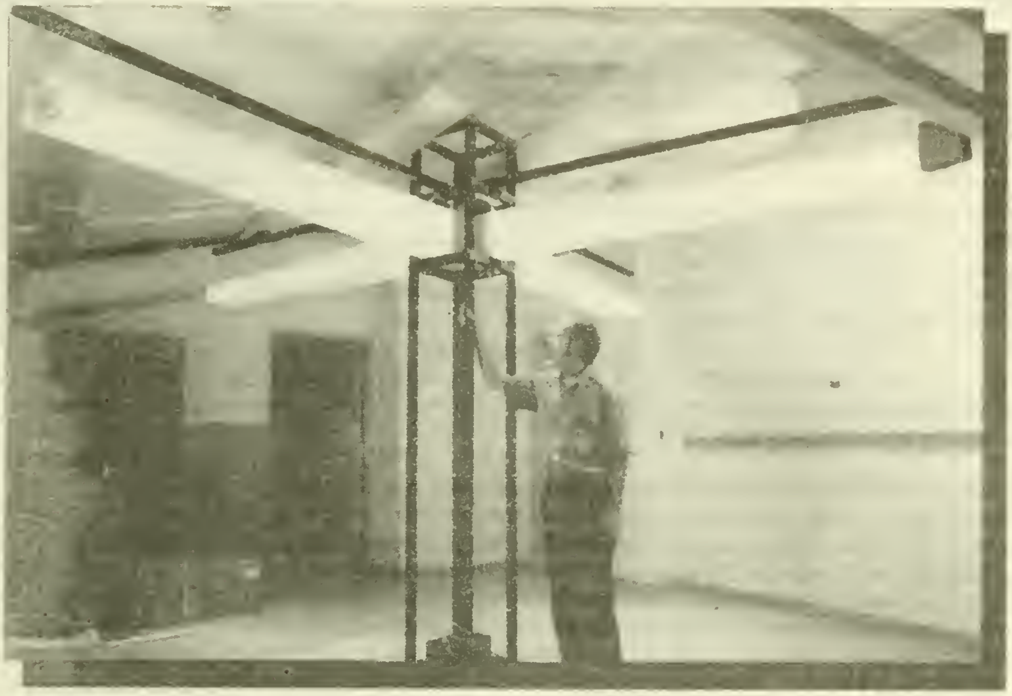
LBL researcher examines prototype sulfur lamp.

LBL expertise in coupling radio-frequency power to electrodeless lamps has enabled Fusion Lighting to downsize a pre-existing product that was unlikely to ever reach the commercial marketplace. The large original lamp produces as much light as 175 full-sized fluorescent lamps and requires a microwave power supply and its own miniature air conditioner. Two new versions are downsized to the size of a coin and require no active cooling. One generates as much light as fifty fluorescent tubes, the other as much as two tubes. However, several technical and economic challenges must be overcome before the sulfur lamp will be commercially viable. Such intense light sources require a fundamental rethinking of the light fixture, which has spurred a program of R&D on "light guides"—long reflective tubes that can conduct and distribute this bright light over a large indoor area. Integrating these guides with architectural daylighting offers the prospect of buildings lit by daylight deep in their interiors. LBL helped demonstrate sulfur lamp and light guide systems at DOE's headquarters and at the Air and Space Museum, both in Washington, DC.

The Future

Complementing LBL efforts in technology development are research activities investigating lighting design and applications, and the human response to lighting. Interdisciplinary research performed in collaboration with medical experts has demonstrated that the fundamental measure of light—the "lumen"—is a poor measure of how people actually perceive light. This research suggests that by "tuning" the spectrum of light sources to optimize the responses of rods and cones in the eye, we will be able to see better and with less energy needed for illumination.

"Market transformation" is another development frontier. LBL researchers are providing technical support to groups that design innovative deployment strategies for efficient lighting. LBL has assisted DOE in developing national standards aimed at improving lighting efficiency and is supporting DOE and U.S. Environmental Protection Agency (EPA) efforts to improve the market penetration of efficient residential lighting technologies.



LBL researcher inspects a centralized light guide system consisting of a 250-watt metal halide lamp, a high-efficiency beam splitter, and four hollow light guides. This results in a lighting load of only 60 watts per work station with light levels even higher than those provided by typical fluorescent systems–and superior light quality. Eventually, sulfur lamps will be used with this type of system.

SEEING WINDOWS THROUGH

$25 Billion

Energy lost through residential and commercial windows costs U.S. consumers about $25 billion a year, a loss comparable to the value of the oil delivered by the Alaska pipeline. LBL pioneered the commercialization of "low-emissivity" windows and labeling systems, which reduce the energy lost through normal, double-glazed windows by 35%. Thanks to LBL's close collaboration with window manufacturers, and a DOE investment of $3 million, the market share for these advanced windows has reached about 35% (with an annual market value of $630 million). Cumulative U.S. energy savings to date from these windows is $760 million and will reach $17 billion—net of added up-front costs—by 2015.

In 1976, in response to the energy crisis, DOE began a program at LBL to examine the potential of new, more efficient window technologies. In 1993, after almost 20 years of an R&D partnership with industry, that effort has resulted in sizable energy savings to U.S. building operators, and the development of a new line of energy-efficient window products that are generating sales and profit opportunities for window manufacturers.

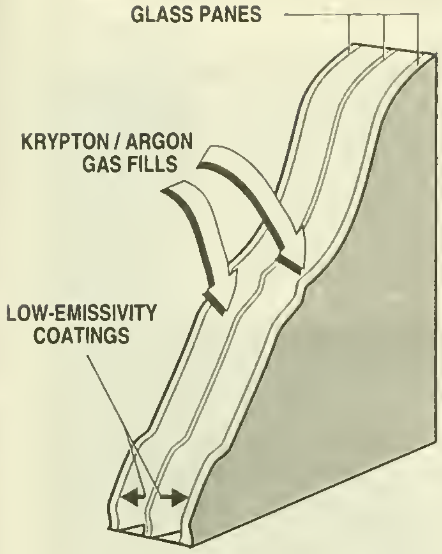
Our initial goal was to develop a clear understanding of the heat transfer mechanisms in windows and identify the technical opportunities for reducing those gains and losses. In cold climates, low-emissivity coatings allow sunlight to enter while reflecting back to the interior the long-wave infrared radiation that accounts for more than half the heat loss. Although the principle of how these coatings work was then understood, no U.S. manufacturer had yet developed a commercial product. At the time, there was no market demand (the benefits were unclear to purchasers), and it appeared impossible to produce coatings of high quality at low cost.

LBL awarded subcontracts to several firms to develop prototype coatings and new, low-cost, thin-film deposition processes. The performance of the coatings was tested at LBL and new computer models were developed to determine the best use of the coatings in the overall window system.

Encouraged by these efforts, by 1980 several large manufacturers were actively involved in low-emissivity window development, making major investments in manufacturing systems for new coatings. Initial product introductions in 1981–82 by a few innovative firms stimulated major manufacturers to offer products of their own. Second-generation products emerged that had greater durability and suitability for a wider range of climates. They were tested at LBL to demonstrate their market potential. By the mid 1980s, virtually every window manufacturer was offering low emissivity (low-e) windows. By 1987, low-e windows claimed 17% of window sales (18 million square meters per year).

Laboratory analyses at LBL showed that the next step to improve window energy efficiency for cold climates was to eliminate the air inside the double-paned insulating unit, replacing it with low-conductivity gas (such as argon). LBL simulation tools, as well as laboratory and field test data, helped convince manufacturers to incorporate this technique into their product and to inform purchasers that this was a reliable, cost-effective approach. Double glazings with both low-e coatings and gas fills lose only 50% of the heat lost by conventional double glazing.

Although substantial efficiency improvements had been achieved, leading manufacturers were interested in pushing the technology further. Analysis suggested that windows with specific thermal and solar gain properties would perform so well that they would have a lower winter heating load than the best insulated walls. LBL staff developed a new "superwindow" concept for a multiple glazed window using two low-e coatings and a new krypton gas fill. LBL teamed with five manufacturers and suppliers (Andersen, Cardinal IG, Owens-Corning Fiberglas, Pella, and Southwall Technologies) and the Bonneville Power Administration to convert this window concept into commercial prototypes. Within two years, one participating manufacturer introduced the first commercial "superwindow" to the market.



"Superwindow" concept, based on multiple glazing, low-emissivity coatings, and gas fills.

Spectrally selective glazings are a recent variant on low-e coatings. Designed for hot climates, they work by selectively filtering out solar heat gain while minimizing the loss of visible light transmission. This advance means potential additional savings in the Sunbelt states and in commercial buildings where cooling loads should be reduced without loss of useful daylighting. In some cases, downsizing the cooling systems (made possible by reduced cooling loads) can offset the added cost of the more efficient windows.

Energy and Environmental Benefits

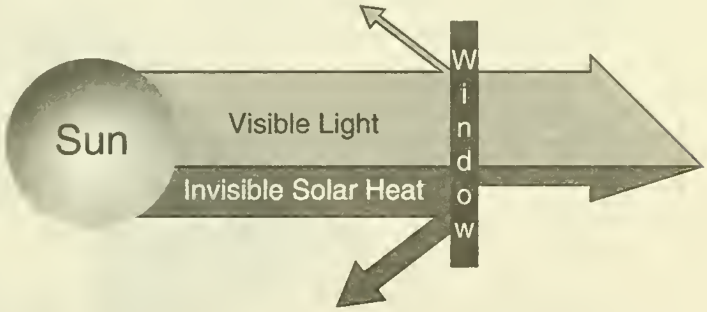
In 1990, the low-e market share rose to about 25%, and in 1993, it reached 36%, The widespread availability of ratings and labels—a development in which LBL plays a lead technical role—should help further accelerate market penetration of more efficient windows.

The cumulative energy savings attributable to advanced window coatings installed as of 1993 was $760 million. Based on energy savings "in the pipeline," i.e., for low-e-coated windows installed as of 1993, businesses and consumers will ultimately save $400 million (*net* of their extra capital investment), which will grow to $17 billion for technologies installed through the year 2015. These enormous savings were leveraged by a cumulative DOE investment through the early 1980s of just $3 million. The environment will also benefit from the use of advanced window coatings: In 2015, energy savings from advanced windows will allow us to avoid the emission of 71 million tons of CO_2, 157,000 tons of SO_2, and 142,000 tons of NO_x.

The Future

Advanced coating technology will lead to "smart windows" by the year 2000. A smart window uses a dynamic coating whose optical properties change from clear to reflective in response to a small electrical current. In partnership with industry, LBL scientists have developed promising prototypes with good performance. In homes, these windows will combine energy efficiency (by reducing summertime solar heat gain and wintertime heat losses) with better comfort and privacy. In the office of the future, smart windows will control solar loads while admitting daylight, allowing electric lights to be dimmed with electronic ballasts.

Toward this end, ion-beam technology developed in LBL's Accelerator and Fusion Research Division is being redirected by LBL's Windows Group to improve energy-efficient window coatings. These ion-assisted processes result in coatings with superior optical properties, longer lifetime, and lower cost. These devices were previously used as sources of particles in accelerators and more recently for some semiconductor processing steps like ion implantation of dopants.

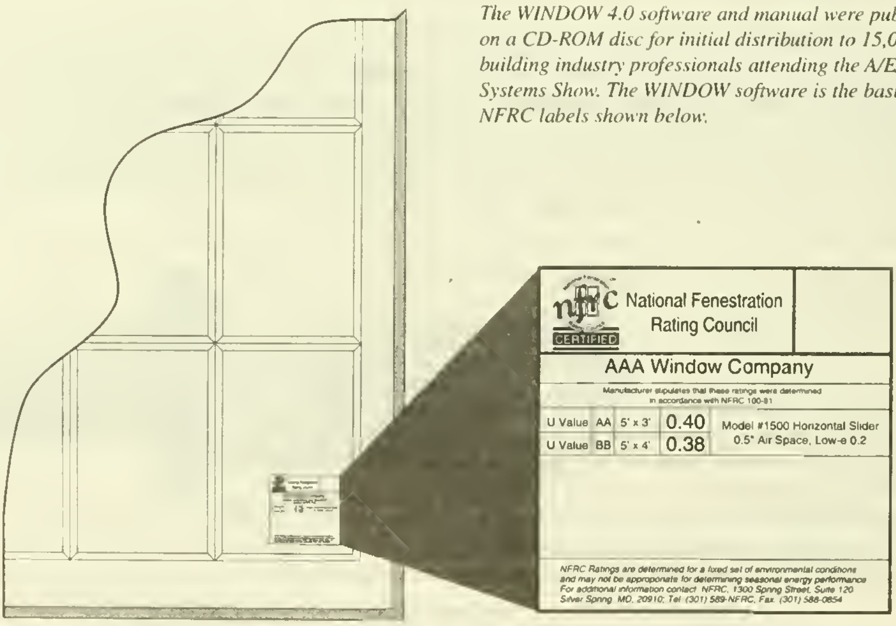


Spectrally selective glazing transmits high levels of visible light while reflecting invisible solar heat.

Labels to Make Windows Clearer

Purchasers of windows are confronted with many difficult decisions. New window features and technology add value, but builders and building owners have little interest in confusing technical details—they simply want to know how the products compare in total performance. In 1989, LBL began working with the window industry, utilities, and state agencies to create a new organization, the National Fenestration Rating Council (NFRC). The goal of the Council is to develop labels for windows that accurately and simply rate their overall performance. LBL has taken the lead in working to develop cost-effective accurate technical procedures for the NFRC, which uses LBL's WINDOW program as the primary rating tool. In 1993 California became the first state to require that all windows sold have an NFRC label.

The WINDOW 4.0 software and manual were published on a CD-ROM disc for initial distribution to 15,000 building industry professionals attending the A/E/C Systems Show. The WINDOW software is the basis of NFRC labels shown below.



SETTING THE STANDARD FOR ENERGY EFFICIENCY

Residential consumers spend $110 billion each year on energy for appliances and heating and cooling equipment. At LBL, our energy policy work includes developing and analyzing appliance standards, many of which have become law. These standards have already saved U.S. consumers $1.9 billion and will result in a $58 billion savings, net of extra up-front costs, by the year 2015. The cumulative federal investment has been $50 million—just one one-thousandth of the benefits to be realized by consumers. Extending these standards to commercial-sector products can pay even higher dividends.

The DOE national laboratories have supported public policy efforts by serving as a key resource for legislators seeking definitive, independent data and technology assessments. As part of this effort, LBL has become the national center for appliance standards analyses. New generations of appliances have been spawned by these efforts. In addition to saving energy for consumers and the nation, these standards help make U.S. manufacturers more competitive in the global marketplace.

LBL's program provides the technical, economic, and manufacturer-impact analyses on which DOE bases mandatory standards that now apply to all major U.S. appliances: air conditioners, clothes washers and dryers, freezers, furnaces, heat pumps, refrigerators, televisions, and water heaters. In addition to technology research, LBL has provided DOE with pivotal support for understanding how the market functions and how certain market barriers to energy efficiency warrant legislative measures such as standards and labeling. Representatives from many countries come to LBL for guidance on developing their own appliance standards.

LBL monitors emerging technologies, identifying those developments that enable commercially viable improvements in appliance efficiency. For inclusion in proposed standards, new technologies must reduce the total life-cycle cost of buying and operating an appliance, while maintaining or increasing the level of service provided.

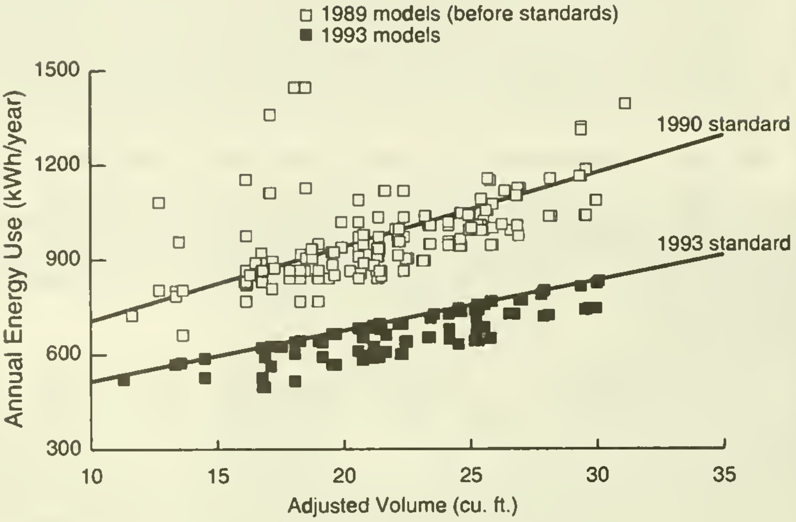
Energy and Environmental Benefits

DOE has invested about $50 million in standards. This sum includes development of test procedures, technical analyses, the administrative costs of public hearings, publication of laws and supporting documents, and program management.

Current appliance standards have already saved consumers $1.9 billion in energy costs and will ultimately save them $58 billion (the lifetime savings of units installed between 1990 and 2015, *net* of the extra investment costs). Coincidentally, U.S. consumers will avoid having to pay for the construction of eighty 250-megawatt electric power plants. These standards yield a benefit-to-cost ratio of almost 2.5 for consumers—energy savings are 2.5 times greater than the up-front cost premium paid for the appliance.

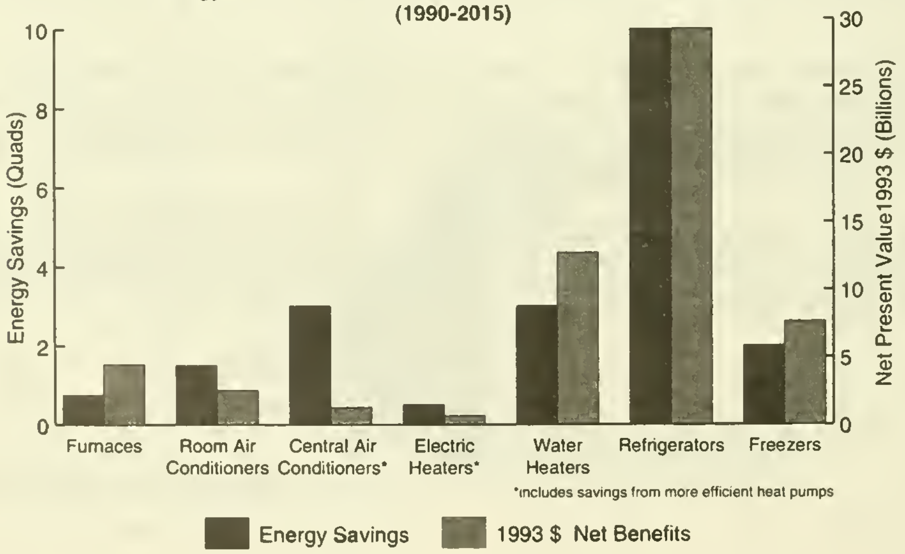
Appliance standards yield sizable environmental benefits as well. In 2015, these standards will enable us to avoid emissions amounting to 53 million tons of CO_2, 111,000 tons of SO_2, and 108,000 tons of NO_x. (These savings assume that chlorofluorocarbons will be phased out of refrigerators and freezers beginning in 1996.)

Refrigerator Standards Eliminate Many Inefficient Models



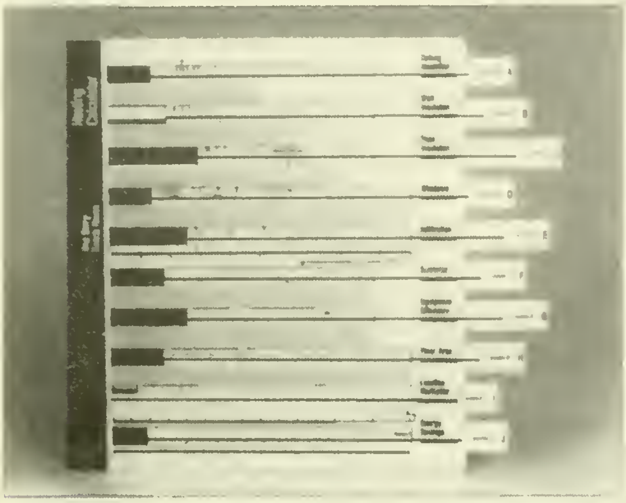
The two sets of data reveal the dramatic impact of appliance standards. The 1990 refrigerator standard eliminated many models sold on the market as of mid 1989. None of the pre-1990-standard models met the forthcoming 1993 standard. By 1993, however, some products beat the standard by as much as 15%. Each point represents a specific top-mounted refrigerator-freezer with an automatic defrost feature. (Note that the standards are expressed as a linear relationship between a refrigerator's volume and its energy use, rather than as single energy-use values. "Adjusted volume" is an adaptation of the nominal refrigerator volume, in which freezer volume is inflated by a factor of 1.63 to yield an equivalent refrigerated volume.)

Energy and Economic Benefits of U.S. Appliance Standards (1990-2015)



Standards for the Residential Building Envelope

About half of all residential energy is used for heating and cooling. Although improving the efficiency of air conditioners and furnaces is important, for optimal savings the building's envelope must also be considered. For more than ten years, LBL has provided technical support to efforts by government and industry to develop building energy standards and guidelines.



Between 1980 and 1983, LBL researchers created a large database of energy consumption in prototypical new houses in 45 U.S. locations using the DOE-2 program. We then converted this technical information into "Energy Calculation Slide Rules" that could be used by the general public. This project, conducted for DOE's Affordable Housing through Energy Conservation Program, won the 1984 *Progressive Architecture* award for research.

Recognizing in 1986 the growing importance of personal computers, LBL converted this database into a simple computer program, PEAR (Program for Energy Analysis of Residences). PEAR gave builders and architects a fast and accurate method to estimate heating and cooling energy needs for any location in the U.S. LBL also gave the database to Pacific Northwest Laboratory (PNL) researchers, who were developing the mandatory building energy standard for federal buildings (known as COST-SAFR), and to ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers), to provide the technical basis of ASHRAE's 90.2 Residential Energy Standard, completed in 1993.

In 1987, LBL became a PNL subcontractor, charged with updating the PEAR database for PNL's flexible computer tool, ARES (Automated Residential Energy Standards), which can generate custom energy budgets for many locations in the U.S. In addition, LBL has distributed several hundred copies of the PEAR program to home builders, energy offices, and government and utility organizations. We have also used the databases in our forecasting and policy analysis efforts.

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USE ARROW KEYS TO MOVE THE CURSOR ( ▶ ◀ ▲ ▼ ),<Space> TO EDIT, ? FOR HELP
<PgDn> FOR NEXT SCREEN, <PgUp> FOR PREVIOUS SCREEN, (End) TO QUIT

GENERAL INPUT                        CONSERVATION MEASURES

State......  GEORGIA Keywd.          Ceiling Insulation........    11.0 R-Val
City......   ATLANTA Keywd.          Roof Color............         DARK Keywd

Prototype......... 1S Keywd.         Wall Insulation........         0.0 R-Val
FoundationType.......SLAB Keywd.     Wall Mass Location.......      NONE Keywd
                                     Wall Color...............      DARK Keywd
Floor Area....... 1548.0 sq.ft.
Wall Perimeter.....  166.0 ft.       Foundation Insulation.....     NONE Keywd
Cross Wall Area.... 1328.0 sq.ft.    Floor Insulation........        0.0 R-Val

North Window Area    38.5 sq.ft.     Window Layers...........         1 Pane
South Window Area    38.5 sq.ft.     Window Sash Type........      PLAIN Keywd
East  Window Area    38.5 sq.ft.     Window Glass Type.......        REG Keywd
West  Window Area    38.5 sq.ft.     Window Movable Insulation.     NONE Keywd

Run Name   BASE CASE                 Infiltration...............    1.0 AC/hr

HEATING ENERGY 749 THRM.                 COOLING ENERGY 2968 KWH.
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The Future

The U.S. still does not have a uniform building energy standard, although standards exist for federal buildings and federally assisted housing, and an increasing number of states have residential energy standards. The ASHRAE-90.2 residential energy standard was approved in 1993 after a nine-year effort. Although it has no legal force, this standard will be influential as it represents the consensus of much of the building industry. Consequently, many states may be motivated to adopt or adapt it, particularly those that have no standards. LBL will continue to provide technical support for the development and implementation of residential building energy standards.

Built into the national legislation for establishing appliance standards are provisions to periodically revise and update them. As technology continues to advance, and economic conditions change, existing standards become obsolete and potential avenues for new savings are created. DOE recently proposed new standards for eight appliance products: water heaters, fluorescent ballasts, room air conditioners, pool/spa heaters, mobile home furnaces, non-ducted heating equipment, ranges and ovens, and televisions. LBL analysis has shown that the proposed standards would save as much money and energy as all existing standards and would result in an actual *reduction* in total residential energy demand—despite the projected growth of the buildings stock. LBL will continue to provide technical support for this process.

LBL is spearheading new efforts to establish efficiency standards for systems used to distribute cooling within residences (i.e., duct systems). Our efforts include conducting technical analyses to support stricter codes for duct installation and leading an ASHRAE effort to standardize efficiency determinations for residential thermal distribution systems. The California Institute for Energy Efficiency is an important partner with LBL in this work.

National energy policy is just beginning to apply efficiency standards to nonresidential uses. LBL has analyzed ballast standards and is working on standards for lighting in commercial buildings and small motors. LBL has been given the task of assessing new technologies specified in the Energy Policy Act of 1992.

LBL is helping DOE evaluate the technology and policy options for the nonregulatory development and commercialization of new energy-efficient products. Innovative "market-pull" approaches and major provisions of the Adminsistration's Energy Partnerships for a Strong Economy program will implement this Congressional mandate. Many new programs are partnerships with industry and utilities; others build on the buying-power of federal, state, and local governments to help create or expand markets for energy-saving products.

TOOLS FOR BUILDING DESIGNERS

$208 Billion

Operating residential and commercial buildings in the U.S. costs consumers almost $210 billion each year. New technologies can reduce this cost, but they can be optimally deployed only with proper design tools. LBL incorporates the knowledge gained over nearly two decades of building energy research into new computerized analytical and design tools, the most important of which is DOE-2. About 5% of commercial floorspace today is designed with DOE-2. Based on a recent survey of major users of the program, DOE-2 facilitates a savings of $85 million annually in energy bills—about $1.9 billion cumulatively for U.S. buildings constructed with the help of DOE-2 through 1993. California building standards (developed using DOE-2) save consumers almost $1 billion each year. Efforts to make existing tools more user friendly are projected to boost their application to 50% of all buildings.

The nation's building industry is immense, but lacks the tools for optimizing energy efficiency. Thus, in the mid 1970s, LBL accepted the challenge of developing a computer program for analyzing energy use in buildings. The resulting program—DOE-2—calculates hourly building energy use and cost from information about the building's construction; climate; operation; heating, ventilating, and air-conditioning systems; and utility rate schedule.

During 1975, the U.S. Energy Research and Development Administration (ERDA, which later became the Department of Energy), and the California Energy Commission (CEC) agreed that a comprehensive building energy analysis computer program was needed to develop and support energy efficiency standards. In response to this need, LBL started a joint project with three national laboratories—LBL, Los Alamos National Laboratory (LANL), and Argonne National Laboratory (ANL)—to develop the Cal-ERDA code, later to become DOE-1 and then DOE-2. LBL led the effort, in charge of overall coordination and development of the basic user interface and simulation code. The objective was a whole-building energy analysis program that could simulate all building types in all climates, a program that was unbiased, well documented, and open to public scrutiny. ANL wrote the user documentation. LANL added active and passive solar simulation capabilities, and developed the engineering documentation. A private company, Consultants Computation Bureau, assisted in developing the interface (Building Description Language) and the programming. A steering committee with representatives from DOE, the California Energy Commission, and industry guided the development effort. To provide a program that would be technically sound and widely accepted, we based DOE-2 on algorithms developed by ASHRAE, a respected industry organization. We also used methods from earlier programs like NECAP, NASA's Energy Cost Analysis Program, and TWO-ZONE, a residential analysis program developed by LBL.

The first version of DOE-2 was released in 1978. Fulfilling its original intent, it became the basis of four major standards: the California Title 24 building energy efficiency standard, considered the most advanced in the world; the national Building Energy Performance Standard, which was abandoned during the Reagan administration before it could be implemented; the DOE/ASHRAE 90.2 standards for residential buildings; and the DOE/ASHRAE 90.1 standards for commercial buildings, which are now voluntary and will become mandatory in each state, as required by EPACT.

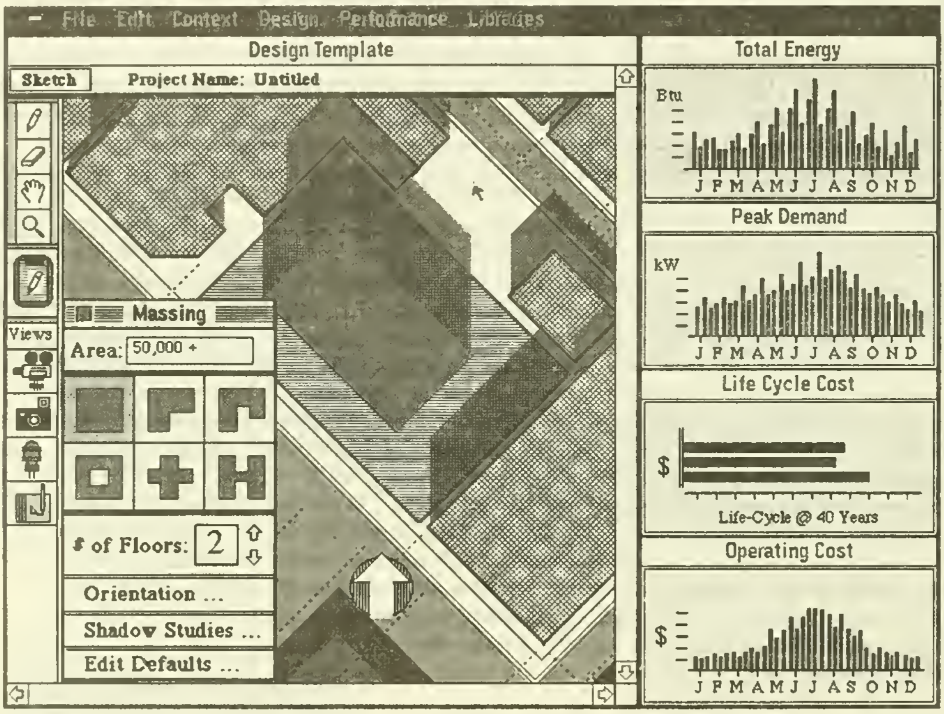
In addition, DOE-2 is now widely used for the design of energy-efficient buildings and for impact analyses of new technologies. During the past ten years, DOE, the private sector, including utilities like Southern California Edison, Pacific Gas & Electric, and Bonneville Power Administration, and utility organizations such as the Electric Power Research Institute and the Gas Research Institute have supported improvements to DOE-2.

The California Energy Commission estimates that the annual energy cost savings from the Title 24 standard, which was designed with DOE-2, was $420 million in 1985, $970 million in 1992, and will increase to $1.6 billion in 1999.

The cumulative California savings are estimated to be: $4.9 billion (1985-1992), and $13.8 billion (1985-1999).

Today there are 1000 DOE-2 user organizations in the U.S. and 42 other countries. In the U.S., DOE-2 is used by 70% of the utilities promoting energy efficiency with demand-side management programs. Most commonly used in the design of new buildings, DOE-2 has also found a niche in the retrofit arena. Identifying energy retrofits for the Audubon Society's national headquarters was one prominent application.

A number of firms—ADM Associates (Sacramento, CA), Gable Dodd Associates (Berkeley, CA), ITEM Systems (Seattle, WA), Finite Technologies (Anchorage, AK), ERG International (Golden, CO), and Partnership for Resource Conservation (Boulder, CO)—have converted DOE-2 into a PC-based program or developed and marketed ancillary software.



Through a schematic design tool that incorporates shadow-casting visualization, the Building Design Advisor (BDA) will assist building designers with initial building massing and orientation decisions, providing feedback on multiple performance considerations such as daylighting, solar gain, and shading from trees. The four charts compare key indicators for three design scenarios. DOE-2 will be the computational engine behind the BDA.

Leveraged Energy and Economic Savings

Although not a hardware technology, DOE-2 directly facilitates energy savings in building projects where it is applied. Results of a 1991 survey showed that users help design or retrofit a total of 326 million square feet of buildings each year with DOE-2 (equivalent to about 5% of all commercial construction), at an average energy savings of 20%. The energy cost savings in these buildings is about $85 million/year. Buildings designed with the help of DOE-2 over the past decade have achieved about $1.9 billion in additional energy savings. For comparison, the total investment in development and support of DOE-2 to date is about $15 million. Based on a cost of $0.10 per square foot, the delivery of design and technical services using DOE-2 is now a $30-million annual industry.

The Future

PowerDOE—a new PC-based and user-friendly interface for DOE-2—is being developed by a joint private/public team with support from Electric Power Research Institute (EPRI), utility companies, the California Energy Commission, and the U.S. Department of Energy. A consortium of utilities and government agencies in Canada recently selected PowerDOE as the basis for its next-generation design tool. Current research efforts are focused on developing and commercializing PowerDOE (for new and retrofit applications), which will increase ten-fold the number of DOE-2 users.

Another goal is to expand DOE-2 use among architects (the program is currently used mostly by engineers) by coupling it to a Building Design Advisor (BDA) software package now under development at LBL. Building designers will be able to use BDA to incorporate energy-efficiency considerations throughout the building design process, assisted by built-in, context-dependent advice on options to improve performance.

LBL has proposed linking this energy design tool with an indoor environment model so that indoor air quality and energy efficiency can be evaluated early in the design process.

MEASURING BENEFITS AND MARKET IMPACT

Various metrics help assess the impact of the four research programs. One is market penetration. As shown in the table below, electronic ballasts have achieved a 23% market share in 1993, while low-emissivity and spectrally selective glazings have captured a 36% market share. Residential equipment standards have achieved full market penetration for the products regulated. DOE-2 design software is used to design about 5% of new commercial floorspace and as an aid in developing mandatory local standards and voluntary national guidelines applicable to all buildings. Two other metrics are the retail value of products and services and the value to consumers of the energy saved.

Market Impact of Energy-Efficient Products and Design Tools Aided by LBL Research and Development[a]

	Electronic Fluorescent Ballasts	Advanced Window Coatings	Residential Equipment and Appliance Efficiency Standards	DOE-2 Buildings Design Tool[e]	Total	Percentage of U.S. Buildings Emissions
MARKET IMPACTS						
Total R&D Investment (current $ millions)	$3	$3	$50	$15	$71	
Product market share in 1993 (% of units sold)	23%	36%	virtually all	5%		
Product market share in 2015 (% of units sold)	77%	79%	virtually all	50%		
Incremental value of product sales in 1993[b] ($ millions, 1993 $)	$200	$630	$1,500	$35	$2,365	
Incremental value of product sales in 2015[b] ($ millions, 1993 $)	$1,300	$1100	$2,200	$300	$4,900	
CONSUMER BENEFITS ($ millions, present value in 1993 dollars)						
Value of energy savings "in the bank" as of year-end 1993[c]	$400	$760	$1,900	$1,900	$4,960	
Lifetime value of savings for technologies installed through 1993[c]	$1,000	$6,300	$7,900	$2,800	$18,000	
Lifetime value of savings for technologies installed through 2015[c]	$18,400	$37,000	$100,000	?	$155,400	
Value of annual energy savings in 2015[c]	$5,100	$5,300	$6,000	?	$16,400	
NET present value of technologies installed through 1993[d]	$700	$400	$4,400	$2,000	$7,500	
NET present value of technologies installed through 2015[d]	$12,800	$17,400	$58,500	?	$88,700	
ENVIRONMENTAL BENEFITS						
Carbon dioxide emissions avoided in 2015 (million tons/year)	73	71	53	?	197	8%
Sulfur dioxide emissions avoided in 2015 (thousand tons/year)	157	157	111	?	425	6%
Nitrogen oxide emissions avoided in 2015 (thousand tons/year)	144	142	108	?	394	3%

Savings from lighting, windows, and appliance standards do not, in general, overlap. Savings gained by using DOE-2 are achieved by a variety of building technologies

a. The time frame adopted for each case spans the first year of a product's use through the year 2015. Savings are computed with respect to a dynamic business-as-usual baseline (i.e., efficiency improvements attained without the new technology).

- For electronic ballasts, the baseline is core-coil magnetic ballasts and T12, 40-watt lamps up to 1990 and energy-efficient magnetic ballasts and T12, 34-watt lamps (mandated by standards) from 1990 forward The efficiency case reflects electronic ballasts and T8, 32-watt lamps—3500 hours-per-year use.
- For windows, the baseline is dual-glazed windows for the residential sector and tinted single-glazed windows for the commercial sector. This baseline tends to underestimate savings in the early years for households (when single-glazed windows are still prevalent). Significant savings are attributed to daylighting made possible by the higher visible light transmission achieved by the advanced glazings in commercial buildings No savings from gas fillings or from stick-on retrofit coatings are assumed
- For appliance standards, the baseline is a market projection of price-driven improvements in energy efficiency Minimum efficiency standards for each appliance are then implemented in the year called for by legislation.
- For DOE-2, the survey of major DOE-2 users indicated that they achieve 20% energy savings beyond what would have been the case without DOE-2. DOE-2 (or its descendants) will eventually be used for at least 50% of commercial construction, and energy performance standards will continue to be tightened based on analysis performed with DOE-2. However, it is too difficult to estimate the prospective savings. These savings would also include parts of the impacts shown here for windows, lighting, and equipment.

b. Retail value is based on the *incremental* cost of the efficient technology compared to the baseline technology, e.g., comparing a $10 magnetic ballast with an $18 electronic ballast yields an incremental cost (retail value) of $8 per ballast. Market share is the percentage of all related product sales (e.g., ballasts) captured by the efficient technology or service shown. As the industry matures, low-e coatings decline in cost from $4 per square foot in 1985 to $1.20 per square foot in 2015. Spectrally selective coatings drop from an initial cost of $5.60 per square foot in 1995 to $1.70 per square foot in 2015 The retail value of DOE-2 design services is estimated based on a fee of $0.10 per square foot

c. Value of energy savings, excluding added cost of efficient equipment. A 7% real discount is used to convert savings to a present value in 1993 dollars.

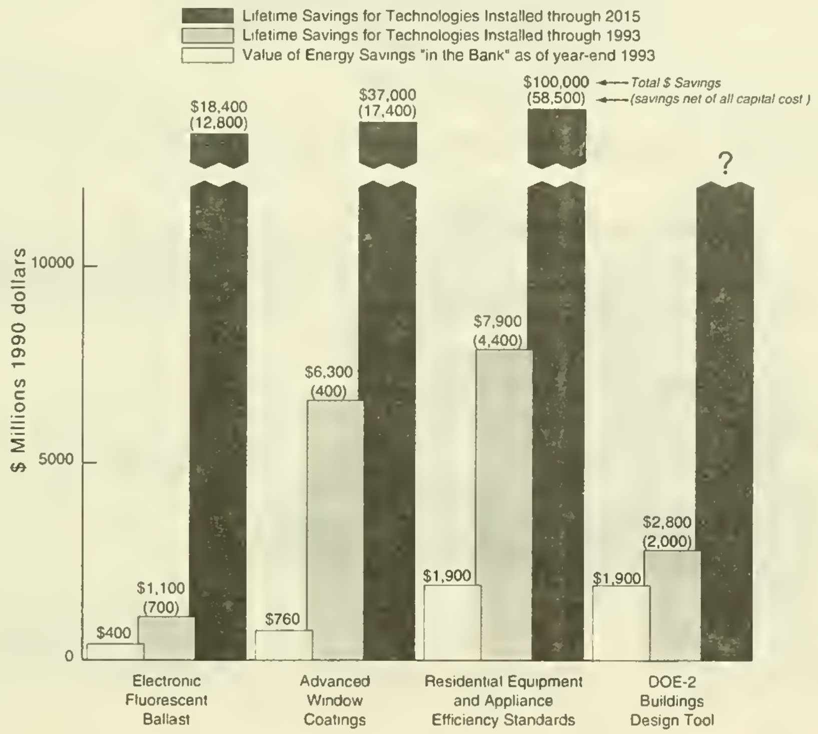
d. Present value of energy savings, net cost of efficient equipment A 7% real discount rate is used to convert savings to present value in 1993 dollars. Net present values include lifetime savings of technologies installed in each year. The extra efficiency investment ("retail value") for buildings designed using DOE-2 to date is inferred based on a three-year payback, values for the future have not been estimated.

e. Excludes savings achieved by building standards based on DOE-2 analyses

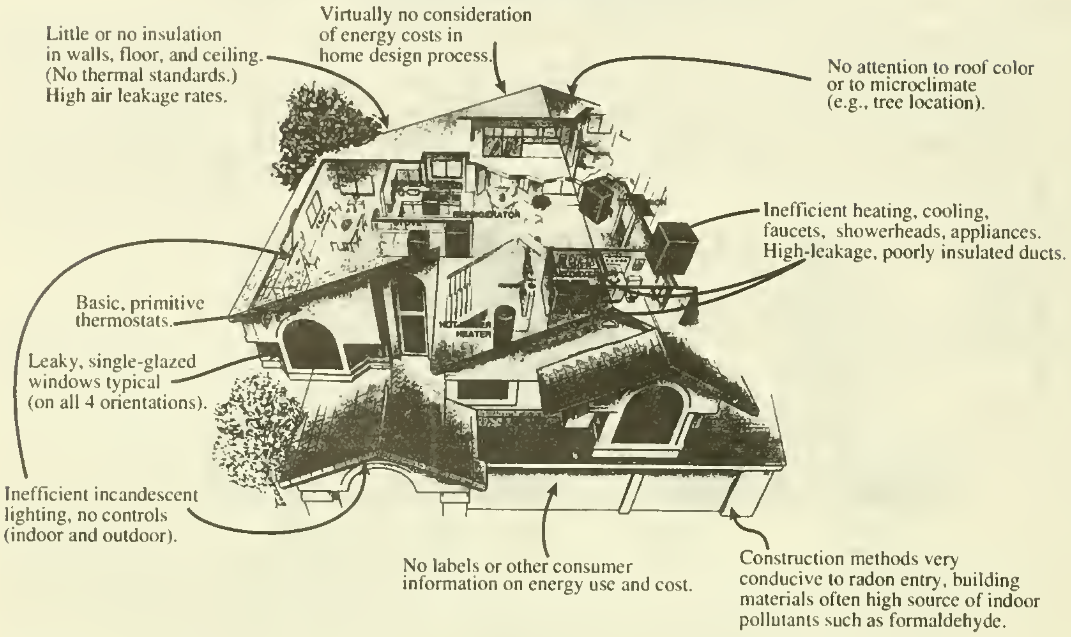
Market Creation

Value of Energy-Efficient Products and Design Tool Services in the U.S. Market

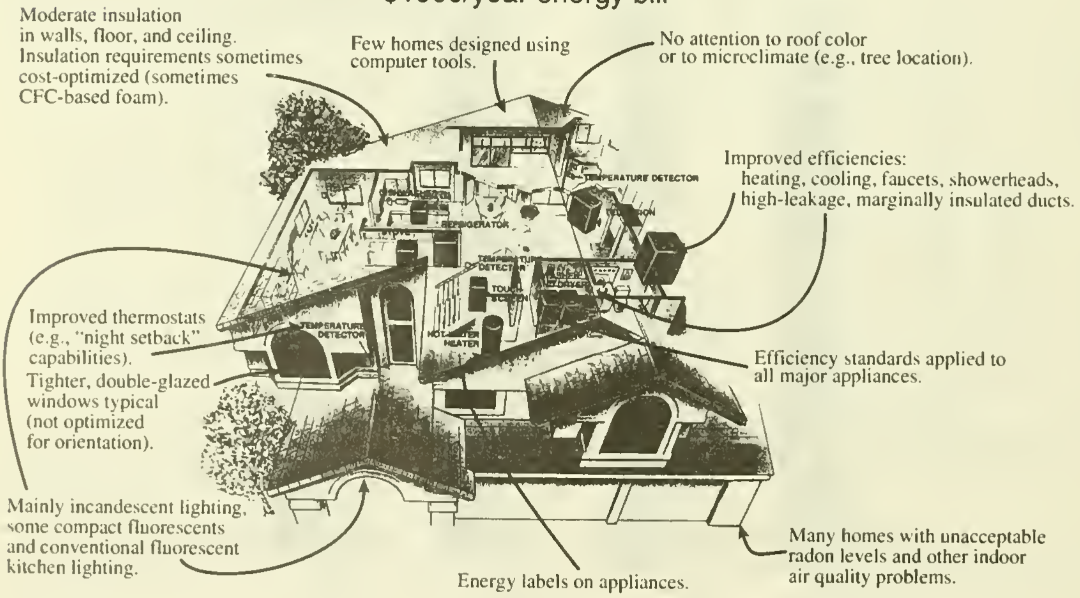
Economic Benefits



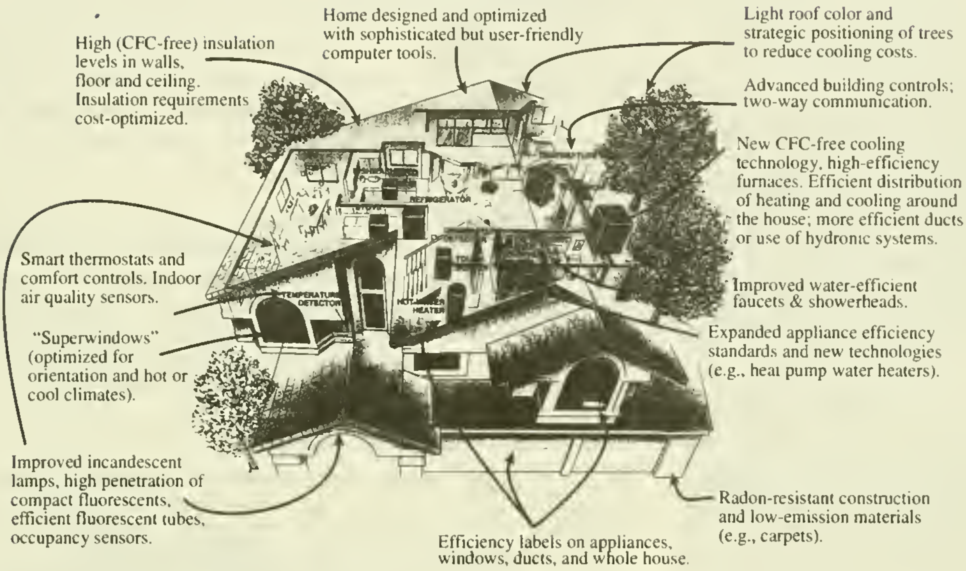
Pre-Oil-Crisis (1973) Home
$2000/year energy bill



Today's Home
$1000/year energy bill



Tomorrow's Home
$250/year energy bill



In most cases, energy efficiency is "invisible" and needn't affect the appearance of o home. The three illustrations depict the energy attributes of pre-oil-crisis (1973) vintage home, today's home, and the home of tomorrow. Many of the improvements shown relate to LBL research described in this report (i.e., technologies, standards, design tools, and indoor air quality considerations). Most of these technologies and strategies are being applied to commercial buildings as well.

LBL'S BROADER ROLE IN THE BUILDINGS ENERGY ARENA

World Wide Web—
The Center for Building Science now has a World Wide Web (WWW) home page easily accessible from the LBL home page. The WWW makes it possible to send and receive text, video, audio, and all types of graphics (including photographs) over the Internet. Mosaic is the user-friendly interface that makes it possible to view and manage this information. Through WWW and the Mosaic browser, Internet users can access LBL's hypertext documents, gopher databases, library catalog, publications list, and Quicktime movies. All that's required is a networked computer (Mac, PC, or UNIX) that runs Mosaic. The WWW address (universal resource locator or URL) is "http://eande.lbl.gov/Building_Science.html".

From the Center's home page, users can view, save, and print text and graphics that describe ongoing projects at the Center, browse all the issues of our newsletter, and view and perform keyword searches on the Center's publication list. All information is linked through hypertext, making it easy to find related topics or articles.

Although best known for our R&D and technology spin-offs to industry, LBL's buildings energy research programs are distinguished in other areas. LBL contributes technical input to public policy issues such as global warming, works with utilities on new paradigms for energy planning, examines the effect of the indoor environment on health and comfort, helps the government manage its own facilities more efficiently, and addresses energy problems both locally and internationally.

To foster the adoption and use of energy-efficient technologies in buildings, the Laboratory relies on its information and technology transfer program. The program ensures that research results are transferred quickly to utilities, major builders, and real estate developers by emphasizing strong working relationships with key professional, trade association, and research organizations. These groups serve as intermediaries and brokers in reaching manufacturers, consumers, and the fragmented building-sector industries. In addition, LBL publishes research results on the Internet.

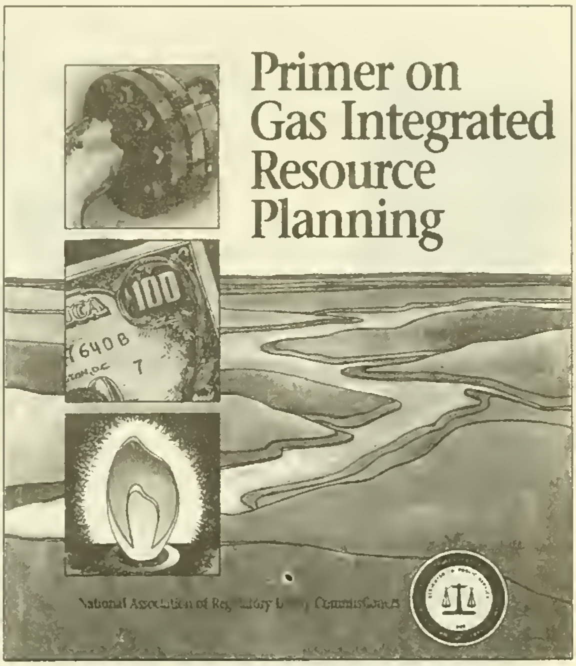
Education is central to LBL's strategy for promoting energy efficiency. To this end, the Laboratory has a relationship to a major university (the University of California at Berkeley) that is unique among the national laboratories. Dozens of faculty, staff, and students from a variety of disciplines work in LBL's energy-efficiency programs. Some graduates stay on at LBL while others move into industry or the public sector.

After the Cold War, in a Warming World

The end of the cold war, the Administration's new energy programs, and various initiatives by states and utilities have created new challenges and opportunities for the national laboratories. The U.S. produces one-quarter of the world's "greenhouse-gas" emissions. Laboratory efforts that have focused on achieving emissions reductions include participating in the prestigious National Academy of Sciences "Mitigation Panel" on climate change and contributing to the Administration's Energy Partnerships for a Strong Economy program (the "cool communities" action was developed at LBL). We also assist DOE in developing and implementing its international energy-policy activities related to climate-change mitigation.

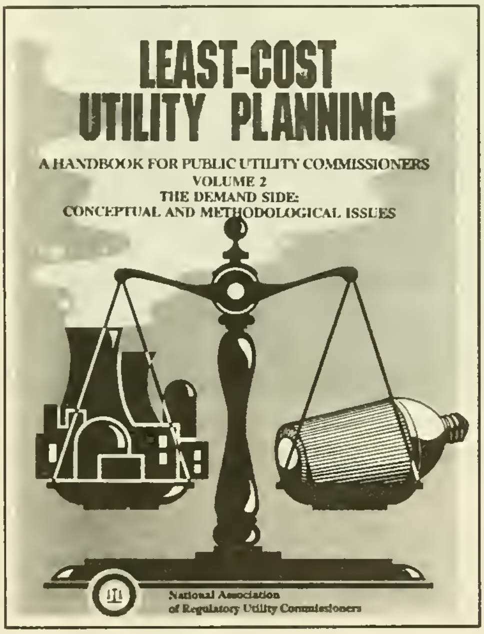
Partnering with Electric and Gas Utilities

The nation's electric and gas utilities spend $2–3 billion each year on energy-efficiency programs. Their investment leverages another $1 billion in private investment, and creates jobs and markets for new, energy-efficient technologies. With utility companies expected to spend a total of $20 billion on energy programs during the 1990s, the cumulative effect of these programs will be to offset the 20–30% of expected load growth during the decade with economic benefits of $40–$50 billion. An emerging possibility is a slowdown in utility demand-side management (DSM) efforts, which may hamper their ability to achieve these projections. Whether or not utilities meet their goals will depend on regulatory trends across the country and other driving factors, including environmental goals and new competitive dynamics among energy suppliers.



For some years, LBL has worked closely with a number of utility companies, their national trade associations (the Electric Power Research Institute and the Gas Research Institute), and especially, state regulatory utility commissions and the National Association of Regulatory Utility Commissioners. LBL's energy-efficiency programs have aided in the development of new methodologies of energy-demand forecasting, evaluation of the impact of energy-efficient technologies on utilities, and market-based programs that utilities initiate to deploy those technologies. LBL researchers pioneered the procedures for making "conservation potential" studies, which are now used routinely by many utilities around the nation. Other work has supported the national trend toward utility regulatory reforms that redefines utility profit rules to decouple profitability from sales volumes. This approach is intended to motivate utilities to market programs that lead to energy savings.

The utilities team has authored definitive "primers" on integrated resource planning (IRP) for gas and electric utilities, which have been translated into several languages. Their other activities include operating the Advanced IRP Seminar for regulatory staff and providing independent review of energy savings estimates of utilities, for example for the energy commissions of California, Wisconsin, and Michigan.



In the mid 1980s, LBL researchers began investigating electricity use and energy-saving opportunities for computers and office equipment. At about 30 TWh, equivalent to the power produced by twenty-four 250-megawatt power plants, office equipment today represents the fastest-growing electricity load in commercial buildings. The savings potential is 25–50%, much of which is achievable at little or no cost by switching idle equipment to a "sleep" mode. LBL studies, in collaboration with electric utilities, EPRI, international groups, and industry provided the technical basis for EPA's successful "Energy Star" labeling program for office equipment.

LBL has authored two handbooks to help gas and electric utilities incorporate energy efficiency and other least-cost strategies into the traditional planning process. The handbooks were prepared at the request of the National Association of Regulatory Utility Officials (NARUC).

Estimated geometric mean radon concentration by county for Minnesota. Darker shades indicate higher indoor radon levels. Homes in unshaded counties have estimated concentrations below 2.5 pCi/L (picocuries per liter); darkest counties are greater than 5.5 pCi/L.

Enhancing Indoor Air Quality

Research on the indoor environment can help reduce the cost of health problems related to poor indoor air quality. An improved indoor office environment can increase worker productivity as well. If such measures avert even one or two absentee days per person, the savings can equal the total cost of all building energy used by that employee for an entire year.

People are indoors about 90% of the time, and indoor air pollutant concentrations often substantially exceed outdoor levels—creating a staggering healthcare cost of about $1 billion annually. Although exposure to air pollutants is dominated by indoor exposure, almost all research and regulatory attention is on outdoor air quality. Indoor air pollutants are responsible for premature deaths in 10,000 lung cancer patients annually (caused by radon), 1,500 deaths due to accidental carbon monoxide poisoning, and 10,000 related medical visits. Each year exposure of young children to environmental tobacco smoke causes an estimated 150,000 to 300,000 lower respiratory tract infections, such as bronchitis and pneumonia. Asthma—with its $6.2 billion annual U.S. healthcare cost—is exacerbated by poor indoor air quality. The indoor environment also affects the rates of transmission of important infectious diseases such as influenza, tuberculosis, and the common cold. More than 20 million cases of influenza occur annually in the U.S.

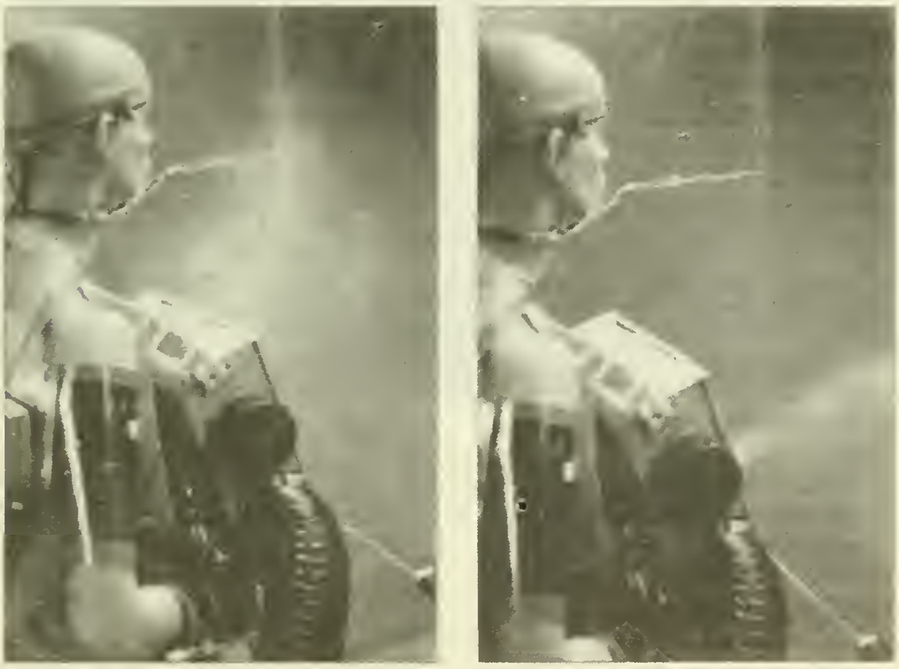
Unless properly conceived and implemented, some energy-saving measures can create indoor air quality problems. Mitigating these problems can waste energy—excess ventilation without heat recovery, for example. LBL recognized that both energy efficiency and the quality of the indoor environment must be optimized, and in the 1970s, LBL established the Indoor Environment Program. With one of the world's premier research groups on the environmental effects of indoor radon, this program has provided basic insights into how radon gas from the soil enters homes. (After cigarettes, radon is the second largest cause of lung cancer.) LBL researchers use geographic information systems to pinpoint areas of the country with the highest radon levels. These results are helping to craft national policy recommendations for more effectively and efficiently identifying regions where houses with elevated concentrations can be found, and once found, to utilize energy-efficient remediation techniques.

The well-known but poorly understood "sick building syndrome," which may affect as much as 20% of all new office buildings, has also been studied at the Laboratory. Among the conclusions of our research: occupants in structures with air conditioning suffer a greater number of building-related health symptoms than occupants in structures with natural ventilation.

The productivity of the U.S. work force increasingly depends on fast and dependable electronic communication and equipment. Electronic equipment failures can impede work performance and engender costly repairs. There is substantial evidence that the deposition of aerosols on circuit boards (leading to electronic short circuits) and the action of corrosive gases on electronic circuits and electrical contacts is a major cause of such failures.

As an example of the economic significance of these failures, consider the telephone industry. The annual cost of circuit-board failures in the 300,000 telephone switching offices of the U.S. is approximately $1 billion, and about 20% ($200 million) of these failures can be traced to indoor air pollution. Many of these failures are attributed to indoor environmental factors, although typical indoor environmental conditions are maintained in the telephone switching offices. Possible methods for reducing failures include improved filtration, better temperature and humidity control, and automatic control of ventilation based on outdoor particle concentrations.

In addition to illuminating the basic processes influencing indoor air quality, LBL's program stimulates and accelerates technologies and strategies for measuring and controlling indoor air pollution in energy-efficient ways. These technologies include low-emission building materials and appliances, heat-recovery ventilation systems, blower-door technology (for testing air leakage in buildings), and energy-efficient radon control technologies. An innovative "airvest" system promises to significantly reduce spraybooth worker exposure to pollutants while cutting ventilation energy costs in half. Researchers have also developed passive samplers for indoor air quality (for example, the formaldehyde-based air samplers now sold by Air Quality Research in North Carolina).



The full-size mannequin in these photographs simulates a worker in a spray booth facing the exhaust filters. In experiments designed by an LBL researcher, smoke was released by a prototype "Airvest" in front of the mannequin to simulate the spraying of paint in the booth.

Research at LBL has made substantial contributions to twelve nationally used ASHRAE and ASTM standards pertaining to ventilation and air quality for the built environment. The program's leader has recently been appointed Chair of the U.S. Environmental Protection Agency's Science Advisory Board's Indoor Air Quality/Total Human Exposure Committee.

Government Partnerships

Buildings research at LBL has helped several Administrations improve efficiency in federal buildings as a means of saving taxpayer dollars and of providing national leadership by example. During the 1980s, LBL researchers helped the Department of Housing and Urban Development to track energy use and identify ways of reducing the $1 billion per year energy bill in public housing. Their research also led to new legislation that removes barriers to energy efficiency in public housing and establishes new business opportunities for private energy service companies. In our most recent effort, we were members of an elite team charged with carrying out the "Greening of the White House" project, unveiled by President Clinton on Earth Day 1994. LBL researchers have provided technical support to DOE's own In-House Energy Management Program, which has achieved annual savings of approximately $155 million in DOE energy bills. The Laboratory supports the Federal Energy Management Program (FEMP) and will play a key role in carrying out a high-profile energy management project at the San Francisco Presidio (a former military base, transferred to the National Park Service in 1994) on behalf of FEMP. LBL researchers are working with the Federal Aviation Administration to identify advanced energy-efficient technologies and modeling tools that can upgrade the work environment in the nation's air traffic control towers and facilities, improving comfort, visibility, and equipment reliability, and thereby improving air travel safety.

The American Institute Of Architects

3D Computer Modeling, rendering and graphics by France Israel and Mieczyslaw Boryslawski of View By View, Inc., San Francisco CA. © Copyright 1994

At an Earth Day 1994 celebration, President Clinton extols the benefits of a compact fluorescent lamp, while a CFL production employee looks on. Also in attendance were Vice President Al Gore and eight cabinet members. Photo by Marvin Jones, courtesy Osram Sylvania, Inc.

Providing a Helping Hand to States

LBL has worked with individual states for two decades. For example, the Washington State Energy Office asked LBL to provide technical assistance on their residential construction projects and proposals for creating a new energy efficiency code. LBL also conducted projects with the New York State Energy Office and the New York State Energy Research and Development Administration involving ventilation and infiltration in low-income multifamily buildings. Over the past few years, LBL has provided technical evaluation for the "Energy Edge" project, in which the Bonneville Power Administration funded the Washington State Energy Office and the Oregon Department of Energy to build and evaluate state-of-the-art commercial buildings throughout the Pacific Northwest.

From its inception, the energy-efficient buildings program at LBL has been particularly attentive to California energy issues. In the early 1970s, Laboratory scientists scrutinized projections that electricity demand in California would grow at six percent per year—a rate that would require dozens of new electric power plants by 1985. We maintained that increased energy efficiency could cost-effectively reduce that growth rate to only one or two percent, generating vast economic savings for the state. Many disagreed with this position, but it proved true. Thanks in part to energy efficiency policies, programs, and standards, California has built no large power plants in a decade and none are currently planned.

LBL researchers have provided technical support to the California Energy Commission almost since its inception, assisting the state's energy-demand forecasting process, providing tools for developing building standards, evaluating spending plans for PVEA (oil overcharge) funds, and developing methods for implementing home energy rating systems. The Laboratory has collaborated on a broad range of topics with each of California's major electric and gas utilities (Los Angeles Department of Water and Power, Pacific Gas and Electric, Sacramento Municipal Utility District, San Diego Gas and Electric, and Southern California Edison).

Marking an important watershed in utility regulation, the Laboratory played a supporting role in the so-called "California Collaborative," in which all the state's utilities (and their regulators) agreed to reform utility profit rules to provide new economic incentives to pursue energy efficiency. More recently, LBL has been part of the steering team of Pacific Gas and Electric's $20-million Advanced Customer Technology Test (ACT^2). This project is the nation's largest high-profile demonstration of the technical and economic potential of energy-efficient technologies and practices in commercial and residential buildings.

LBL is also the home of the California Institute for Energy Efficiency (CIEE), an innovative partnership of California's energy utilities, the California Energy Commission, the California Public Utility Commission, the University of California, and DOE. Each year CIEE funds and coordinates a substantial program of research at California universities and university-affiliated DOE laboratories, focusing on technologies crucial to the state and the region. The Institute emphasizes applications that simultaneously improve end-use efficiency and lower utility operating costs.

International Activities

Many of the DOE efficiency-related activities have spun off beneficial ideas and information to other countries. Several countries have emulated LBL methodologies for developing appliance and building standards. Low-e windows and electronic ballasts are also finding overseas markets. The DOE-2 computer program is used in 42 other countries and has been used to develop building energy efficiency standards in, among others, the ASEAN nations (Singapore, Thailand, Malaysia, Indonesia, and Philippines), Canada, Brazil, Kuwait, Saudi Arabia, Hong Kong, Australia, and Switzerland.

LBL's own activities in the international arena include energy demand and policy analysis for industrialized and developing countries and formerly planned economies. Two special projects focus on Russia and China, which include helping Russian window companies identify efficiency-enhancing technologies within their defense industry, establishing an Energy Efficiency Center in Beijing, and assisting in the formation of joint ventures between U.S. and Chinese industries. DOE laboratories have provided general training and technology transfer for dozens of utilities and energy planners from outside the U.S.

LBL's international group helps scientists and energy policy makers from 16 countries in Eastern Europe and the former Soviet Union, Asia, Africa, and Latin America assess their opportunities for reducing emissions of greenhouse gases. With this goal, the Laboratory has established networks of experts in energy and forestry for the U.S. Environmental Protection Agency, the federal entity responsible for creating the developing country emissions scenarios used by the prestigious Intergovernmental Panel on Climate Change. LBL is participating in DOE's Country Studies Program. This initiative grew out of the commitment made by the U.S. at the 1992 Earth Summit to help countries comply with the Framework Convention on Climate Change. The program is designed to help developing and transitional countries to (1) develop inventories of their anthropogenic emissions of greenhouse gases, (2) assess their vulnerabilities to climate change, (3) assess their ability to mitigate greenhouse gas emissions, and (4) formulate and evaluate response strategies for mitigating and adapting to climate change. LBL was selected to provide technical support for the third task—mitigation assistance—because of its substantial knowledge of the technologies, policies, and analytical methods for reducing greenhouse-gas emissions. In support of this activity, LBL brought together a technical support team of 30 researchers from academic, private, and government institutions experienced in global climate change issues. In addition to LBL, the team includes five U.S. national laboratories: Oak Ridge National Laboratory, Pacific Northwest Laboratory, Brookhaven National Laboratory, Argonne National Laboratory, and the National Renewable Energy Laboratory. This group's first project was a two-week, intensive, hands-on workshop attended by 60 representatives of the target countries.

In addition, we have established an informal program through which energy researchers from developing countries work at LBL on projects of mutual interest. Over the past ten years, more than 100 researchers have spent more than 50 person-years at the Laboratory on such projects.

FROM THE LAB TO IMPLEMENTATION

The Center for Building Science Applications Team

The Center for Building Science's Applications Team (the "A-Team") marshals LBL's unique capabilities and networks to conduct field projects whose purpose is to deploy advanced energy-efficiency and indoor environmental quality concepts in both the U.S. and overseas buildings sectors. The aims of the Team are to:

- *Demonstrate proven and emerging building technologies in order to accelerate their adoption by consumers and building professionals.*
- *Elevate professional standards of practice.*
- *Transfer new energy management methods and tools to the private sector.*
- *Provide feedback to the federal energy R&D planning process.*

The A-Team's philosophy is to apply an integrated approach to retrofitting existing buildings and designing new ones. This approach encompasses the various stages of a building life cycle as seen from the perspective of facilities management, addressing the areas of energy, illumination, comfort, and the indoor environment.

The A-Team assembles project teams from the 250-person staff in the Center's three research programs, LBL's In-House Energy Management Program (IHEM), other research organizations and laboratories, and private firms. The IHEM program managed a study and retrofit budget of $18 million through 1994 for LBL's own facilities, including project planning, financial analysis, engineering, procurement, construction management, commissioning, monitoring, and evaluation. One of IHEM's notable achievements was completion of DOE's first comprehensive performance contracting agreement with a private energy services company for retrofit of a laboratory building.

The Facilities Management Building Lifecycle

To accomplish its goals, the A-Team also makes use of its relationships with other professionals in energy-efficiency implementation from R&D centers across the country—government agencies, electric and gas utilities, state energy offices, manufacturers of energy-efficient technologies, and technical committees that define energy-related standards and guidelines.

Bridging R&D in Practice

The A-Team forges a new link between existing DOE building R&D activities and deployment initiatives. A-Team activities will benefit R&D program planners by providing improved feedback and recommendations for eliminating inefficiencies and missed opportunities during the implementation of new technologies and methods in the field. More specifically, the A-Team

- Develops, implements, and evaluates proven, cost-effective energy-efficiency measures in existing buildings.
- Assembles confidence-building demonstrations of emerging technologies and energy management practices not commonly used by building professionals.
- Develops and disseminates state-of-the-art field guidelines and protocols, for example, for measurement and verification.
- Demonstrates the potential for achieving energy savings while maintaining or improving indoor environmental factors influencing human productivity and well-being such as indoor air quality, lighting quality, and thermal comfort.
- Transfers design and application methods and tools to private-sector practitioners such as architecture and engineering firms that collaborate with the A-team.
- Supports energy savings performance contracting on a national level.

In the Field

The A-Team benefits private-sector building professionals by raising market awareness of the value of energy efficiency, for example, through high-profile demonstrations and independent verifications of performance and cost-effectiveness and by partnering with private-sector firms on specific projects. Feedback from these efforts is also valuable in product development and marketing.

San Francisco's Presidio viewed from the top of the Golden Gate Bridge.

A-Team services are available to federal agencies, utilities, states, regional or national efficiency program designers, and large public, private, or institutional building owners. To maximize their impact, the A-Team chooses projects selectively, emphasizing high-visibility, replicability, and the specialized services and resources possessed by LBL and project collaborators. Examples include creating a master plan for energy efficiency retrofits at the Presidio of San Francisco in cooperation with DOE and the National Park Service, conducting super-audits of the Federal Aviation Administration's air traffic control towers and other facilities, and investigating ways that California industries can reduce energy costs in their laboratory facilities.

AWARDS AND CITATIONS

National Fenestration Rating Council Technical Achievement Award - 1994

Dariush Arasteh

In recognition of exemplary contributions to the NFRC mission through outstanding scientific and technical achievement and leadership in the development of NFRC technical procedures.

Federal Laboratory Consortium Award for Excellence in Technology Transfer - 1994

Michael Siminovitch

Thermally efficient compact fluorescent downlights.

U.S. Department of Energy, Sadi Carnot Award - 1993

Arthur Rosenfeld

For lifetime achievement in the field of energy conservation and renewable energy.

U.S. Federal Energy Management Program Sustained Exemplary Service Award - 1993

LBL In-House Energy Management Program

National Research Council's Transportation Research Board Fred Burggraf Award - 1993

Jonathan Koomey, Deborah Schechter, Deborah Gordon

Excellence in transportation research by researchers 35 years of age or younger. For the article entitled "Cost Effectiveness of Fuel Economy Improvements in 1992 Honda Civic Hatchbacks."

Federal Laboratory Consortium Special Award for Excellence in Technology Transfer - 1993

Stephen Selkowitz and Dariush Arasteh

Superwindows.

Popular Science Magazine's Best New Product Award - 1991

Dariush Arasteh, Stephen Selkowitz, Brent Griffith

Grand award in home technology category for development of gas-filled insulating panels.

PEW Charitable Trust Award - 1991

Ashok Gadgil

Award of $150,000 over three years, for work related to promoting energy efficiency in developing countries.

Energy Efficient Buildings Association Technical Award - 1991

Stephen Selkowitz

Recognizing exceptional technical contributions to energy-efficient buildings design and practice.

Federal Laboratory Consortium Special Award for Excellence in Technology Transfer - 1989

Fred Winkelmann, Ender Erdem, Kathy Ellington, Bruce Birdsall, Fred Buhl

For developing, documenting, disseminating, and supporting the DOE-2 program for simulating building energy use.

Citation from Progressive Architecture Magazine - 1989

Stephen Selkowitz, Dariush Arasteh, Michael Wilde, Bob Sullivan, Francis Rubenstein

For development of a Skylight Design Manual and accompanying software to help architects and engineers use skylights in a more energy-efficient manner.

American Physical Society's Leo Szilard Award for Physics in the Public Interest - 1989

Anthony Nero

For work on indoor radon, nuclear proliferation, and reactor safety.

ASHRAE Willis H. Carrier Award - 1988

Joseph Eto

For best presentation by an author under the age of 32 describing work using DOE-2 to study economic impacts of then-pending revisions to the ASHRAE standards for ventilation.

ASHRAE Crosby Field Award - 1988

Joseph Eto

For the best technical paper describing work using DOE-2 to study economic impacts of then-pending revisions to the ASHRAE standards for fresh air ventilation.

Federal Laboratory Consortium Special Award for Excellence in Technology Transfer - 1988

Stephen Selkowitz and co-workers

For developing and transferring to industry the WINDOW thermal analysis computer program.

U.S. Department of Energy, Sadi Carnot Award - 1988

Sam Berman

For contributions to the development of high-frequency solid-state ballasts and advances in energy-efficient windows.

American Physical Society's Leo Szilard Award for Physics in the Public Interest - 1986

Arthur Rosenfeld

For advancing energy-efficiency technologies.

Citation from Progressive Architecture Magazine - 1985

Stephen Selkowitz and co-workers

For developing the sky simulator that enables architects and engineers to realistically test daylighting designs.

Citation from Progressive Architecture Magazine - 1984

Ron Ritschard and Joe Huang

For developing energy calculating slide rules.

ASHRAE Willis H. Carrier Award - 1979

Stephen Selkowitz

For best presentation by an author under the age of 32 of a paper describing advanced window system performance.

USER FACILITIES AND RESEARCH LABORATORIES

LBL's energy-efficient buildings programs operate several user facilities and research laboratories, some of which are available by arrangement to building industry professionals, architects, manufacturers, the academic community, and other national laboratories.

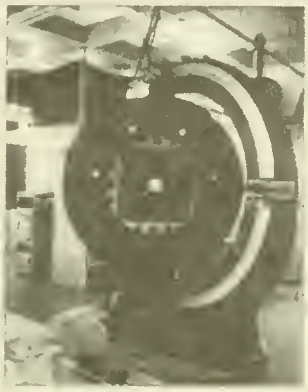
MoWiTT

IR Thermography Lab

- *The Energy-Efficient Fixtures Laboratory* is dedicated to the development of optically and thermally efficient long-tube and compact fluorescent fixture systems. Testing devices characterize the thermal and photometric performance of fixtures and advanced compact fluorescent prototypes, and include temperature-controlled photometric integrating chambers and experimental plenum systems for studying the performance of recessed downlights using compact fluorescent lamps.
- *The Integrating Sphere* is used for relative photometry of light sources. The total lumen output of any source can be measured under standard thermal and electrical conditions. The sphere is used extensively by the LBL's Lighting Systems Group to measure the efficacy and lumen output of a broad range of light sources.
- *The Infrared Thermographic Lab* includes a high-resolution, infrared imaging camera, a computer processor/printer, and a cold/hot chamber to hold samples for testing. The camera system is portable and can measure surface temperatures that can be correlated to various heat loss or gain parameters. The IR camera is useful for assessing heat loss from existing buildings in the field as well as from building components and appliances in the laboratory.
- *The Mobile Window Thermal Test Facility (MoWiTT)* contains two highly instrumented, side-by-side calorimetric test chambers that are used to test the thermal performance of window and wall elements under actual outdoor conditions. The facility may be rotated to face in any direction and is currently located in Reno, Nevada, which experiences both summer and winter extreme climate conditions. The facility can directly measure solar heat gain and can determine window and shading system properties for a wide variety of solar control options. With 200 data channels collecting data every few seconds, MoWiTT can directly measure cooling load shapes on peak summer days with excellent time resolution. The facility can also be used to validate computer models and to compare various technologies in real time. Industry has used MoWiTT results to justify new product development.
- *The Radon Test House*, located in Richmond, California, is used for studies of the transport and behavior of radon progeny and indoor aerosols.
- *The Environmental Chamber* can be conditioned to maintain desired temperature, humidity levels, and ventilation rates. The facility is used by LBL researchers and collaborators for a variety of indoor air pollution studies such as assessing emissions from consumer products and building materials.

Thin Film Deposition and Characterization

Sky Simulator



Solar Heat Gain Scanner

- *The Sky Simulator* is a 24-foot-diameter hemispherical facility used to test daylighting performance in scale-model buildings under controlled and reproducible conditions. Computerized control of light sources within the hemisphere can create luminous distributions typical of clear, uniform, or overcast skies representative of any desired location, orientation, climate, and season on Earth. It can also be used as a sun simulator to test shading strategies in scale models up to 1.5 square meters in size. Light levels within the models are measured by 60 photosensors, and the measurements are used to predict daylight illuminance conditions in full-sized buildings. The facility is well-suited to test the effect of shading from overhangs, fins, awnings, shade systems, vegetation, and adjacent obstructions.
- *The Solar Heat Gain Scanner* is used to characterize the complex optical properties of shading systems such as venetian blinds. The system measures transmitted and reflected energy and light at all incidence and outgoing angles. The only facility of its kind in the U.S., it has become the basis for a new procedure to predict solar heat gain through shading systems. This work is cost-shared by DOE and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).
- *The Thin-Film Materials Laboratory* houses a wide range of apparatus to deposit and analyze thin-film, spectrally selective coatings for energy control purposes. The laboratory also includes spectrophotometers to measure solar, near IR, and far IR properties.
- *The Geographic Information System (GIS)/Image Processing Laboratory* has image processing software operating on a SUN SPARC workstation that runs image processing and vector-based and raster-based GIS software. A PC-based GIS system is also available.
- *The Hypermedia Laboratory* is used to develop design tools of the future that will not only have faster and better modeling algorithms but will also have vastly improved user interfaces incorporating new multimedia software and hardware capabilities. The ability to integrate data and text with advanced graphics, animation, sound, and video will enhance the value and usefulness of the next generation of design and analysis tools. The hypermedia computer lab has the equipment necessary for experimenting with these emerging technologies and prototyping and testing promising solutions. The laboratory has been used to develop several prototypes including an interactive computerized kiosk with videodisk for Southern California Edison.

KEY PUBLICATIONS

General

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"Energy Efficiency, Market Failures, and Government Policy," M.D. Levine, E. Hirst, J.G. Koomey, J.E. McMahon, A.H. Sanstad, Lawrence Berkeley Laboratory Report No. 35376 and Oak Ridge National Laboratory Report No. 383 (1994).

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Lighting

"Energy Efficiency and Performance of Solid-State Ballasts," R. Verderber, S. Selkowitz, S. Berman, *Lighting Design & Application*, pp. 23–28 (April 1979).

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"A Discussion of Heat Mirror Film: Performance, Production Processes and Cost Estimates," B. Levin, P. Schumacher, Lawrence Berkeley Laboratory Report No. 7812 (October 1977).

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Appliance and Building Standards

"U.S. Residential Appliance Energy Efficiency: Present Status and Future Policy Directions," I. Turiel, D. Berman, P. Chan, T. Chan, J. Koomey, B. Lebot, M.D. Levine, J.E. McMahon, G. Rosenquist, S. Stoft, *Proceedings of the 1990 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Washington, DC, pp. 1.213–1.234 (August 1990).

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Design Tools and Other Software

"DOE-1: A New State-of-the-Art Computer Program for the Energy Utilization Analysis of Buildings," G.S. Leighton and H.D. Ross; A.H. Rosenfeld, F.C. Winkelmann, M. Lokmanhekim, LBL Report No. 7836 and *Proceedings of the International Symposium on the Use of Computers for Environmental Engineering Related to Buildings*, Banff, Canada (May 1978). (The current version is DOE 2.1E.)

CIRA—a PC-based tool for residential retrofit analysis, now marketed as EEDO by a private firm (Burt Hill Kosar Rittelmann and Associates, Butler, PA).

PEAR—a simplified PC-based tool, based on extensive DOE-2 simulations, readily usable by builders, architects, or lenders to provide reliable estimates of building energy consumption. See "Program for Energy Analysis of Residences: Pear 2.1 User's Manual," LBL Pub-610 (March 1987).

RADIANCE—a computer generated graphic simulation of lighting in indoor environments that is photometrically accurate and ultra-realistic. See "The Radiance Lighting Simulation and Rendering System," G. Ward, *Computer Graphics*, Association for Computing Machinery (July 1994).

SUPERLITE—a mainframe and microcomputer program that calculates daylight illuminance distributions for complex room and light source geometries with tested accuracy. See "The DOE-2 and SUPERLITE Daylighting Programs," S. Selkowitz, J.J. Kim, M. Navvab, F. Winkelmann, *Proceedings of the 7th National Passive Solar Conference*, International Solar Energy Society (June 1982).

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WINDOW—a thermal analysis computer program that is the *de facto* standard used by U.S. window manufacturers to characterize product performance. See "WINDOW 4.0: Documentation of Calculation Procedures," E.U. Finlayson, D. K. Arasteh, C. Huizenga, M.D. Rubin, M.S. Reilly, LBL Report No. 33943 (July 1993).

COMIS (Conjunction of Multizone Infiltration Specialists)—An advanced computer model that simulates the air flow distribution in multizone buildings. This program was developed in an international effort by researchers from nine countries. See "The COMIS Infiltration Model—A Tool for Multizone Applications," H.A. Feustel, M.H. Sherman, *Proceedings of the XXI Symposium of the International Centre for Heat and Mass Transfer*, pp. 771–779, Dubrovnik, Yugoslavia, LBL Report No. 26550 (1989).

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Proceedings of the ASEAN Conference on Energy Conservation in Buildings, K.H. Olson, W.W. Ching (eds.), U.S. Agency for International Development (1984).

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Least-Cost Utility Planning: A Handbook for Public Utility Commissioners, F. Krause, J. Eto, prepared for the NationAssociation of Regulatory Utility Commissioners, Washington DC (December 1988).

Primer on Gas Integrated Resource Planning, C. Goldman, G.A. Comnes, J. Busch, S. Wiel, prepared for the National Association of Regulatory Utility Commissioners, Washington DC (December 1993).

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"Characterizing the Source of Radon Indoors," A.V. Nero and W.W. Nazaroff, *Radiation Protection Dosimetry* **7**, pp. 12–39 (1984).

"Distribution of Airborne Radon-222 Concentrations in U.S. Homes," A.V. Nero, M.B. Schwehr, W.W. Nazaroff, K.L. Revzan, *Science* **234**, pp. 992–997 (1986).

"Residential Duct System Leakage: Magnitude, Impacts, and Potential for Reduction," M.P. Modera, *ASHRAE Transactions*, **95** (2), pp. 561–569 (1989).

"Phase 1 of the California Healthy Building Study," W.J. Fisk, M.J. Mendell, J.M. Daisey, D. Faulkner, A.T. Hodgson, M. Nematollahi, J.M. Macher, *Indoor Air* **3**, pp. 246–254 (1993).

Global Climate

Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base, National Academy of Sciences, National Academy Press (A.H. Rosenfeld served as member of Mitigation Panel) (1992).

Federal Energy Efficiency

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"Deterrents to Energy Conservation in Public Housing," E. Mills, R.L. Ritschard, C.A. Goldman, *Energy Systems and Policy* **11** (3), pp. 169–183 (1987).

Some of Our Partners...

The Lawrence Berkeley Laboratory has repeatedly been on the forefront of demonstrating that energy efficiency can not only compete effectively with energy production, but can offer significant advantages in terms of environmental and economic impacts and competitiveness. . . LBL has earned the support and trust of the entire energy efficiency industry and deserves the opportunity to continue this work in the critically important role of getting our national energy strategy working.

Peter F. Gerhardinger
Manager–New Products Technology, Libbey Owens Ford Co.

We have been working with LBL's Lighting Systems Group in an effort to adapt their technology for commercialization. . . We can now see a clear role for these technologies in our products. The implementation of this technology should greatly enhance an already attractive market. . . As taxpayers we are pleased to see us getting so much bang for our buck. The LBL group will be responsible for a great deal of energy savings. They should please everyone but OPEC.

Bruce Pelton
Vice President, Lumatech Corporation

With the information I recently received from LBL concerning the performance of compact fluorescent lamps with attached reflectors, we can now improve the quality of our product with minimum investment while at the same time providing the end user with greater light output at even uct efficiency. . . LBL's work not only benefits the original equipment manufacturer, providing insight on how to produce a more efficient product, but in the long term benefits the consumer and society with reduced emissions and reduced energy bills. Clearly the output of LBL benefits society, manufacturers and end users.

Steve Johnson
President, Mitor Industries Inc.

Investment by the Department of Energy allowed Southwall Technologies, working closely with LBL, to introduce in 1981 the first insulating glass containing a heat reflecting, low emissivity coating. . . [The product] served as the catalyst in creating a high performance window industry.

Southwall Technologies, Press Release

We committed well over a year ago to early in-depth data gathering, analysis, cooperation and communication with DOE and LBL, and we're very pleased with the results of that effort.

Charles Samuels
Association of Home Appliance Manufacturers, Government Relations Counsel
U.S. Department of Energy Public Hearings on Appliance Standards

Refrigerator manufacturers have been working closely with LBL for over a year now to evaluate design options and develop cost data for this appliance standards rulemaking. We very much appreciate the cooperation and professionalism that LBL has shown throughout this process.

Terry Thiele
Senior Counsel for Government Relations, GE Appliances
U.S. Department of Energy Public Hearings on Appliance Standards

Industry Partners

AB Volvo
ADM Associates
Aerovironment
Air Quality Research
American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Andersen Corporation
Apple Computer
Asahi Glass
Association of Home Appliance Manufacturers
Bellcorp
Cardinal IG
Chevron
Conoco
Consolidated Edison
Cooper Lighting
Delray Lighting
Edison Price
Electric Power Research Institute
ERG International
Exxon USA
Finite Technologies
Fusion Lighting
Gable Dodd Associates
Gas Research Institute
General Electric
Honeywell
Indy Lighting
ITEM Systems
Libbey Owens Ford
Lightolier
Lithonia
Lumatech
Microflect
Mitor Industries
National Fenestration Rating Council
Northern States Power
Osram
Owens-Corning Fiberglas
Philips Lighting
Pacific Gas and Electric
Partnership for Resource Conservation
Peerless Lighting
Pella Windows
Prescolite
Reggiani
Rolscreen
San Diego Gas and Electric
Shell Oil
Southern California Edison
Southern Company Services
Southwall Technologies
Staff Lighting
Zumtobel
3M Corporation

Lawrence Berkeley Laboratory is one of the founders of so-called end-use-based economic engineering analysis and utility least cost planning. These two revolutionary advancements in energy analysis and planning are considered key to creating a burgeoning, lucrative global market in super-efficient environmentally superior products and services. . . LBL is one of the most respected energy R&D laboratories in the world. . . which has catalyzed development of super-efficient technologies and building design software.

Senator John Glenn
Senator Herb Kohl

The long-standing LBL-EPRI relationship has greatly improved the forecasting abilities of the electric power industry. With the resulting end-use models and associated databases, utilities can more easily integrate the impacts of demand-side management programs, efficiency standards, and new technologies into their long-term forecasts. This improves the quality of a variety of utility functions.

Phil Hanser
Manager, Demand-Side Management Program
Electric Power Research Institute

World-renowned Lawrence Berkeley Laboratory has performed critical work leading to the development of important new building technologies like electronic ballasts for fluorescent lighting and low-emissivity windows. These two products alone have created important new global markets for U.S. companies and saved Americans millions of dollars.

Ed Smeloff
Director, Sacramento Municipal Utility District

The Lawrence Berkeley Laboratory has been a major motivating force for energy efficiency in California for over 15 years. As early as 1978, the intellectual leadership of LBL staff highlighted that efficient appliances could pay for themselves by reducing consumer utility bills, and also eliminate the need for a large nuclear plant in Southern California. LBL pioneered the concept of "conservation supply curves" that has facilitated the economic comparison of efficiency with conventional energy supplies, and resulted in the California Energy Commission establishing conservation as the state's preferred source of new energy supply. They have also consistently shown the link between conservation with environmental benefits, which has led to efficiency being the foundation of California's efforts to meet our environmental goals. . . LBL also has advised the legislature on regulatory and policy improvements that should be made to help California achieve its energy and environmental goals which resulted in the introduction of 20 new bills in the last legislative session. The Commission is implementing efficiency programs that can trace their roots to LBL's long-standing efforts to ensure that advances in science also improved California's economy and environment.

Charles R. Imbrecht
Chairman, California Energy Commission

Public Sector or Non-Governmental Partners

Agency for International Development
Alliance to Save Energy
American Council for an Energy-Efficient Economy
Audubon Society
Bonneville Power Administration
California Air Resources Board
California Department of Health Services
California Energy Commission
California Institute for Energy Efficiency
Central European University
Cigarette and Tobacco Surtax Fund of The State of California
Danish Energy Agency
Environmental Defense Fund
European Association for the Conservation of Energy
Federal Aviation Administration
General Services Administration
Green Buildings Council
International Association for Energy-Efficient Lighting
International Energy Agency
Kuwait Institute of Scientific Research
Los Angeles Department of Water and Power
Mexican National Commission on Energy
National Association of Regulatory Utility Commissioners
National Heart, Lung and Blood Institute
National Institute of Environmental Health Science
Natural Resources Defense Council
New York State Energy Research and Development Authority
Organization for Economic Cooperation and Development
Pew Charitable Trust
Rockefeller Family and Associates
Rocky Mountain Institute
Russian Lighting Research Institute
Sacramento Municipal Utility District
Sierra Club
Stockholm Environment Institute
Swedish National Board for Industrial and Technical Development
Texas Governor's Energy Office
The Energy Foundation
U.S. Consumer Product Safety Commission
U.S. Department of Energy
U.S. Department of Housing and Urban Development
U.S. Environmental Protection Agency
U.S. Food and Drug Administration
U.S. Navy
University of California
World Energy Council

Listed are companies or organizations that have funded or otherwise participated in LBL research projects or directly utilized the research results. Further information available on request.

About the Center for Building Science

Addressing significant energy-related issues, the Lawrence Berkeley Laboratory's Center for Building Science has become an international leader in developing and commercializing energy-efficient technologies and analytical techniques, and documenting ways of improving the energy efficiency and indoor environment of residential, commercial, and industrial buildings.

The Center is the home of three programs—Building Technologies, Energy Analysis, and Indoor Environment. It serves as a national and international source of information for energy-efficient technology, provides technical support to energy and environmental policymakers, supports and creates institutions and demonstration programs, provides a training ground for students in the energy field, and facilitates transfer of technology and information to the private sector.

Researchers at the Center recognize that despite significant, steady progress since the energy crises of the 1970s, a large potential for energy savings remains to be realized. The Center's interdisciplinary staff of 250 studies a wide spectrum of environmental, economic, and technical aspects of energy-efficiency activities, each helping to document that energy efficiency is a new and highly cost-effective energy resource.

Colophon: *This report prepared by Evan Mills and edited by Allan Chen and Jeff Kahn. Original graphics and interior design by Sam Webster. Cover design by Flavia Robles. Cover photography by Richard Blair.*

Printed on recycled stock with soy based inks.

This work was funded by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Building Technologies of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

PUB-758 (Rev. 3/95)

Q17. **On page 15 of your prepared testimony, you state that "recent studies make clear that private sector R&D has been fairly flat since 1991, and U.S. companies have been shifting away from basic and applied research toward a focus on incremental product and process improvement. Increased international competition and downsizing of corporate laboratories have shortened the time horizon of most private sector R&D."**

Please provide specific documentation for these statements.

A17. According to data from the National Science Foundation, real private sector investment in research and development declined by - 0.3% from 1991 to 1995 as shown in the following data:

PRIVATE SECTOR R&D INVESTMENT
(BILLION DOLLARS–CONSTANT 1995)

1991 = $102.0
1992 = $103.5
1993 = $102.6
1994 = $102.5
1995 = $101.7

Survey data from the Industrial Research Institute indicates that industry has shifted their focus away from basic and applied research toward a focus on incremental product and process improvement according to the following data:

PERCENT OF PRIVATE COMPANY RESEARCH BUDGETS

Phase of Research	1988	1994
Basic Research	6.0%	1.7%
Applied Research	21.0%	15.4%
Product Development	34.0%	41.8%
Process Development	20.8%	22.5%
Technical Services	18.2%	18.5%

These trends are documented in a recent Department of Energy report, "Corporate R&D in Transition–Changing Patterns of Private Sector Investment in Research and Development," published by the Office of Policy in March 1996.

Q18. **On page 15 of your prepared testimony, you state: "Low energy prices have further undercut private sector investment in new energy technologies. Since the mid-1980s, real private sector investment in energy R&D has dropped 35 percent."**

Please provide specific documentation for these statements.

A18. According to data collected by the Energy Information Administration and the Federal Energy Regulatory Commission on private sector investment in energy research and development by major energy producers, major pipeline companies, and investor-owned electric utilities, real investment declined by -34.9% from 1984 to 1993, as shown in the following data:

PRIVATE SECTOR INVESTMENT IN ENERGY RESEARCH AND DEVELOPMENT (BILLION DOLLARS–CONSTANT 1995)

	1984	1993
Major Energy Producers	2.718	1.505
Major Pipeline Companies	0.192	0.193
Investor-Owned Electric Utilities	0.768	0.695
TOTAL	3.678	2.393

Between 1984 and 1992, real energy prices fell by about -28%. According to the Energy Information Administration's "Annual Energy Review 1994", the real energy expenditure price index was 127.7 in 1984 and 92.3 in 1992.

These trends are documented in a recent Department of Energy report, "Corporate R&D in Transition–Changing Patterns of Private Sector Investment in Research and Development," published by the Office of Policy, in March 1996.

Q19. On page 15 of your prepared testimony, you also state: "Continued federal funding in advanced gas turbine technology, fuel cells, and other high-efficiency fossil fuel combustion technology is essential for keeping the costs of consuming energy low, as is continued funding for energy-efficient transportation, building, and industrial technologies."

Please provide specific documentation that these technologies will not be developed and commercialized without DOE funding.

A19. It is difficult analytically to determine the probability of the development of a particular technology absent federal R&D funding. However, private R&D in technology development has steadily fallen for the last five years as increasing numbers of businesses are reluctant to make risky long-term investments. This is true for a number of reasons–including the speed of technology development, shareholder focus on near-term profits, difficulty in protecting intellectual property rights, vastly increased costs of developing technologies, etc. To avoid developing technologies that might be developed absent federal funding, EERE uses a test in designing programs that ascertains the need for a government role before embarking upon any program. We only fund a technology if:

- the private sector won't do it by itself;
- there is a high social rate of return; and
- there is a strategic need of the country.

Because we use this test at the front end, the large majority of benefits resulting from EERE programs would either not occur or be substantially delayed without DOE funding.

In either case, the result would be substantial losses to the American people in terms of energy savings, pollution, competitiveness and jobs.

Q20. On page 19 of your prepared testimony, you state "that the United States . . . is now the leader in most areas of renewable technology. . ."

Q20a. Which specific areas of renewable technology is the U.S. the leader?

A20a. In terms of worldwide sales, U.S. PV and geothermal firms lead their competitors. The U.S. has about 44% of the PV market. Japan is second with about 22%. The technology level in U.S. products is second to none and, in our view, is advancing faster than that in competing countries. In the 1990 to 1995 time period, U.S. geothermal companies captured about 30% of the market, with Italy and Japan close behind and New Zealand, Mexico, Russia, and France serving primarily their own domestic markets. The principal reason for U.S. geothermal leadership is the more sophisticated technology U.S. firms are able to bring to projects. There are currently no significant sales of solar thermal systems or of advanced biomass systems of the type under development in our program. However, the U.S. is poised to commercially introduce new technology in each of these areas over the next 1-3 years that should begin market life as world leaders.

Q20b. Which specific areas of renewable technology is the U.S. not the leader?

A20b. Wind is the principal technology area where the U.S. lags. Currently, U.S. firms capture an estimated 10% of the world market, trailing Denmark, Holland, and Germany. Recent sales spurts in India and China following the Secretary's visit are a hopeful sign but the principal boost is expected to occur as a result of the DOE cost shared effort now underway with several U.S. firms leading toward significantly advanced "next generation" wind turbines.

Q21. On page 20 of your prepared testimony, you state that "in the past decade, German and Japanese companies snapped up several major American PV companies that accounted for 63% of the PVs manufactured in the United States."

Q21a. Which specific American PV companies did they "snap up"? Please provide the name of the specific PV companies.

A21a. The following companies were "snapped up" by German and Japanese companies over the past decade:

- ARCO Solar, Camarillo, CA, was purchased by Siemens Solar Industries (SSI), Camarillo, CA, in 1989. Siemens Solar Industries is a subsidiary of Siemens, USA (an American company owned by Siemens AG, a global German company).

- Mobil Solar, Inc., Billerica, MA, was purchased by ASE Americas, Inc., Billerica, MA, in 1993. ASE Americas (an American company) is owned by

ASE GmbH, which is a joint venture of the global German Daimler Benz Aerospace AG and Germany's largest utility, RWEAG.

- Solec International, Hawthorne, CA, was purchased by the Japanese Sanyo/ Sumitomo Sitex joint venture in 1994 and retains its name as Solec International, Hawthorne, CA.

- Blue Ridge Associates, Large, PA, was purchased by the Japanese Ebara Corp. in 1994.

Q21b. Please provide the DOE level of funding, by fiscal year, provided to each of the companies listed in Q21a, as well as the rationale of spending U.S. tax dollars to subsidize foreign-owned firms.

A21b. The amount of DOE funding of these companies over the past several years is shown in the following table:

SUMMARY OF DOE R&D SUPPORT–DOLLARS IN MILLIONS
(DOE Funds/Company Funds)

COMPANY	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996
Siemans Solar Industries, Inc.						
PVMat R&D Funding		1.66/1.83	1.64/1.80	1.70/1.86		0.85/0.85
Thin Film R&D Funding	0.60/0.55	0.60/0.55	0.60/0.55	0.60/0.55	0.75/0.75	
ASE Americas, Inc. (Since 1994)						
PVMat R&D Funding						
Solec International						0.44/0.65
Ebara International						
United Solar Systems Corporation						
Thin Film R&D Funding	0.78/0.78	0.78/0.78	0.78/0.78	1.11/1.10	0.83/0.82	0.83/0.82
Energy Conversion Devices, Inc.						
PVMat R&D Funding		1.50/1.76	1.67/1.96	1.81/2.12		
Thin Film R&D Funding				0.50/0.24	0.50/0.24	0.50/0.24

The Department's rationale for spending U.S. tax dollars is based upon that derived from the following events and experiences:

Both Siemens Solar Industries and ASE Americas have closed down their production facilities in their home countries to concentrate their investments in the U.S. Similarly, the Japanese companies are making most of their photovoltaic investments in their U.S.-located subsidiaries.

Having in a large measure fostered the rapidly-growing photovoltaic power industry as a U.S.-focused manufacturing technology providing thousands of U.S. jobs today, the DOE photovoltaic program continues to support R&D for U.S.-based companies that agree to continue expanding their production in the U.S. Siemens Solar has recently expanded production in its Vancouver, WA, plant by a factor of three; ASE Americas is expanding its

Billeria, MA, plant production by a factor of two. Both companies have announced plans for additional expansion.

Since Solec International was sold to the Japanese Sanyo Corp. in 1994, production in Hawthorne, CA, has been increased by a factor of two and plans have been announced to increase it by a factor of four to five more times. Solec has not received DOE R&D funds to date, but the new owners are investing large sums in U.S. manufacturing facilities perceived to be a result of U.S. technology dominance.

Ebara Corp, a Japanese company, purchased the rights to dendritic web crystalline silicon technology that was largely developed by the Westinghouse Corporation during the 1980's at their Large, PA, plant facilities, and that was supported by the DOE photovoltaic program for many years. They are now using the facilities, manpower, and technology in a pilot production of commercial products.

The United Solar System Corp. (USSC) is a joint venture between the U.S.-owned Energy Conversion Devices, Inc., developer of amorphous silicon technology and manufacturing in numerous cooperative activities with the DOE photovoltaic program, and the Japanese Canon, Corp., which provided the investment capital for the recently dedicated 5 megawatt amorphous silicon manufacturing plant in Troy, MI.

Scientific staff from Siemens, ASE Americas, and USSC are teamed with scientists from U.S.-owned companies, universities, and DOE laboratories in resolving technical problems in a number of photovoltaic technologies including amorphous silicon copper indium diselenide, and cadmium telluride. The contributions of these three companies to the resolution of outstanding technical issues has been exemplary in that continuing advances in U.S. engineering and manufacturing technology.

Under these circumstances, the continuing competitiveness of the U.S. in technology and the expansion of U.S.-based manufacturing jobs of high-technology photovoltaic cells, modules, and systems is tied to a significant extent to the continuing interactions of the program with all of the U.S.-based photovoltaic companies.

Q22. On page 21 of your prepared testimony, you state that "Germany and Japan . . have far larger governmental incentives for the use and export of renewable energy. . . "

What, specifically, are these "far larger government financial incentives"?

A22. Wind, photovoltaics and geothermal are examples of renewable technologies benefiting from foreign government incentives for use and export. For example in Germany, electricity from wind power plants is purchased at a subsidized price set at 85 per cent of the retail. This price is approximately $.08/KWH compared to about $0.03 in the U.S. In addition, under the German "250 MW Wind" program, wind plant operators are further subsidized \$0.04 or \$0.06/kWh for 10 years, depending on whether the energy is used by the operator or sold to the grid. The resulting subsidized price for wind energy is \$0.11 to \$0.14/kWh. Wind energy is further supported by subsidies offered by some German states, and by the "Eldorado" export assistance program that pays up to 70 percent of the cost of turbines sold in certain countries.

Japan encourages utilities to pay a 10-percent premium over retail for kWhs of renewable electricity fed into their grid, has a nationwide net-metering policy, and has instituted uniform utility interconnection standards nationwide. The residential roof-top Building Integrated Photovoltaic (BIPV) initiative received \$40 million or 30 per cent of the annual PV budget. The residential BIPV funding is expanding in an effort to meet the ambitious goals of 65,000-70,000 residential systems by the year 2000.

In Japan, geothermal energy development is supported by incentives for both domestic use and export. Geothermal resource exploration in Japan is supported by a \$100 million fund. Export is encouraged by favorable financing packages including long-term, low interest loans (under 5%) with grace periods up to 7 years. Japan has also implemented a major financial subsidy for photovoltaics. A 7-percent tax credit has been established for enterprises installing PV systems.

Q23. On page 23 of your prepared testimony, you say that DOE has been forming partnerships with the steel, aluminum, petroleum refining, chemicals, pulp and paper products, glass and metal casting industries to develop clean technologies.

Q23a. Please provide a detailed listing of these partnerships.

A23a. The Secretary of Energy has signed partnership compacts with industry representatives of the Forest Products, Steel, Metal Casting and Glass Industries. The Aluminum Industry is scheduled to sign a partnership compact in September. The partnership compact with the Chemicals industry is planned later in 1996 as soon as their vision document is complete. The Refining industry has initiated steps to develop an industry vision. These research partnerships center around the research needs identified in each industry's vision of the future. The vision document developed by the industries identify the characteristics of each industry both past and present, the drivers for future technological change, and targets for future characteristics such as the level of emissions, recycling, productivity and other key industry characteristics affecting competitiveness.

Q23b. For each of the partnerships listed in Q23a, please provide the level of both DOE funding and private sector funding for each of FY 1993-FY 1997.

A23b. Although the industry-lead partnerships developing from the Industries of the Future (IOF) strategy are a new way of doing business between industry and government, OTT has a history of developing advanced energy efficiency and renewable energy technologies with the process industries. The table below provides this history of partnering with industry in research activities. The IOF strategy builds on this history and places industry in the lead in identifying their research needs and allows OIT to actively meet its customers'/partners' needs.

	FUNDING (IN THOUSANDS OF $) FEDERAL/NON-FEDERAL					
INDUSTRY	PARTNERS	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997
Aluminum	6 Companies	4,300/1,038	4,222/1,736	2,699/1,374	1,341/601	6,587/3,091
Chemicals	70 Companies 15 Universities	3,000/ 10,000	10,000/ 10,000	20,000/ 20,000	13,000/ 13,000	13,000/ 13,000
Forest Products	442 Companies 13 Universities USDA Forest Service 2 Trade Associations 1 Industry Environmental Association 17 National Laboratories	5,518/ 2,791	6,495/ 3,214	9,688/ 6,110	11,278/ 7,895	13,104/ 10,484
Glass	12 Companies	0/ 0	0/ 0	2,292/ 3,500	1,396/ 2,164	5,182/ 8,032
Metal Casting	175 Companies 14 Universities 4 Trade Associations/ Societies	1,500/ 1,760	2,000/ 2,320	2,500/ 2,900	1,700/ 2,000	5,500/ 5,500
Refining	38 Companies 8 Universities 8 National Laboratories 4 Trade Associations/ Societies	8,424/ 2,808	11,279/ 3,760	9,686/ 5,779	6,550/ 4,079	6,839/ 4,413
Steel	17 Companies 1 Universities 5 Federal Laboratories 1 Trade Association	5,345/ 2,208	4,564/ 1,948	4,447/ 1,580	6,618/ 2,777	10,050/ 3,517

Q24. On page 2 of your prepared testimony, you state: "The government has a role in advancing pollution prevention for several reasons. First, pollution prevention technologies often benefit many companies only a small amount, so no one company has the incentive to spend the money by itself. Second, prevention has so many public benefits not fully captured in the marketplace: reduced resource consumption, improved environment, reduced energy consumption, and increased jobs and competitiveness. Thus the private sector will inevitably underinvest in R&D on clean technologies."

Please explain why "the private sector will inevitably underinvest in R&D on clean technologies," and provide the supporting documentation to support this explanation.

A24. We now have over twenty years of evidence that the private sector has underinvested in R&D on clean technologies. Industries not only underinvested in clean technologies for twenty years, they very rarely invest. The period of environmental regulation from 1970 to at least 1990 was characterized by costly investments in compliance with command-and-control type of regulations, NOT in avoidance or prevention. These compliance costs approach $150 billion/year according to a November, 1990, EPA report "The Cost of a Clean Environment." The 20-year legacy of compliance is a legacy of the failure of the private sector to anticipate and to prevent pollution. Only since about 1990, have a few forward-looking companies like Dow and 3-M embraced the concept of pollution prevention and have followed their beliefs with investments. The DOE portfolio of energy-efficient technologies are at the forefront of a large and fundamental change in the thinking of the private sector from reactive compliance to proactive prevention. Because of the close connection between energy production, consumption and pollution, the Department of Energy currently provides over 70% of all federally-funded R&D for pollution prevention technologies. (National Science and Technology Council, "*Technology for a Sustainable Future*," July, 1994.)

Q25. During your oral testimony, on page 38 of the hearing transcript, you stated: "By 2010, this diversified investment portfolio, we believe could reduce oil imports by 1.5 million barrels of oil per day, a $1 billion per year savings to the country."

Q25a. Please document the claimed reduction in oil imports of "1.5 million barrels of oil per day."

A25a. The estimated potential oil reduction of 1.5 million barrels of oil per day in 2010 has been documented as part of the performance metrics for the FY 1997 budget for the Office of Transportation Technologies. The oil reductions came from the following specific programs with the assumptions explained below:

		MBPD
1.	Hybrid Vehicles	.49
2.	Biofuels	.41
3.	Heavy Duty Trucks	.20
4.	Electric Vehicles	.13
5.	Alternative Fuel Vehicles	.11
6.	Other Technologies	.16
	TOTAL	1.50

1. Hybrid Vehicles. Hybrid vehicles that are 70% more efficient than conventional vehicles enter the market in 2002 and hybrids that are 150% more efficient enter the market in 2006. Collectively, they gain 27% of light vehicle stock and save .49 MBPD because they are more efficient. A vehicle choice model (based on a stated preference survey) is used to project the market share of hybrid sales relative to conventional vehicles and the other alternative vehicles.

2. Biofuels. The R&D being done on this program results in a supply potential of 12 billion gallons of ethanol from grasses and trees in the year 2010. This fuel would be used in flexfuel and dedicated alcohol vehicles. The vehicle choice model projects that 19% of the light vehicles will be flexfueled in 2010 and that 1.1% will be dedicated alcohol vehicles. The 12 billion gallons of ethanol used by these vehicles will replace 0.41 MBPD of oil through substitution.

3. Heavy Trucks. This OTT program results in an advanced diesel engine for class 7 and 8 trucks (those over 26,000 gross vehicle weight) that is 20% more efficient than conventional diesel engines. These advanced diesels start penetrating the market in the year 2000 and make up about 15% of the stock of heavy trucks in 2010. They would replace 0.20 MBPD of oil through efficiency.

4. Electric Vehicles. Electric vehicles enter the market in 2000 and grow to 3% of the light vehicle stock according to projections from the vehicle choice model. This number of electric vehicles would displace 0.13 MBPD of oil via substitution.

5. Alternative Fuel Vehicles. This includes CNG and LPG (propane) vehicles. These two vehicle types each attain a .9% share of the light vehicle market and together reduce oil use by 0.11 MBPD in 2010 via substitution.

6. Other Technologies. The oil reductions from fuel cell vehicles (only 0.7% of the vehicle stock in 2010), lightweight conventional vehicles (7.6% of the 2010 stock), and advanced diesels (6.3% of the 2010 stock) combine to reduce oil consumption by 0.16 MBPD in 2010.

Q25b. Please document the claim of "a $1 billion per year savings to the country."

A25b. The savings of $1 billion to the country was a typographical error. It should have read $13 billion for the year 2010. Because of the increased efficiency of hybrid, electric, fuel cell, advanced diesel, and lighter conventional vehicles, their owners will purchase less fuel. This reduction in fuel costs in 2010 is $23 billion. (To put this number in context, in 1995 vehicle owners spent over $110 billion for motor fuel.)

But some of the alternative vehicles purchased in 2010 will have higher purchase prices than conventional vehicles, so these incremental costs must be deducted from the fuel savings total to obtain a net value. The 2010 incremental expenditure for the alternative fuel vehicles is $10 billion. Thus, this $ 10 billion subtracted from the gross reduction in fuel costs of $23 billion results in a net reduction of $13 billion for vehicle owners in 2010.

Q25c. Please provide evidence that these claimed reductions and savings would not occur without DOE funding.

A25c. The largest potential oil reduction benefits in the year 2010 came from the hybrid vehicle program and from the biofuels program. Without DOE funding, neither of these programs would exist. The hybrid program was started by DOE and would not have been pursued by the Big Three auto companies without DOE funding. The biofuels program would not exist (except for the current corn ethanol activity) without DOE funding. The need to develop renewable motor fuels from a non-food crop would not be researched without the funding in the OTT budget for this program.

For the other vehicle programs (advanced diesels, electric vehicles, lightweight vehicles, and fuel cells) it is unlikely that they would come to market as soon as assumed without DOE support for R&D.

Q26. During your oral testimony, on page 38 of the hearing transcript, you stated: "Were Congress to make the cuts they are thinking about, it would make the oil crisis scenario more likely."

Q26a. Please document the cut that Congress is "thinking about."

A26a. On October 12, 1995, the U.S. House of Representatives passed H.R. 2405, the Omnibus Civilian Science Authorization Act of 1995. Funding levels contained in that bill for Energy Efficiency and Renewable Energy programs represented a reduction of 55% and 40% respectively from prior year funding levels.

Q26b. Please document the claim that cuts to DOE funding "will make the oil crisis scenario more likely."

A26b. Research and development on energy efficient and renewable energy technologies represent an opportunity to reduce our oil dependence and counter the effects of the threat of disruptions to imports of oil from often unstable regions, and place some restraint on the economic and geopolitical impact of the increased dependence on Persian Gulf oil. At the same time, domestic jobs are created when money that would have gone overseas to purchase foreign oil instead goes to U.S. workers manufacturing technologies for highly-efficient cars and trucks, or for growing domestic biofuels.

Q27. During your oral testimony, on page 40 of the hearing transcript, you say that "we have completely changed the program design of the Department of Energy's programs."

Q27a. Please explain the "old" program design.

Q27b. Please explain the "new" program design and elucidate specific changes.

A27. Every year EE assesses the benefits and costs of it's energy efficiency and renewable energy portfolio prior to developing a budget request. This includes soliciting input from customers, assessing likely future benefits, responding to Congressional guidance and pursuing strategic goals. Over the course of the last three years, the EERE portfolio has been re-designed to respond to vital national issues, maximize benefits to taxpayers and businesses–both large and small–and to be as customer-oriented and customer-responsive as possible. In addition, to modifying our portfolio to meet new market realities and likely futures, the Office of Energy Efficiency and Renewable Energy has re-engineered how we implement our programs. We have reinvented how government interacts with the private sector. This affects our programs in a number of ways.

1) We work more closely with our customers, building voluntary partnerships with industry, business, state and local governments and energy consumers. Instead of assuming that government knows best, we use the talent and creativity of our customers to help design and implement these programs.

2) We use relatively small amounts of Federal money to leverage large amounts of private investment.

3) We stress flexibility and innovation. And rather than sweeping, over-reaching programs, we help small businesses, consumers, large companies and others move to a new energy future through a balanced program of next generation technologies and market driven incremental improvement.

4) We have cut administrative costs and overhead and we are downsizing operations and learning how to operate more efficiently.

5) We listen to our customers and acting on their needs where appropriate. For example, States told us there was room for improvement in the delivery of our grant programs. Subsequent cuts in our administrative overhead have allowed us to consolidate our State grant programs to meet State and local needs more effectively.

6) We are committed to continuous improvement, customer involvement and market-driven action. We strive to operate more like a business, and less like a bureaucracy.

7) We set clear goals and annual progress targets so that we may show that technologies with inherent risk are making expected progress or needed adjustments to deliver a better future and larger return on investment.

Q28. During your response to a question by Mr. Roemer, on page 69 of the hearing transcript, you say that "[t]he nation's energy bill is $500 billion a year."

Please document that claim.

A28. According to the Yergin Report–"Energy R&D: Shaping our Nation's Future in a Competitive World", June, 1995, pp. 6-7–the United States is spending $500 billion per year on energy.

Q29. During your response to a question by Mr. Wamp, on page 77 of the hearing transcript, you state: "In the case of Oak Ridge, just one example, which is advanced refrigerator/freezer compressors, a $1 million investment in Oak Ridge has saved the U.S. economy $5 billion in the 1980s."

Q29a. Please document this claim, and provide supporting documentation.

A29a. From 1978 through 1980, ORNL sponsored a research subcontract for DOE with Columbus Products Company to develop a high-efficiency (energy efficiency ratio, or EER, of 5.0) compressor for household refrigerators. By making design changes to the motor, suction muffler, and compressor valve assembly and piston, the

Columbus Products compressor achieved a 44%[1] improvement over the compressor technology used in refrigerators at the time (EER 3.5).

The resulting technology was incorporated into a compressor product line manufactured by Greenville Products Co. (Kelvinator) of Grand Rapids, Michigan, which produced and sold them through the mid-1980's. The technology was then transferred to Americold Compressor Co. of Cullman, Alabama. Americold continued improving compressor designs on their own through the 80's and 90's and have exceeded the performance standards set by the DOE-supported development. They are now marketing refrigerator compressors with EERs of 5.2-5.5 for use withR-134a (replacement for CFC-12) and are developing a new line of R-134a compressors for refrigerators and freezers, manufacturing over 4 million per year.

The availability of high efficiency compressors was a major reason the refrigerator energy use (on a shipment-weighted-average basis) dropped from about 1500 kWh/yr in the late 1970's to about 900 kWh/yr in 1990. Availability of improved compressors pioneered by DOE's research effort is responsible for approximately half of this improvement.

The shipment-weighted average energy use of new refrigerators in the late 70's (when DOE-sponsored research started) was about 1500 kWh/yr. New refrigerators were produced at an average rate of about 6.25 million units/yr between 1980 and 1990. By incorporating energy efficiency improvements into the refrigerator, 150 billion kWh or 1.7 quads of cumulative energy have been saved with energy efficient compressors accounting for 75 billion kWh. At an average consumer cost for electricity of $0.08/kWh this results in $6 billion in energy cost savings.

Total funding for the high-efficiency refrigerator/freezer compressor program was:

	DOE
FY 78	$112,000
FY79	$264,000
FY80	$226,000
FY81	$225,000
Total	$827,000
Columbus Products co-fund =	$276,000
Total program funding =	$1,103,000

Q29b. Please document the private sector investment in this technology.

A29b. The private sector cost share was $276,000 by Columbus Products Company in the DOE sponsored research and development effort.

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[1]Staelin, R., and Redinger, R.P., "Research and Development of Energy Efficient Appliance Motor-Compressors, Vol. 2 - Market Evaluation," ORNL/Sub/7229/2, December 1980, page iii.

Q29c. Please provide evidence that advanced refrigerator/freezer compressors <u>would not</u> have been developed and commercialized without the DOE funding.

A29c. There is no firm evidence that advanced refrigerator/freezer compressors would not have eventually been developed without DOE funding. However, prior to the issuance of the DOE competitive solicitation for advanced compressor development, there was no energy efficiency-related R&D being carried out by the major U.S. refrigeration system manufacturers. The technology developed by DOE led to a motor/ compressor which was 44% more efficient than the state-of-the-art at that time, and this technology dominated the market until 1990 when efficiency standards and other influences began to propel compressor development forward again.

Q30. During your response to a question by Mr. Ehlers, on page 89 of the hearing transcript, you state "that the Japanese out spend us just on photovoltaics by over two to one."

Please document this statement, and provide supporting documentation.

A30. The Japanese programs in renewable energy technology are documented by the Resources Total System Co., Ltd. 2-7-11 Shinkawa, Chuo-ku, Tokyo 104, Tel. (81)-3-3551-6345. Mr. Osamu Ikki, President, provided a document to DOE staff containing a summary of PV related budget items in 1996 amounting to 13. 10 billion yen, or more than $130 million.

These same numbers are reported in PV News, March, 1996, Vol. 15, number 3, p. 5, and PV International Report, Vol. SV, No. 1, January, 1996, p. 2. "Report from Japan: Japanese Renewable Energy Budget Increased: PV Rooftop Program Growing", etc.

[*Note: Copies of these documents are attached.*]

PV Activities in Japan - December 1995

Resources Total System Co., Ltd.
Osamu Ikki
2-7-11 Shinkawa
Chuo-ku, Tokyo 104
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E-mail: ged02723@niftyserve.or.jp

Considering business recovery was the main deciding factor when the government decided about next year's budget in December. The original bill presented by the Ministry of Finance reflected general fiscal conditions, budget demand was met with stringency, but as a result of recovery debates almost the whole amount was accepted. See PV related budget items below.

(billion yen)

PV related budget items	1995 budget	1996 demand	1996 budget
PV system promotion	11.89	14.12	13.10
Residential PV system monitoring	3.31	4.42	4.06
PV field test on public facilities	1.70	2.55	1.90
Development of solar grade silicon production technologies	0	0.05	0.04
Development of PV system application technologies	6.88	7.10	7.10
Regional new energy promotion	0.70	1.21	0.95
Regional new energy vision policy	0.27	0.70	0.47
Regional new energy projects	0.43	0.51	0.48
Other policies	0.37	0.59	0.39
International new energy model projects	0	0.20	0
Research for new energy standardization	0.37	0.39	0.39
Promotion of service stations for emergency	0		0.17

The item that attracts most attention is probably the 'Residential PV monitor project' that was allotted 4.06 bill. yen, a 22% up, under today's strict fiscal restrictions. This item will become an important moving factor for 1996 and it will be beneficial both for the industry and private citizens considering the installation

Renewable energy related budget items in 1996

(billion yen)

1. PV system promotion	**13.10** 13x10⁹ Yen #130x10⁶
O Residential PV system monitoring	4.06
O PV field test on public facilities	1.90
O Development of solar grade silicon production technologies	0.04
O Development of PV system application technologies	7.10
2. Promotion of waste generation	**8.81**
O Waste generation development subsidy	1.08
O Technology development for new type of solid waste fuel power generation	0.67
O High efficiency waste generation technologies	2.53
O Promoting the establishment of environmentally friendly energy communities	4.53
3. Clean car popularization program and others	**2.22**
O LNG car popularization project	1.35
O Electric vehicle popularization project	0.12
O Infrastructure for environmentally friendly cars ('Eco-Station 2000')	0.75
4. Regional new energy promotion	**0.95**
O Regional new energy vision policy	0.47
O Regional new energy projects	0.48
5. Other policies	
O Wind generation field tests	0.31
O Research for new energy standardization	0.39
O Promotion of service stations for emergency	0.17

of residential PV systems. Good news before Christmas. This application is not well established yet, but at least a 6 to 7 MW market has been created. This system has been is place for 3 years and it became popular with strong public support. How long it can go on, is a future issue though. We should rather think that the time has come, when further expanding of this market mainly depends on free market decisions and not subsidized demand. Otherwise, when the 1000 rooftop project (2250 in Germany) is finished, the PV industry will lose directions, as it happened in Germany, and development will stagger. Since the solar cell manufacturer CANON and in the housing construction interested Asahi Solar are to enter the market in 1996, to attract customers fervent price competition, with the earlier manufacturers, can be anticipated.

Good news for manufacturers of crystalline cells is that the new budget provides for developing manufacturing technologies for solar grade silicon. Solar cell manufacturers around the world feel uncertain about the future of silicon raw materials, so we can only hope that the project will lead to viable new technologies in this special area. On the other hand it is unfortunate that the International New Energy Model Project did not get approved. America and Europe consider developing countries an important market Japan is too conservative in that respect. It is very difficult to change this practice, but soon Japan has to deal with the problem how to approach the overseas market.

Also other ministries have approved budget items for PV installations. For example the Ministry of Construction has included the design and establishment of PVs in its expanded list of items financed under the Urban Environmental Model Project.

It has been one year since the New Energy Introductory Plan was adopted, but to test the plan on the basis how many systems have been installed would be inappropriate. PV technology could be introduced through residential monitoring programs, PV field tests, utility companies, various ministries, agencies or local governments, industries or private Individuals, but the amount of PV system installations haven't been analyzed yet. The plan can not be realized in the 5 years to 2000, unless an action program gets prepared and items of the program get carried out, otherwise estimates are meaningless. For the introduction a framework has to be created to facilitate cooperation among suppliers, legislators, installers and customers. Hopefully we will see this happen in 1996. Fortunately, NTT has announced plans that would make it a major corporate customer and various agencies and local government bodies started working on introduction too. It would be nice to see feverish activities picking up this seedling of an industry.

As for the government, we could see PV related budget items appear again in MITI's budget. As a result of negotiations with the Agency of Natural Resources and Energy, the Residential PV System Monitoring Project got 4.06 bill. yen allotted what is close to the full amount of the requested 4.42 bill. Also the 'Development of solar grade silicon production technologies' project got 40 mill. out of a requested 50 mill., although according to unofficial previous assessments it was not accepted as a budget item. In the energy related budget of the Ministry of Construction, besides expanding the Ecocity Program under the 'Urban Environmental Model Project', subsidies will be provided for the installation of PV systems and similar to improve energy saving. Further the Ministry has contributed to the development of environmentally friendly blocks of apartments which effectively utilize rainwater and sunshine to save energy and improve the neighboring environment. Such blocks of apartments have been established in several locations and are selling well. There are three locations where apartments are currently available. Including new ones still on designing boards, test houses of real estate agencies there are 16 places with environmentally friendly blocks of apartments. The Environment Agency issued a PV introduction manual for local public organizations. This is a collection of information needed in case an organization decided to install PVs.

As for power companies, Central Research Institute of the Electric Power Industry and Electric Power Research Institute held the 'America-Japan PV Workshop', which dealt with questions of utilization, on Miyako Island in Okinawa. Information has been exchanged in relation to effective legislation and efforts in the two countries. Tohoku Electric Power Company completed the installation of a 5kW PV system on the rooftop of its Iwate branch and started testing. Chubu Electric Power Company installed an 18kW PV system on its Shizuoka branch rooftop and outer walls.

As for manufacturers, Japan Photovoltaic Energy Association is planing its incorporation as a public company, in reaction to PV promotion efforts by MITI. It is expected that functions can be broadened and cooperation with MITI and other ministries or agencies becomes more effective. MSK established PV test and research facilities on its factory site in Nagano to reinforce its application development. M. SETEK decided to increase, in 1996, its 12 casting lines in China, in response to growing demand of single crystal silicon solar cells. Hitachi starts experimental sales of emergency PV products like emergency service stations, which can be fully energy and water self supporting in case of emergencies, similar support systems for schools and emergency toilet water supply systems.

As for customers, KAJIMA has completed environmentally friendly bachelor flats which utilize rainwater and sunshine. Amorphous solar panels are integrated in the roofing material and output is 20kW. Asahi Solar and Sharp in cooperation with major property developers will advance into the housing market. The majority of the products will be residences with PV modules or solar thermal equipment integrated in the roofing material. MINOLTA is getting involved with PV operated lighting control systems.

As for new products and product applications, Weck has developed a small emergency power supply utilizing PVs. MINOLTA launched its new lighting control system on the market.

Objectives of the Fiscal Year (FY) 1996 New Energy Budget Demand (PV related)

Sept. 1995
Energy Conservation and Alternative Energy Policy Division
Agency of Natural Resources and Energy
Ministry of International Trade and Industry
(NOTE: Translated by Resources Total System Co., Ltd.)

Basic policy

To increase the budget for technology development and introduction of photovoltaic energy to realize the Basic Guideline for New Energy Introduction adopted in December 1994 from the perspectives of energy security and environmental issues such as measures for CO_2 emission.

1. PV system promotion

[14.12 bill. yen (11.89 bill. yen)]

(1) Residential PV monitor subsidies

4.42 bill. yen (3.31 bill. yen)

People participating in this program can get a 50% subsidy for installing a PV system and, by becoming a monitor, contributing to the further development of system performance to better match of customer needs.

(Project for FY 1996)

1) Residential PV system monitoring

- number of houses: 1,800 houses (3.5kW per house)
(in FY 1995 1,200 houses (3kW per house))
- subsidy rate: equal to 50% (fixed amount)
- amount of subsidy: maximum 650,000 yen per kW (850,000 yen in FY 1995)
- subsidy administration: New Energy Foundation

2) PV promotion guidance

Guiding companies, performing PV construction, with latest know-how. Educating new owners on maintenance and management, and providing information on available products.

-subsidy administration: New Energy Foundation

Yen
1. PV Sys. Promotion 11.89×10^9
2. Regional New Energy Promotion 0.7×10^9
3. Other Policies 0.37×10^9
Total PV ¥ 13.03×10^9
≅ $130M

(2) Subsidies for promoting field tests on public facilities

2.55 bill. yen (1.7 bill. yen)

In the period between FY 1992 and FY 1994 to collect basic data, preparing for the most advanced level of PV applications, PVs have been established on museums, schools, public halls and other public establishments.

From FY 1995, since the main factor hindering wider use of PVs is the price compared to other existing generation systems, system standardization and price reduction have been schemed by the appropriate authorities.

(Project for FY 1996)

- number of sites: 40 sites (22 in FY 1995)
- subsidy rate: 2/3 of the expenditures for field tests
- subsidy administration: New Energy and Industrial Technology Development Organization (NEDO)

(3) Subsidies for developing solar grade silicon production technologies

50 mill. yen (new)

Silicon used for PV applications, SOG-Si, does not need to be purified to that super high level that is required for semiconductors. Anticipating wide use of PV systems, dictates the need for early establishment of large capacity, cheap production technologies.

For the early application of the solar grade silicon production technologies developed by NEDO and others, technological testing is carried out.

(Project for FY 1996)

- objectives of the technological tests

  process structure integrating

  final refining into the casting technology

  setting particulars of the detailed project, quality evaluation method

  planing to produce development schedule, substrate equipment by FY 1997
- subsidy administration: New Energy and Industrial Technology Development Organization (NEDO)

(4) Development of PV system application technologies

7.1 bill. yen (6.88 bill. yen)

As part of the New Sunshine project, research is directed toward new production technologies to significantly decrease the cost of solar cells and system development.

2. Regional New Energy Promotion

[1.21 bill yen (0.7 bill. yen)]

(1) Subsidies for the Regional New Energy Vision policy

700 mill. yen (270 mill. yen)

This subsidy is there to compensate expenses incurred by regional public organizations when investigating New Energy applications and economies, for preparing their "Vision", that is a plan for fitting PV applications into the harmony of the given region.

(Project for FY 1996)

- Subsidy rate: fixed amount
- Recipient: municipalities
- Number of recipients: 34 authorities (13 authorities)

(2) Regional New Energy Projects

510 mill. yen (430 mill. yen)

Under this project, the local public organizations promote the use of regional energy sources, by conducting feasibility studies on such operations and assisting the creation of model projects.

(Project for FY 1996)

1) Regional New Energy development, consumption and generation feasibility tests

- Subsidy rate: 50%
- Recipient: regional public organization
- Number of recipients: 9 organizations (7 organizations)

2) Regional New Energy development, consumption and generation model projects

- Subsidy rate: 30%
- Recipient: regional public or private organizations
- Number of recipients: 9 organizations (7 organizations)

3. Other Policies

[590 mill. yen (370 mill. yen)]

(1) Subsidy for International New Energy Model Projects

200 mill. yen (new)

This project helps developing countries to acquire modern New Energy technologies (PV systems, wind turbines, etc.). In cooperation with the recipient countries feasibility studies are conducted, experts dispatched and model projects established.

(Project for FY 1996)

- Items:
  1. feasibility study
  2. expert dispatch
  3. international model projects for new energy introduction
- New Energy: PV systems, wind power
- subsidy administration: New Energy and Industrial Technology Development Organization (NEDO)

(2) Research for New Energy standardization

390 mill. yen (370 mill. yen)

Standardization of installation methods and collecting various data to promote new energy such as PV, wind and others.

Nov. 1995

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PV in Japan

〈Market〉

① Production of Solar Cell

		(Value)
FY 1992	16.1 MW	15.5 billion Yen
FY 1993		13.9
FY 1994		12.8 (estimation)

② Application	(FY 1992)	(FY 1993)
Consumer Use	7,311 kW	6,679 kW
Power Use	8,016 kW	7,773 kW
Test, R&D	780 kW	217 kW
Total	16,107 kW	14,669 kW

③ Technology	(FY 1992)	(FY 1993)
Single Cry. Si	2,371 kW	2,129 kW
Poly Cry. Si	5,631 kW	6,012 kW
a-Si	7,179 kW	5,653 kW
CdTe and Others	926 kW	874 kW
Total	16,107 kW	14,669 kW

④ Market Sector	(FY 1992)	(FY 1993)
Domestic	6,880 kW	6,662 kW
Export	9,227 kW	8,007 kW
Total	16,107 kW	14,669 kW

〈Government Policy〉

① Cabinet

Establishment of Basic Guidelines for New Energy Introduction

For PV	400 MW	by the year 2000 (FY)
	4600 MW	by the year 2010 (FY)

② MITI

1) Energy Policy

Promotion of Dissemination of distributed type Electric Power Generation

2) R&D Program

New Sunshine Program (1993 ~)

Cell, PV System, BOS, Building-integrated PV Module

3) Introduction & Dissemination Policy

PV Field Test (1992 ~)

1992	235 kW (11 systems)
1993	481 kW (19 systems)
1994	285 kW (11 systems)

Subsidization (2/3 of Total installation cost)

PV Home Project

1994	577 PV Homes (2100 kW, Ave. 3.6 kW/home)
1995	1200 PV Homes (3600 kW, at 3 kW/home)

Subsidization

(1/2 of Total installation cost or ¥ 850,000/kW in 1995)

4) International Cooperation

Nepal	44 kW (1992 ~ 1996)
Mongol-	40 kW (1992 ~ 1996)
Thailand	44 kW (1992 ~ 1996)
Malaysia	110 kW (1992 ~ 1997)

③ Other Ministries

Start of Using PV System by their Budgets

i.e. Ministry of Construction

Ministry of Post & Telecommunication

〈Solar Cell & BOS Manufacturers〉

① Putting Emphasis on
- Grid Connected PV Home
- Grid Connected PV System for Various Buildings
  such as Public Facilities
- PV Integrated Building Materials

② Tie Up with Housing Sectors
- Kyocera - Higashi Nihon House, ...
- Sharp - Mitsubishi Homes, ...
- MSK / Solarex - Misawa
- Showa Shell / SSI - Mitsui Homes
- Matsushita / BP Solar - Pana Home
- Sanyo / Solec - Sanyo's own route

③ Price

¥6,000,000/3kW (All Companies)	1994 PV Home Project
¥4,300,000/3kW (Depend on Companies)	1995 PV Home Project

④ Inverter Manufacturer
- Commercialization of Inverter for Grid Connected PV Home

⑤ New Comer
- Canon (10 MW/year Plant by a-Si Technology, 1996)

〈Electric Power Companies〉

PV Introduction Target by the year 1995 (FY)	2400 kW
1993 PV Installation	498 kW
1994 PV Installation	506 kW
1995 PV Installation	969 kW (planed)

(at Their Facilities, Technical Lab., Branches.)

PV Introduction Target by the year 2000 (FY) Under Planning

Purchase of Surplus Electric Power from PV System
Purchasing Price = Selling Price
f.e. ¥25/kW in Tokyo for Home Use

fabrication capability shortly. According to president Mark Farber, "As Evergreen looks to its second year, our goal is to begin pilot manufacturing by Spring of 1996, with initial products used for qualification testing and market introduction. We're facing a few months of hard work to get new processes and equipment operating and integrated, but we're committed making our first solar cells soon." Contact Evergreen Solar, Inc., 211 Second Ave, Waltham, MA 02154 USA. Phone 617 890 7117. Fax 617 890 7141.

NREL has scheduled restructuring and reduction in its work force in response to impending reductions in federal research budgets. Work force reductions may eliminate more than ten percent of its present 900 employees. The reduction will occur in two phases. The first phase will be a voluntary separation program in November and December. The second phase, if necessary to meet budget requirements, would include involuntary separations to begin in January, 1996. The full sequence of reductions and reassignments is expected to be completed Spring 1996. "This is a very challenging time for NREL and its research partners in industry and universities," said NREL Director Dr. Charles Gay. "Congressional budget cuts are forcing reductions in research programs at the very time when renewable energy technologies are proving their real value and commercial potential in a wide array of applications here in the United States and as exports to countries around the world. NREL is implementing fundamental changes in how it operates to improve its efficiency so that the lab can fulfill its science and technology mission at reduced budgets now being discussed in Washington," Gay said.

Kirk Collier forms Enerscope. Kirk, previously manager of Photovoltaics at the Florida Solar Energy center has formed **Enerscope, Inc.**, "An Energy Research and Development Company". Kirk can be reached at Enerscope, 109 Tequesta Harbor Dr., Merritt Island, FL 32952. Phone 407 454 4136. Fax 407 454 4171.

INTERNATIONAL NEWS

JAPANESE SET GOALS FOR FY '96 NEW ENERGY (PV) BUDGET

The Japanese Energy Conservation and Alternative Energy Policy Division of the Ministry of International Trade and Industry (MITI) has released detailed spending plans for its Photovoltaic Energy Conversion program for Fiscal Year 1996 (4/1996-3/1997). . The Japanese PV program is composed of three major elements: PV Systems Promotion (11.89 billion Yen -- $119 million), Regional New Energy Promotion (.7 b Yen -- $7 million), and Other Policies (.37 b Yen -- $3.7 million.). *PV NEWS* thanks Osamu Ikki of Resources Total Systems Co. Ltd. for providing the translation. (2F Kanya Bldg, 2-7-11 Shinkawa, Chuoku, Tokyo 104, Japan). Osamu Ikki's translation is provided below:

" I. PV SYSTEMS PROMOTION

1. **Residential PV monitor subsidies** (3.3 b. Yen - $33 million) Program participants can get a 50 % subsidy for installing a PV system and becoming a monitor contributing to the further development of system performance to better match customer needs.

Residential PV system monitoring

- 1800 houses -- 3.5 kW per house. (In FY 1995, 1200 houses -- 3 kW per house)
- Subsidy rate of 50 %
- Subsidy maximum 650,000 Yen/kW - $6,500 per kW installed. (850,000Y in 1995)
- Subsidy administered by New Energy Foundation

PV promotion guidance

-Guiding companies performing PV construction with latest know-how. Educating new owners on maintenance and management and providing information on available products.

-Administered by New Energy Foundation

2. **Subsidies for promoting field tests on public facilities** (1.7 b Yen - $17 million) The goal of this program is to collect basic data on PV in museums, schools, public halls and other public establishments. Since high price is hindering the wider use of PV, system standardization and price reduction have been targeted as program goals by the appropriate authorities.

-number of sites - 40 (1995- 22)

-subsidy rate 2/3rd of expenditures for field tests

-subsidy administration: New Energy and Industrial Technology Development Organization (NEDO)

3. **Subsidies for developing solar grade silicon production technologies.** **(50 million Yen)**

Silicon used in the production of PV cells does not need to be purified to the level required for semiconductor device production. The anticipated wide use of PV systems, dictates the need for early establishment of large capacity, using low-cost processes.

The FY 1996 project has the following objectives:

-process structure integration

-final refining for ingot casting

-selecting specifications of the detailed process

-develop quality evaluation method

- to produce development schedule, key equipment by FY 1997

-administered by New Energy and Industrial Technology Development Organization).

4. **Development of PV system application technologies** (6.88 b Yen - $69 million))

As part of the New Sunshine Project, research will be directed toward new production technologies in order to significantly reduce the cost of solar cells and system development.

II. REGIONAL NEW ENERGY PROMOTION (.7 b Yen- $7 million)

1. **Subsidies for the Regional New Energy Vision Policy** (.27 b Yen- $2.7million)

This subsidy is to compensate regional public organizations for expenses incurred investigating "New Energy" applications and economics for preparing their "Vision", that is, plans for fitting PV applications into the harmony of the given region. The FY 1996 project has:

-fixed subsidy amount

-municipalities are recipients

-number of recipients: 34

2. **Regional New Energy Projects** (.43 b Yen-$ 4.3 million)

Under this project, the local public organizations promote the use of regional energy sources, by conducting feasibility studies on such operations and assisting the creation of model projects. The FY 1996 project involves:

-Regional New Energy development consumption and generation feasibility tests.

-subsidy rate 50 %

-recipient: regional public organization

-number of recipients: 9 organizations

-Regional New Energy development, consumption and generation model projects.

-subsidy rate - 30%

-recipient: regional public or private organizations

-number of recipients: 9 organizations

III. OTHER POLICIES (.57 b Yen-$5.7 million)

1. Subsidies for International New Energy Model Projects (.2 b Yen)

This project helps developing countries to acquire modern New Energy technologies (PV, Wind, etc). In cooperation with the recipient countries, feasibility studies are conducted, exports dispatched and model projects established. The FY 1996 project involves:

- -feasibility studies
- -exports
- -international model projects for new energy introduction

2. Research for New Energy Standardization (.37 b Yen)

Standardization of installation methods and collecting data to promote new energy such as PV, wind and others.

SANDIA CONTRACT HELPS DEPLOY PV IN RURAL VIETNAM

A joint solar electrification project funded in part by the Department of Energy through the Sandia National Laboratories is helping people in remote areas of Vietnam enjoy the benefits of electricity for the first time. The pilot project, which was completed last spring, used U.S. PV home systems from USSC to electrify 100 households. Thirty more households, five community power and lighting systems, and street lights at two village markets were installed using products from other manufacturers including BP Solar, Siemens Solar, Solar Outdoor Lighting, and ASE Americas. The project helped more than 2000 people gain access to electric light, which in most places replaced kerosene lamps, and provided sufficient electrical power to operate televisions and radios. The project was a joint effort by Sandia's International Renewable Energy Design Assistance Center (DAC), the Solar Electric Light Fund (SELF), a nonprofit organization and contractor to Sandia and Unisolar, San Diego CA. It was carried out in association with the Vietnam Women's Union, the largest women's organization in the world with 11 million members. Sandia provided $35,000 of the project's total $87,000 cost. SELF and the Rockefeller Brothers Fund provided the remainder of the funding.

SELF introduces solar power systems to rural areas throughout the developing world to demonstrate their commercial viability and to stimulate their continued and expanded use as an economical and financially feasible means of providing electricity in rural area of developing countries. The SELF project manager Marlene Brown spent two months in Vietnam training technicians, supervising and helping to install the systems. The project began in January 1995 in two Provinces in southern Vietnam in the Mekong Delta, and in one province in the North. 130 families in five villages received the 22 watt, Unisolar Kits with three fluorescent lights, a charge controller, and a battery. All systems were provided with an outlet to power radios and black and white televisions. According to SELF, the project in Vietnam is already resulting in volume sales through the VWU and the private sector. Vietnam represents a huge potential market for U.S. energy products. Of the country's 71 million people, only 20 percent have access to electricity. For details on this and other PV home projects in the developing world contact Neville Williams, SELF, 1734 20th Street, N.W., Washington DC 20009. Phone 202 234 7265. Fax 202 328 9512. email "solarlectric@self.org" Marlene Brown can be contacted at 505 844 0032 in Albuquerque, NM and Sandia manager Michael Ross can be contacted at 505 844 5550.

Q31. **During your response to a question by Mr. Olver, on page 106 of the hearing transcript, you state:**

> **"To give just a couple of examples, just so we can stop being abstract about this and get very factual, we issue detailed analysis of what the cost of conserved electricity from our standards is. Typically, the cost of conserving electricity is two cents a kilowatt hour, three cents a kilowatt hour.**
>
> **The proposed–one of the refrigeration standards that we are considering would have a cost of conserved electricity of 2.9 cents a kilowatt hour and a payback to the consumer of 3.7 years. Most consumers are paying eight and a half cents per kilowatt hour."**

Please document these statements, and provide supporting documentation.

A31. In most cases, efficiency standards increase the first cost of appliances and decrease the operating (energy) expense. The cost of conserved energy (CCE, in $/kWh) is the ratio of increased purchase price (amortized over the life of the appliance) to annual energy savings, and provides a means of comparison between the cost of saving, instead of supplying, energy. The CCEs for each class of refrigerators (7 classes) and freezers (3 classes) were presented in the U.S. Department of Energy, Technical Support Document: Energy Efficiency Standards for Consumer Products: Refrigerators, Refrigerator-freezers, & Freezers (DOE/EE-0064) which was published in July, 1995. The table below shows those CCES, and a conversion of those results from 1992$ to 1995$.

Cost of Conserved Energy (CCE)

Proposed Refrigerator and Freezer Product Class	Standard Share in 2000	DOE/EE-0064 (July, 1995)	1995$/1992$ CCE 1995$	Payback (Years)
Refrig., Refrigerator-Freezer	**100%**			
Compact Refrigerator	13.1%	0.010	0.011	0.9
Top mount refrigerator-freezer	65.4%	0.029	0.032	3.7
Side-by-side refrigerator-freezer	8.3%	0.031	0.034	4.0
Bottom mount refrigerator-freezer	1.2%	0.032	0.035	4.1
Top mount refrigerator-freezer with through the door service	1.2%	0.072	0.078	9.2
Side-by-side refrigerator-freezer with through the door service	10.8%	0.021	0.023	2.6
Freezers	**100%**			
Manual defrost upright freezer	38.6%	0.004	0.004	0.5
Auto defrost upright freezer	12.7%	0.031	0.034	3.9
Manual defrost chest freezer	48.7%	0.022	0.024	2.8

For example, for the most popular class of refrigerator-freezer, the top-freezer automatic defrost with no through-the-door service, the average retail price of a new refrigerator-freezer in 1998 with no change from the current standards was projected to be $559.52, while the price with proposed revised standards was projected to be $623.89. The increase in purchase price is $64.37 (1992$) to achieve annual energy savings of 196 kWh (difference of 680 kWh/yr with existing standards, and 484 kWh/yr with proposed revised standards). The amortized purchase price (using an interest rate of 6% real, and a refrigerator lifetime of 19 years) is 64.37/11.2=$5.77, giving a CCE (1992$) of $5.77/196=$0.029/kWh (1992$). To convert to 1995$, the ratio of Consumer Price Index (CPI) (1995)/CPI(1992) is 1.086, so CCE (1995$)=$0.032/kWh (1995).

This cost of conserved energy can be compared to the cost of supplying energy. According to the Annual Energy Outlook, 1996, the residential electricity price is $0.087 /kWh in 1995, and projected to be $0.086 in 1998.[1]

The Technical Support Document also contains details of the calculation of payback to the consumer. The payback period (PBP) measures the amount of time needed to recover the additional consumer investment in increased efficiency through lower operating costs Continuing the example of the top-mount auto-defrost refrigerator-freezer with no through-the-door services the increase in purchase price is $64.37 (1992$). The average annual operating cost at $0.088/kWh (1992$) is $59.86 with existing standards, and $42.62 with proposed revised standards, or a savings of $17-24 per annum. The payback period is the ratio of the increase in purchase price to the decrease in annual operating cost, $64.37/$17.24=3.7 years. The Table above shows payback from proposed standards for each class of refrigerators, refrigerator-freezers, and freezers in the right most column.

SUCCESS STORIES: THE ENERGY MISSION IN THE MARKETPLACE

Q32. The following "success story" appears on pages 175 and 176 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Fluorescent Lamp Electronic Ballasts**
>
> **Department of Energy research and development created the current state-of-the-art electronic fluorescent lighting ballast, which was unknown in the mid-1970s. The electronic ballast not only improved lighting quality, but has saved consumers $750 million in consumer energy bills from a $3 million research and development investment. This new industry's sales totaled $275 million in 1992, accounting for 25 percent of total ballast sales. Electronic ballasts are expected to replace magnetic ballasts in at least 75 percent of applications by 2015."**

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[1]U.S. Department of Energy, Energy Information Administration. Annual Energy Outlook. 1996, Washington, D.C., DOE/EIA-0383 (96), January, 1996. (p.78). (Convert residential electricity price from dollars per million Btu to dollars per kilowatt-hour by multiplying by 0.003412 million Btu per kWh. Convert from 1994$ to 1995$ by multiplying by CPI(1995)/CPI(1994)=152.4/148.2 =1.028.)

Q32a. Please detail, by appropriate fiscal year, the $3 million DOE R&D investment in this technology, including a listing of the recipients of this funding.

A32a. Approximately $500,000 was spent in the form of contracts to two small companies (Stevens Electronics and Iota Engineering (which became Excel, then EETech, then. finally EBT, which is today a major manufacturer of electronic ballasts)) over the fiscal years FY77-FY82. These included initial subcontracts to produce a small number of prototype electronic ballasts, as well as follow-on subcontracts to produce approximately 700 ballasts for installation at the Pacific Gas & Electric Co. building demonstration site in 1977. From FY 1976-1984 DOE funded researchers at LBL of approximately $2 million to support industry R&D by establishing early demonstration sites for electronic ballasts, conducting laboratory testing of prototypes produced under subcontract (as well as prototypes by other manufacturers not under subcontract, for example Triad Utrad) and developing specifications for electronic ballasts. The $2 million figure includes LBL costs to manage the first electronic ballast demonstration site at PG&E (1977-1979) and disseminate the results as well as providing technical assistance to the ballast industry in the development of standards for electronic ballasts (primarily through ANSI technical committee). This figure also includes DOE/LBL co-funding of an electronic ballast demonstration at the Veteran's Administration hospital in Long Beach California where approximately 400 dimming electronic ballasts were installed in 1979. As a result of the demonstration, the hospital became the first federal facility to specify the use of electronic ballasts.

Q32b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A32b. It is extremely difficult to estimate since manufacturer investment data is jealously guarded as confidential. To estimate this value, we note that there were approximately 12 small ballast manufacturers, other than Iota and Stevens, that began to manufacture electronic ballasts starting in 1977. If each of these 12 companies invested only $100,000 annually over the five years from 1980-1984 (a very conservative number), the total industry investment would be $6 million (12 companies x $100,000/yr x 5 yrs=$6 million). This provides a lower bound on the private sector investment in technology for the five year period 1980-1984. The actual investment was probably much larger.

Q32c. Please provide detailed documentation of the $750 million in consumer savings.

A32c. Detailed documentation of the $750 million in savings is provided in the table below. GAO has audited this success story and notes that the $750 million is gross savings; that the analysis by which it was derived did not consider the additional cost of electronic ballasts ($8 each); and that when this premium is considered, consumers spent $52 million more for ballasts than they saved in electricity during the period examined. Despite this, GAO recognizes the value of this technology. It states: "Yet, over a longer period, ... electronic ballasts still save money. Carried over several years, the value of the energy savings will offset the higher initial costs of the electronic ballasts. According to DOE's analysis, this net savings will total $1.3 billion by 2000."

The ballasts have a payback time of 2.7 years, and a service life of 12 years, so of course in the early years (the DOE claim ended in 1995), consumers will see a negative cash flow. But the life-cycle saving is $17 per ballast. By April 1995, about 100 million electronic ballasts were purchased and in place, saving electricity for the next 12 years. During their service lives their net saving will thus be about $1.7 billion. [The $17 life-cycle saving is calculated as follows: $25 from electricity savings (discounted at 6% real interest rate) less the $8 cost premium.]

Estimated Consumer Energy Savings–Fluorescent Lamp Electronic Ballasts

YEAR	1988	1989	1990	1991	1992	1993	1994	1995
Magnetic Ballasts Shipped (1,000s)	74,609	76,285	78,363	80,386	83,710	82,730	76,184	69,246
Total Ballast Market (1,000s)	75,673	77,711	81,364	88,729	96,860	107,130	110,344	113,654
Electronic Ballast Market Share	1%	2%	4%	9%	14%	23%	31%	39%
Total Stock of Electronic Ballasts (1,000s) [assumes 12-year life/retirement	1,064	2,490	5,491	13,834	26,984	51,384	85,544	129,952
Electronic Ballasts Replacing Original Magnetic Ballasts (1000s)	1,064	2,490	2,490	2,490	2,490	2,490	2,490	2,490
Electronic Ballasts Replacing Efficient Magnetic Ballasts Shown (1000s)	0	0	3,001	11,344	24,494	48,894	83,054	127,462
Electricity Savings for Stock in Year (GWh)	112	261	387	738	1,290	2,315	3,750	5,615
Value of Electricity Savings in Year Shown ($1993 million)	8	18	27	52	90	162	262	393

Engineering Assumptions
Annual operating hours: 3500 hours
Assume ballast powers: Two 32 watt lamps

Cumulative Savings (1988-1995) --> 1,012
Cumulative Savings as of April 1995 --> 749

("Success Stories" was published on May 22, 1995. Interpolating the annual data to find the estimated savings through the end of April 1995 yields the $750 million figure.)

Annual Energy Savings vs Base Case

Basecase for years 1988-1989	90 watts	105 kWh
Basecase for 1990-1995	72 watts	42 kWh
Electronic ballast	60 watts	0

Note: 1 GWh = 1 billion watt-hours=1 million kilowatt-hours

Q32d. Does DOE hold the patents for this technology, and if not, why not?

A32d. DOE does not hold the patents for this invention. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor further this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

There were many patents issued in the early 1970's for electronic ballasts, particularly by Lutron, which produced an expensive ballast that lost money and was discontinued. In an article written by Gene Foley, researcher at the Alliance to Save Energy, called "High Frequency Electronic Ballasts," he shows that it took a 3-way collaboration of industry, government, and utilities to commercialize electronic ballasts

Q32e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A32e. See answer to sub-question (d). Licensing agreements are typically entered into by firms negotiating with the patent hold, which is usually the contractor, not DOE. See Appendix A for details on applicable Federal statutes. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q32f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A32f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes. DOE can list the fees it has received.

Q32g. Please provide evidence that the electronic fluorescent lighting ballast <u>would not</u> have been developed and commercialized without the DOE funding.

A32g. The electronic ballast would probably have been eventually commercialized by the ballast industry, but market introduction might have been delayed. As noted in part (b) above, there were 10 other companies starting to manufacture electronic ballasts about the same time as the two companies DOE funded. It is not clear whether major ballast manufacturers would have been interested in the technology without DOE's investment, however.

We note that Universal (a large ballast company) acquired Stevens Luminoptics in 1981 with the intent of commercializing the electronic ballast technology. DOE's funding of Stevens certainly contributed to Universal's interest.

Q33. The following "success story" appears on page 176 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Advanced Energy Efficient Windows**
>
> **A 20-year Department of Energy research and development partnership with industry culminated in the development at Lawrence Berkeley Laboratory of an advanced energy-efficient window that uses low-emissivity coatings to block heat gain or loss. No U.S. manufacturer had invested in this technology before the Department's R&D investment. Cumulative consumer energy savings attributable to using low-emissivity windows are $1.8 billion. This enormous savings was leveraged and catalyzed by a Department of Energy investment of just $3 million through the early 1980s. The Department teamed with five window manufacturers (Andersen, Cardinal IG, Owens-Corning Fiberglass, Pella, and Southwall Technologies) and the Bonneville Power Administration to convert the concept into commercial prototypes. Today, every major glass and window manufacturer offers low-emissivity products. Their market share is one-third of all residential windows."**

Q33a. Please detail, by appropriate fiscal year, the $3 million DOE R&D investment in this technology, including a listing of the recipients of this funding.

A33a. Approximately $1 million was invested in R&D efforts of two small companies over the period FY 1976 to 1979: Suntek Incorporated (since renamed "Southwall"), Corte Madera, CA, received $700,000 between FY 1976 and FY 1979; and Kinetic Coatings Incorporated, Burlington, MA, received $300,000 between FY 1977 and FY 1979.

From FY 1976-1982, DOE provided approximately $2 million to Lawrence Berkeley National Laboratory (LBL) to support industry's low-E R&D efforts with thin film testing, field testing of low-E prototypes, annual energy simulations of low-E, and initial development of the WINDOW computer tool. LBL also served as technical managers for the contracting to Suntek and Kenetic Coatings.

Q33b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A33b. Private sector investment is very difficult to estimate since this type of information is generally considered as confidential by industry. Southwall (formerly Suntek) initially raised more than $10 million in venture capital in the early 1980's after successfully demonstrating the potential for low-E technology. These funds were used to complete product development, perform engineering design of the equipment required to produce low-E coatings, and set up the initial production facility. Kinetic Coatings was not successful in obtaining follow-on funding.

The success of Southwall in producing and marketing low-E technology subsequently stimulated other companies to make even larger investments over time to provide competitive low-E window products. The industry appears to have made a $150 million investment in low-E production capability over the last 15 years, based on the following assessment. Current low-E production is about 300 million sq. ft. per year, which is the output of about 10 sputtering machines at 20 million sq. ft./machine and five-on-line coaters at 20-50 million sq. ft. Each sputtering machine or on-line coater represents a direct manufacturing investment of about $10 million, or a total of about $150 million.

In addition, substantial R&D investments were made by industry to bring low-E technology to high-rate, cost-effective production. This investment is estimated at approximately 10 percent of the production investment, or $15 million. Additional investment was made by glass producers in testing and marketing the coatings, and by the window manufacturers who had to make R&D and marketing investments in the transition from use of standard insulating glass to low-E insulating glass.

Q33c. Please provide detailed documentation of the $1.8 billion in cumulative consumer savings.

A33c. Cumulative consumer energy savings was developed by combining industry sales information with computer simulations of energy savings per unit of flow-E glazing installed in residential and commercial buildings. Glazing industry market sources were used to establish yearly sales of low-E glazing (in billion square feet) for the time period of 1984 to 1995. Computer simulations were used to estimate the annual energy savings per square foot of window, for several different climates and then averaged over climates, and account for HVAC system efficiency and fuel/electricity costs. The computer simulations were validated by comparison to results from outdoor test cells and measurements in buildings. The table below provides the specific calculations supporting the development of the $1.8 billion of cumulative savings estimate.

Estimated Consumer Energy Savings–Low Emissivity Window Coatings

YEAR	RESIDENTIAL SALES (BILLION SQ. FT.)	COMMERCIAL SALES (BILLION SQ. FT.)	RESIDENTIAL SAVINGS/ YEAR ($/SQ. FT.)	COMMERCIAL SAVINGS/ YEAR ($/SQ. FT.)	ANNUAL SAVINGS BY VINTAGE ($ BILLION)	SAVINGS BY STOCK IN A GIVEN YEAR ($ BILLION)
1985	0.006	0.001	0.200	0.410	0.002	0.002
1986	0.059	0.012	0.200	0.400	0.017	0.018
1987	0.120	0.024	0.190	0.390	0.032	0.050
1988	0.170	0.034	0.190	0.380	0.045	0.096
1989	0.180	0.036	0.180	0.360	0.045	0.141
1990	0.160	0.032	0.180	0.350	0.040	0.181
1991	0.170	0.034	0.170	0.340	0.040	0.221
1992	0.190	0.038	0.170	0.330	0.045	0.266
1993	0.210	0.042	0.160	0.320	0.047	0.313
1994	0.230	0.046	0.152	0.282	0.048	0.361
1995	0.230	0.046	0.154	0.284	0.048	0.410
Total	1.725	0.345			0.409	2.059

Cumulative Savings (1988-1995) --> $2.1 Billion

Cumulative Savings as of April 1995 --> 1.8 Billion

("Success Stories" was published on May 22, 1995. Interpolating the annual data to find the estimated savings through the end of April 1995 yields the $1.8 billion figure.)

GAO has audited this success story and has noted that the material presented above "does not consider the added cost of these windows. According to industry analysis, low-E windows sold in 1985 for $2-3 per sq. ft. more than normal double-glazed windows. These additional retail costs may eventually diminish to <$ 1/sq.ft. Yet, over the period DOE examined, the additional costs exceed the value of the energy saved."

GAO also concludes, "Over a longer period, the added costs of these windows will be offset by the value of the energy savings. However a complete analysis should incorporate the price premium for the windows."

As published in From the Lab to the Marketplace (Lawrence Berkeley Laboratory, March 1995) the net present value of low-E glazing installed through 1993 is $400 million.

Q33d. Does DOE hold the patents for this technology, and if not, why not?

A33d. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q33e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A33e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q33f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A33f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q33g. Please provide evidence that the advanced energy-efficient windows would not have been developed and commercialized without the DOE funding.

A33g. Low-E coating technology would probably have been developed eventually by industry. However, its initial introduction would have been much later and resulting market penetration would have been slower.

Two key events, both directly influenced by DOE investments, moved low-E commercialization forward in the late 1970s and early 1980s:

1) DOE funding directly resulted in the first firm (Suntek, later renamed Southwall) offering low-E windows for sale. The company came to DOE for R&D funds when it was unable to obtain private sector investment for its R&D because it was a small company and its technology was seen as unproved and too risky. After 3 years of federal support for R&D the company was able to raise the venture capital needed to complete production engineering and ultimately to procure its first low-E coating machine.

2) The first major window manufacturer to adopt low-E was Andersen Windows, who utilized low-E coated glass produced by Cardinal IG, a major U.S. glass manufacturer. Both Anderson and Cardinal stated that DOE-funded efforts in the late 1970s and early 1980s were important factors in the critical decisions that led them to make major capital investments in these new coating technologies at that time.

Q34. The following "success story" appears on page 176 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Sulfur Lamp

In October 1994, the Department of Energy and a small Maryland company, Fusion Lighting Inc., unveiled the sulfur lamp, or S-Lamp, a revolutionary new type of light system in which microwaves are used to heat a sulfur core. The S-Lamp is a scientific and technological breakthrough, considerably more efficient than even fluorescent lights, with fewer associated environmental problems. The quality of light is vastly improved, more nearly approximating natural sunlight, and the installation costs are one-sixth that of conventional lighting. At present, the new system is being demonstrated at the Department's Headquarters, where it lights the outdoor entrance to the building, as well as at the Smithsonian Air and Space Museum. Two S-Lamp bulbs have replaced 240 mercury bulbs, providing four times the light

at one-third the cost. Unlike other high efficiency lamps, the Sulfur Lamp uses no mercury and produces 50 percent less ultraviolet light. The United States uses 520 billion kilowatt hours annually for lighting. The S-lamp is expected to have enormous potential commercial and residential applications."

Q34a. Please detail, by appropriate fiscal year, DOE's R&D investment in this technology, including a listing of the recipients of this funding.

A34a. The following table summarizes of DOE's R&D investment in sulfur lamp technology:

DOE SULFUR LAMP FUNDING (*includes capital equipment funds*)
(In Thousands of $)

FISCAL YEAR	DOE FUNDING	RECIPIENT(S)
1992	438	LBL=438
1993	915	LBL=915
1994	1,425	LBL=200 Fusion=1,225
1995	1,416 500 (NICE-3 Grant)	Fusion=1,416 NICE-3: State of Maryland=100 Westinghouse=400
1996	1,450	Fusion=1,150 Westinghouse=300
Total	6,144	LBL=1,553 Fusion=3,791 State of Maryland=100 Westinghouse=700

Q34b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A34b. At its founding in 1992, Fusion Lighting Inc. possessed the unique and valuable technical ability to stimulate light production from small electrodeless bulbs by use of microwaves. This technology was developed over a 15-year period in their parent company, Fusion Systems, although the intended application was to produce intense ultraviolet for industrial processing. This technology had a very high value, estimated to be $17 million, and can be considered as an investment in the sulfur lamp by the private sector even though it is not included in the direct investment estimates given below.

The inventor of the sulfur lamp, Michael Ury, V.P. of Research at Fusion Lighting, has stated on the record that DOE's timely support to their fledgling company together with DOE's initiating and sponsoring the highly publicized first public demonstrations of sulfur lighting in Washington, D.C. enabled Fusion to raise most, if not all, of the private venture investment listed below. Due to the confidential nature of these private sector investments, we are only able to provide this information in the form of aggregated estimates. This information is drawn from a number of talks with industry involved in sulfur lamp and application development.

Private venture capital funds to Fusion	($ Thousand)
1992 to 1995	$6,000
Foreign investment in lamp R&D:	greater than $1,000
Foreign investment in electronics and fixtures	$1,500
US industry support for fixture development:	greater than $2,000
Investment by US Postal Service and Air Force in sulfur lamp demonstrations in 1996	$950
TOTAL	greater than $11,450

Q34c. Does DOE hold the patents for this technology, and if not, why not?

A34c. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

The basic sulfur lamp was invented and patented by Fusion Lighting of Rockville, MD without government support and they hold the primary patents. LBL has applied for a patent on work it has done to develop a means for operating the lamp electronically at very low powers and low frequencies.

Q34d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A34d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q34e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A34e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q34f. Please provide evidence that the sulfur lamp would not have been developed and commercialized without the DOE funding.

A34f. The inventor of the sulfur lamp, Michael G. Ury, has stated that without DOE support, Fusion Lighting's efforts to develop their discovery into a commercially viable product would perhaps have failed–or at best, progress on lamp development would have taken longer and been more risky. Given the national importance of conserving lighting energy, which consumes 25% of all electricity used, and given that Fusion Lighting was a very small company with a brand new technology in an industry dominated by a few multinational giants, it was and is entirely appropriate to use some Federal government resources to launch this effort. Mr. Ury stated this in testimony to the US House of Representatives Committee on Science, Subcommittee on Technology and Basic Research, Chairpersons Schiff and Morella, on June 27, 1995. He has also explained that because Fusion was a small start-up company, they did not have the capital resources to maintain an R&D effort long enough to develop a commercial product. To continue development to that point, they would probably have had to sell their proprietary interests to one of several foreign firms that expressed strong interest in acquiring this technology.

Q35. The following "success story" appears on page 176 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Computerized Analytical Tool for Energy Efficient Building Design**
> **Department of Energy research and development has created a powerful analytical software tool, DOE-2, for reducing energy use in buildings. DOE-2 calculates hourly building energy use and cost from information on the building's construction, climate, operation, heating, ventilating, and air-conditioning systems, and utility rate schedule.**
>
> **At least 5 percent of commercial buildings today are designed with DOE-2. Use of the software accounts for $1.9 billion in energy savings for buildings constructed through 1993."**

Q35a. Please detail, by appropriate fiscal year, the DOE R&D investment in this software, including a listing of the recipients of this funding.

A35a. The DOE funding for the DOE-2 building energy simulation program is shown below (in thousands of dollars):

RECIPIENT	FY76-89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	TOTAL
LBNL	10,000	285	340	380	300	550	550	550	12,955

Q35b. Please detail, by appropriate fiscal year, private sector investment in this software.

A35b. The private sector investment in the DOE-2 building energy simulation program is shown below (in thousands of dollars) along with the ratio of private to government funding.

YEAR	PRIVATE SECTOR INVESTMENT IN DOE-2	RATIO OF PRIVATE SECTOR TO GOVERNMENT FUNDING
FY76-89	1,500	15%
FY90	170	60%
FY91	180	53%
FY92	230	61%
FY93	998	333%
FY94	1,125	205%
FY95	1,150	209%
FY96	750	136%
Total	6,103	47%

Q35c. Please provide detailed documentation of the $1.9 billion in energy savings for buildings constructed through 1993.

A35c. The $1.9 billion in energy savings for buildings constructed through 1993 is based on a 1994 survey of users of the DOE-2 building energy simulation program. The savings estimates are documented on pages 17-20 of *From the Lab to the Marketplace,* January 1995, Lawrence Berkeley Laboratory, Berkeley, California.

In a 1995 survey of users of the DOE-2 building energy simulation program, 105 of 1200 users responded. They were asked how many square feet of new and retrofit buildings they designed with DOE-2 up to 1995 and in the year preceding the survey. They were also asked what percent energy savings they realized by using DOE-2 vs. not performing energy simulations. The total building floor area of new buildings and retrofitted existing buildings in the United States analyzed by the respondents with DOE-2 was 514 million ft^2, with average energy savings of 22%. With average annual energy cost for large commercial buildings of $1.50 /ft-year, extrapolating from the 105 responders to the total DOE-2 user base, and assuming that the calculated energy savings are realized when the buildings are operated, the energy cost savings is (1200/105) * (514 million ft^2) * (\$1.50/ft^2-year) * 0.22 (percent savings) = $1.94 billion/year for the year preceding the survey (1994).

Q35d. Does DOE hold the patents for this software, and if not, why not?

A35d. The current version of DOE2 is copywrited and distributed and sold by Energy Science and Software Technology. Software cannot be patented. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent or other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q35e. If DOE holds the patents for this software, what licensing agreements does DOE have with private sector firms? Which firms?

A35e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q35f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A35f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q35g. Please provide evidence that the software <u>would not</u> have been developed and commercialized without the DOE funding.

A35g. It is possible that, eventually, building energy simulation programs with the complexity and range of capability of DOE-2 would have been developed by the private sector. However, private sector efforts to develop building energy simulation program over the last 20 years have been hampered by what users perceive as inherent bias in the private sector energy simulation programs bias toward a particular energy source, type of equipment, or other limiting factor. None of the private sector developers of building energy simulation programs are perceived by users to be entirely without bias. Only government-funded building energy simulation programs, such as DOE-2, are considered objective and not self-serving. Most, if not all, private sector building energy simulation programs are based on government-funded building energy simulation programs. Further evidence of these statements follows.

In the 1995 survey of users of the DOE-2 building energy simulation program, the reasons respondents gave for selecting DOE-2 over other, public and private sector building energy simulation programs, include: "flexibility, range of modeling options, equipment configurations, and ability to compare complex energy systems", "recognition", "peer acceptance", "accuracy", "best available", "speed", "continuously improving", "industry standard", "international credibility", "other programs considered self-serving", "unbiased", "validated", "client preference", "support", "reliability", "completeness", "hourly", "detailed hourly reports", "whole building", and "parametric run capability". DOE-2 has the largest user base of any public or private sector building energy (developed by the Department of Defense and no longer under development) and TRNSYS (developed by the University of Wisconsin with support from federal agencies), both have fewer than 400 users.

In 1992, the Electric Power Research Institute decided to develop a new building energy simulation program. They first reviewed all the available public and private sector tools, concluding that none of them except the DOE-2 building energy simulation program would meet their needs. They then started a joint effort to develop a new version of DOE-2 with the Department of Energy's Lawrence Berkeley National Laboratory. Since 1992, the Electric Power Research Institute and its member electric utilities have expended approximately $3 million in this development effort. The new version of DOE-2, PowerDOE, will be released in early FY 1997.

6. **The following "success story" appears on pages 176 and 177 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

"High-Efficiency Refrigerator/Freezer Compressor

From 1978 through 1980, the Department of Energy, through Oak Ridge National Laboratory, sponsored a contract with Columbus Products Co. to develop a high-efficiency compressor for household refrigerators. The resulting product achieved a 44-percent improvement over the compressor technology used in refrigerators at the time. The availability of high-efficiency compressors was a major reason that refrigerator energy use dropped from about 1,300 kilowatt-hours per year in 1980 to about 900 kilowatt-hours per year in 1990. Use of the improved compressors pioneered by this research effort has saved consumers at least $6 billion in energy costs from 1980 through 1990."

Q36a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A36a. The profile of DOE funding for this technology is shown below. The recipient was Oak Ridge National Laboratory and the Laboratory's subcontractor was Columbus Products Company of Columbus, Ohio.

FY78 = $112,000
FY79 = $264,000
FY80 = $226,000
FY81 = $225,000
Total = $827,000

Q36b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A36b. During the fiscal years 1978-1981 Columbus Products contributed $276,000 towards the high efficiency compressor R&D program. Private sector co-funding by fiscal year is not available. Additional significant funding investments were made by Columbus Products to incorporate the high-efficiency compressor into their product line. These investments fall outside the scope of the DOE R&D program and are not available.

Q36c. Please provide detailed documentation of the $6 billion savings in energy costs from 1980 through 1990.

A36c. Cumulative Energy Use and Savings Estimates through 1990 (for units introduced from 1980-1990 inclusive) are summarized in Table 1. The computation is as follows:

i. Total energy use without efficiency improvements (1) : 618.75 billion kWh/yr
Energy Costs (3): $52.47 billion

ii. Savings with all refrigerator technology improvements: 146.295 Billion kWh/yr
Energy Cost Savings (3): $12.41 billion

iii. Savings attributable to compressor improvement (2): 73.148.billion kWh/yr
Energy Cost Savings (3): $6.203 billion

(1) Based on a Utility (generation, distribution and transmission) heat rate of 11,500 Btu/kWh. 1 Quad = 10^{15} Btu
(2) Based on compressor energy saving representing 50% of total refrigerator energy savings during this time period (1980-1990).
(3) Energy costs at $0.0848/kWh.

Table 1: High Efficiency Refrigerator Compressor
Savings through 1990 for units produced from 1980-1990

YEAR	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Shipment weighted average energy use (kWh/yr) (1)	1500 (4)	1350 (4)	119[illegible]	1175 (4)	1150	1099	1077	1065	973	960	926	884	
Energy savings (kWh/yr) per unit (2)	Baseline	150	302	325	350	401	423	435	527	540	574	616	
Shipment (millions) (3)	Baseline	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	
Years Installed	Baseline	11	10	9	8	7	6	5	4	3	2	1	
Total energy consumed without improved compressor (Billion kWh)	Baseline	103.125	93.750	84.375	75.000	65.625	56.250	46.875	37.500	28.125	18.750	9.375	618.750
Energy savings due to all technology advances (Billion kWh)	Baseline	10.313	18.875	18.281	17.500	17.544	15.863	13.594	13.175	10.125	7.715	3.850	146.295

(1) "Energy Use Date," Refrigerators, Automatic Defrost, Top Mount Freezer (shipment weighted averages), Association of Home Appliance Manufacturers, August 1992.
(2) Based on 1979 stock average energy consumption of 1500 kWh/yr.
(3) Average annual refrigerator shipments of 6.25 million units was used for 1980-1990.
(4) Estimated.

Q36d. Does DOE hold the patents for this technology, and if not, why not?

A36d. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent or other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q36e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A36e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q36f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A36f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q36g. Please provide evidence that the high-efficiency refrigerator/freezer compressor <u>would not</u> have been developed and commercialized without the DOE funding.

A36g. There is no firm evidence that advanced refrigerator/freezer compressors would not have eventually been developed without DOE funding. However, prior to the issuance of the DOE competitive solicitation for advanced compressor development, there was no energy efficiency-related R&D being carried out by the major U.S. refrigeration system manufacturers. The technology developed by DOE lead to a motor/compressor which was 44% more efficient than the state-of-the-art at that time, and this technology dominated the market until 1990 when efficiency standards and other influences began to propel compressor development forward again.

Q37. The following "success story" appears on page 177 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Flame Retention Head Oil Burner

In the early 1970s, concern with oil supply and price volatility increased interest in improving the efficiency of oil use. The Department of Energy sponsored field testing by the Oil Heat Research and Development Program at Brookhaven National Laboratory, which established the energy conservation benefits of the retention head oil burner. A second Department effort published the findings in a consumer-oriented information booklet. In several years the retention head burner achieved total dominance of the market for new and replacement oil burners. Consumer energy cost savings to date from this innovation total more than $5 billion."

Q37a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A37a. DOE investment is as follows:

YEAR	TOTAL BNL (1)	STATE ENERGY OFFICES, MARKETING, TRAINING, AND ADVERTISING FIRMS (2)
FY77	$372,000	
FY78	258,000	
FY79	511,000	$3,800,000
FY80	250,000	2,600,000
FY81	225,000	800,000
Total	$1,616,000	$7,200,000

(1) Includes: BNL laboratory testing and field evaluation of energy efficiency, reliability and compatibility of flame retention head burners in retrofit of existing furnaces and boilers.
(2) Includes: promotional campaign and oil dealer training to increase the market penetration, and promotional and educational materials for use in the marketing campaign and training effort.

Q37b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A37b. The private sector, burner manufacturers and oil heat dealers, made moderate investments to adopt this technology throughout their product service offerings. No record of these investments is available to DOE.

Q37c. Please provide detailed documentation of the $5 billion savings in consumer energy cost savings.

A37c. See the following table:

Flame Retention Head Oil Burner
Annual Equipment Sales and $ Savings Statistics

Year	Number of FRH Burners Sold	Cumulative Number of FRH Burners Sold	Annual Savings (Quad/yr)	Fuel Price Current Year $/gallon	Cumulative Savings (Quads)	Cumulative $ Billion Units (Current Year $)
1979	100,000	100,000	0.002	0.704	0.002	0.010
1980	200,000	300,000	0.005	0.974	0.007	0.052
1981	300,000	600,000	0.011	1.194	0.018	0.157
1982	464,000	1,064,000	0.019	1.160	0.038	0.313
1983	401,000	1,465,000	0.027	1.078	0.064	0.496
1984	408,000	1,873,000	0.034	1.091	0.099	0.768
1985	429,000	2,302,000	0.042	1.053	0.140	1.056
1986	555,000	2,857,000	0.052	0.836	0.192	1.149
1987	578,000	3,435,000	0.063	0.803	0.255	1.462
1988	491,000	3,926,000	0.071	0.813	0.326	1.895
1989	555,000	4,481,000	0.082	0.900	0.408	2.622
1990	471,000	4,952,000	0.090	1.063	0.498	3.782
1991	427,000	5,379,000	0.098	1.019	0.596	4.338
1992	447,000	5,826,000	0.106	0.934	0.702	4.683
1993	459,000	6,285,000	0.114	0.911	0.816	5.312

Dollar saving based on a typical and conservative savings of 13% in fuel use and a baseline fuel use of 1,000 gallons per year per home. Fuel oil heating value = 140,000 Btu per gallon.

Cumulative Savings Through 1993 = $5.312 Billion = 0.816 Quad = 5.829 Billion Gallons of Fuel Oil

Q37d. Does DOE hold the patents for this technology, and if not, why not?

A37d. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent or other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the

Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q37e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A37e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the, Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q37f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A37f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q37g. Please provide evidence that the flame retention head oil burner <u>would not</u> have been developed and commercialized without the DOE funding.

A37g. The DOE did not invent the flame retention head burner. The DOE's main contribution consisted of eliminating critical market barriers to widespread adoption of the technology. Therefore, it is impossible to accurately predict what would have happened to this technology in the absence of DOE efforts. However, this technology was commercially available in 1970 and languished on the market without achieving any measurable market penetration until DOE's involvement in the late .70's. The fact that the flame retention head burner failed to achieve any measurable market penetration during the 70's is even more remarkable considering that during this time period fuel oil prices increased by 380%. Obviously there were significant market barriers preventing the acceptance of this product and this realization drove DOE's decision to get involved.

The DOE program attacked the technical barriers associated with proving the compatibility, safety, reliability and energy savings in retrofitting the new burner to existing furnaces and boilers. DOE and the States attacked the information and confidence barrier for both the homeowner and oil heat dealers and service personnel. The oil heating industry is extremely conservative and will not adopt any new technology that is not fully proven as safe and effective. Three years after DOE's involvement the retention head flame burner captured 80% of the sales market; after seven years, the penetration was 100%. Lacking a consistent national effort with significant resources, such as DOE's program, it would have taken many years for the retention head burner to achieve significant market penetration.

Q38. **The following "success story" appears on page and 177 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

> **"Flame Quality Indicator**
>
> **The flame quality indicator, developed by the Oil Heat Research and Development Program at Brookhaven National Laboratory, has been called the most significant advance in oil heating technology since the introduction of the flame retention head burner in the 1980s. The flame quality indicator ensures that the burner operates at peak efficiency throughout the year by monitoring the brightness of the oil burner flame and warning the consumer when the burner needs maintenance. From a Department of Energy investment of slightly more than $1 million, this technology potentially can reduce oil use by 290 million gallons per year, which represents $3 billion to consumers over 10 years. Currently, three licensed manufacturers have entered the market. The flame quality indicator received the 1992 R&D Magazine R&D 100 award and the 1993 'Best of What's New' from Popular Science magazine."**

Q38a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A38a. The Flame Quality Indicator (FQI) was developed as part of the Oil Heat Research & Development Program at Brookhaven National Laboratory (BNL). Initially, this project examined some alternative controls options such as direct flue gas carbon monoxide monitoring and zirconium oxide oxygen sensors. However, most of the budget for the Controls Project in FY 8796 has been directed toward the Flame Quality Indicator. The annual funding is summarized below. The recipient was Brookhaven National Laboratory.

DOE R&D Investment in FQI Technology
(In Thousands of $)

FY	87	88	89	90	91	92	93	94	95	96	TOTAL
$	100	120	65	128	120	100	226	246	120	65	1,290

Q38b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A38b. Private sector investment in this technology has included:

- Field tests sponsored by Canada Mortgage and Housing Corporation (CMHC) in Ottawa during the 1989/90 and 1990/91 heating seasons. This field test included initial evaluation of the FQI, zirconium oxide oxygen sensors, and peak-hold stack thermometers. CMHC cost=$75,000.

- Currently, New York State Energy Research and Development Authority (NTSERDA) and Davis Aircraft products are involved in a project to commercialize an advanced form of the FQI. The budget for this project in FY 1995 and FY 1996 was $132,000 each year; 50% from each organization.

- Energy Kinetics and Davis Aircraft Products, FQI licensees, have invested in the FQI commercialization: estimated at $32,000 in FY 95 and $50,000 in FY 96. For Davis Aircraft Products this is in addition to above cooperative projects.

The following table provides a summary of the private sector investment in this technology by fiscal year:

Private Sector Investment in FQI Technology
(In Thousands of $)

FY	90	91	92	93	94	95	96	TOTAL
$	38	37	0	0	0	374	392	841

Q38c. Please provide detailed documentation of the claims that "this technology potentially can reduce oil use by 290 million gallons per year, which represents $3 billion to consumers over 10 years."

A38c. The savings to consumers over a period of 10 years is based on the following computation: 12 million oil-heated homes, each using 607 gallons of fuel oil-per year, gives a total annual usage of 7,284 million gallons per year; a 4% improvement in efficiency, due to the Flame Quality Indicator, would save 291 million gallons per year, or 2.91 billion gallons over a period of a decade; at the current price of $1.05 per gallon, this would provide $3.05 billion in cumulative *potential* savings.

The 12 million estimate of the number of oil-heated homes is based on 1989 Census Bureau data. More current data are now available. The Energy Information Administration's most recent residential energy consumption survey (October 1995) estimates 10.7 million oil-heated households. If we apply the same computations to this estimate of 10.7 million households, we have a total annual usage of 6,495 million gallons of fuel oil per year, and a savings of 260 million gallons per year, or 2.6 billion gallons over a ten year period resulting from the 4% improvement in efficiency. At the current price $1.05 per gallon, potential cumulative reductions in oil expenditures would be $2.73 billion over a decade.

Q38d. Does DOE hold the patents for this technology, and if not, why not?

A38d. DOE owns U.S. Patent No. 5,126,721, relating to this technology.

Q38e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A38e. DOE has licensed Energy Kinetics. Inc. of Lebanon, N. J., and Davis Aircraft products, of Bohemia, NY, for commercial use of U.S. Patent 5,126,721.

Q38f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A38f. DOE has received initial fees of $900.00 from each of the licenses.

Q38g. Please provide evidence that the flame quality indicator <u>would not</u> have been developed and commercialized without the DOE funding.

A38g. The Flame Quality Indicator was invented at BNL under the DOE-funded Oil Heat R&D Program. This concept was very novel as evidenced by: the patent; the R&D 100 Award; and the "Best of What's New" Award from Popular Science Magazine. Strong industry interest in this concept developed only after BNL had completed several design iterations and several years of field tests in actual homes in the real world.

Q39. The following "success story" appears on page 177 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Compact Fluorescent Lamps With Convective Venting**
>
> **Compact fluorescent lamps produce less light and operate at reduced efficiencies at the elevated temperatures often associated with constricted environments (such as within recessed fixtures). A Department of Energy laboratory has received a 1994 Federal Laboratory Consortium Award for Excellence for developing a convective venting method to alleviate this problem. The cooling action produced by the convective venting yields an approximate 18-percent increase in lumen output, while increasing lamp service life from 750 to 10,000 hours. This approach has been adopted by several large fixture manufacturers (Delray Lighting, Lithonia, Kurt Versen, and Prescolite)."**

Q39a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A39a. Lawrence Berkeley Laboratory (LBL) was the recipient of all DOE funding for this research. By fiscal year it is::

FY 1991:	$ 96,000	FY 1994:	$178,000
FY 1992:	$ 98,000	FY 1995:	<u>$121,000</u>
FY 1993:	$123,000	Total 91-95:	$616,000

Q39b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A39b. The private sector has made substantial investment in adopting DOE/LBL convective venting fixture technology. One LBL patent is licensed to a large manufacturer, Lumatech, who has invested in setting up and manufacturing a fixture based on this technology. But ten other fixture manufacturers are employing DOE/LBL developed fixture technology. LBL did this by freely placing this technology in the public domain and publishing several influential articles describing this technology. Additionally, LBL has freely consulted when asked (with no remuneration) with individual fixture companies and has helped them adapt the technology. LBL has not patented and therefore cannot license much of the technology it developed.

Q39c. Does DOE hold the patents for this technology, and if not, why not?

A39c. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent or other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q39d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A39d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q39e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A39e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q39f. **Please provide evidence that the compact fluorescent lamps with convective venting would not have been developed and commercialized without the DOE funding.**

A39f. We do not claimed that convective venting for compact fluorescent fixtures would not have been developed and commercialized without DOE funding. However, the following is indirect evidence that the development and commercialization of convective venting would have been significantly delayed without DOE funding and involvement.

All technical publications describing the various methods of improving the thermal performance of CFL fixtures by convective venting were authored by researchers at LBL. A reference search of the DIALOG Compendex Plus database (using the keywords "convective venting") reveals that all five references were authored by LBL staff.

Numerous companies have acknowledged LBL's role in articulating the advantages of improved thermal management for fluorescent lamps (of which convective venting is a key strategy) and of accelerating the adoption of this strategy into practice. As evidence of this we can cite: a) advertising literature from DelRay, a manufacturer of compact fluorescent fixtures, explicitly acknowledging LBL's role in furthering this technology; and b) testimonial letters from five major manufacturers of compact fluorescent fixtures explicitly acknowledging LBL's contributions to improving the energy efficiency of compact fluorescent downlights.

Q40. **The following "success story" appears on pages 177 and 178 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

"Softdesk Energy Building Software

A collaboration among the Department of Energy, the University of Oregon, and Softdesk, Inc., resulted in Softdesk Energy, a software building design system that incorporates energy-saving features into computer-based building designs. The program integrates specialized software, computer-aided drafting tools, and commonly used manual tools for energy-use estimation. Used during the design process, the one-of-a-kind system provides quick feedback on a building's future energy consumption. The system also determines energy use impacts from internal factors such as lighting, temperature, humidity, ventilation, and building use. Softdesk Energy requires minimal input from the architect, which significantly reduces design time and costs and encourages the exploration of energy-efficient building designs. The system is designed and equipped to incorporate other energy design tools such as code and standards compliance, lighting design tools, detailed energy analysis packages, and heating, ventilation, and

air-conditioning equipment selection tools. Of 167,000 computer-aided building design users, 100,000 (60 percent) are Softdesk users."

Q40a. Please detail, by appropriate fiscal year, the DOE R&D investment in this software, including a listing of the recipients of this funding.

A40a. The DOE funding for the Softdesk Energy program is shown below (in thousands of dollars):

Recipient	FY91	FY92	FY93	FY94	FY95	FY96	Total
Pacific Northwest National Laboratory	0	80	75	260	400	250	1,065
University of Oregon	75	100	150	140	100	100	590

Q40b. Please detail, by appropriate fiscal year, private sector investment in this software.

A40b. The private sector investment in the Softdesk Energy program is shown below (in thousands of dollars) along with ratio of private to government funding.

Recipient	FY91	FY92	FY93	FY94	FY95	FY96	Total
Private Sector Funding			100	150	350	700	1,300
Private Sector Funding to Government Funding			44%	38%	70%	200%	79%

Q40c. Does DOE hold the patents for this software, and if not, why not?

A40c. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

The Softdesk Energy program was developed under a Cooperative Research and Development Agreement (CRADA) among Pacific Northwest National Laboratory (PNNL), University of Oregon (UO), and Softdesk, Inc. The Trane Company joined the CRADA in November 1995. Under the CRADA, the Softdesk Energy program was developed jointly by PNNL, UO, and Softdesk. Softdesk promotes, markets, and distributes Softdesk Energy at no cost to the government or to users. Softdesk Energy is distributed and supported at no cost to users of Aptitude and Softdesk Energy's AutoArchitect programs.

Q40d. If DOE holds the patents for this software, what licensing agreements does DOE have with private sector firms? Which firms?

A40d. See answer to sub-question (c) Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In the cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q40e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A40e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authority to the government to require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q40f. Please provide evidence that this software would not have been developed and commercialized without the DOE funding.

A40f. The objectives of the R&D effort behind the Softdesk Energy program were to provide the broader architectural design community with easy access to the DOE's energy tools and to lower the cost of considering energy efficiency in the whole building design process. Our private sector CRADA partners, Softdesk and The Trane Company, had not pursued development of energy tools integrated within a computer-aided design environment because they did not have the in-house staff expertise, without partners the risk was deemed too high, and relative to other R&D efforts, the priority was low due to perceived low return on investment. From its initial release in June 1995 through December 1995, more than 2,000 copies of the Softdesk Energy program had been distributed by Softdesk.

Q41. The following "success story" appears on page 178 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Appliance Efficiency Standards**
>
> **The Department of Energy is required by law to set energy-efficiency standards for a number of appliances, including refrigerators and freezers, stoves and ovens, dishwashers, water heaters, and heating and cooling equipment. The Department updates the standards to ensure that models coming onto the market incorporate the best available efficiency technologies. These standards have already saved U.S. consumers nearly $2 billion on their energy bills. Consumers save $2.50 on energy bills for every extra $1 paid to purchase appliances meeting the efficiency standards."**

Q41a. Please provide detailed documentation, by appliance, of the nearly $2 billion savings in consumer energy cost savings.

A41a. The calculation of energy savings was based upon comparing the results of two scenarios from the Lawrence Berkeley Laboratory (LBL) Residential Energy Model. The first (hypothetical) scenario assumed no efficiency standards. and projected U.S. residential energy expenditures, including electricity, natural gas, heating oil, and LPG, (utilizing the most current fuel prices from the Energy Information Administration). The second scenario added efficiency standards (as set by the National Appliance Energy Conservation Act (NAECA)), which eliminate some less energy efficient options from the set of appliance designs available for purchase. The Table below shows results by appliance from the analysis, conducted in June, 1994. These numbers include only standards set by NAECA and do not reflect savings which will result from two updated standards, one on refrigerator products which became effective in 1993 and one on clothes washers, dryers, and dishwashers, which became effective in 1994. Also, many of the NAECA standards became effective in 1990 and savings from them will increase through the years as the appliance stock turns over.

ENERGY COST SAVINGS FROM APPLIANCE STANDARDS

(In Billions of 1990$)

(Source: LBL Residential Energy Model, June, 1994)

	NAECA 1990-93 Fuel Cost	PreNAECA 1990-93 Fuel Cost	Energy Savings (=PreNAECA -NAECA)
Space Heating			
Electricity	41.08	41.08	0.00
Gas	63.65	63.67	0.01
Oil	28.91	28.92	0.01
Total			0.02
Air Conditioning	37.21	37.48	0.28
Water Heating			
Electricity	48.51	48.71	0.20
Gas	34.56	34.95	0.40
Oil	3.77	3.84	0.07
Total			0.66
Refrigerator	40.92	41.25	0.33
Freezer	11.49	11.59	0.10
Dryer			
Electricity	14.92	14.98	0.06
Gas	1.33	1.33	0.00
Total			0.06
Dishwasher	2.32	2.34	0.03
Washer	2.57	2.68	0.11
Total			1.59 (Billion 1990$) (1)

(1) To convert to 1995$, Consumer Price Index (CPI)(1995)/CPI(1990)=1.166. Total = 1.85 (Billion 1995$)

Q41b. Also, please provide detailed documentation, by appliance, that "[c]onsumers save $2.50 on energy bills for every $1 paid to purchase appliances meeting the efficiency standards".

A41b. The ratio of projected savings on energy bills to increased cost of appliances is based upon the net present value of energy savings (discounted to the present, and summed over the life of the appliance) divided by increased purchase price. The table below shows results for each rulemaking. For NAECA standards plus updates of the standards, the ratio is 2.59 to 1. For the standards set in the Energy Policy Act (EPAct) and proposed rules under NAECA, the ratio is higher.

NET PRESENT VALUE (NPV), and NPV as Benefits and Costs
(Values in Billions of 1990$)
(Source: LBL Residential Energy Model, June, 1994)

Standard	NPV =	Benefit	Cost	Benefit/Cost
Forecast to 2015				
NAECA '87	40.0	69.0	29.0	2.38
NAECA '88 (Ballasts)	7.6	10.3	2.7	3.81
Refrigerator/ Freezer update '89	10.5	15.5	5.0	3.10
"Clean Three" update '91	2.5	4.0	1.5	2.67
Totals to 2015	60.6	98.8	38.2	2.59
Forecast to 2015				
EPAct '92 (lamps only)	56.0	73.0	17.0	4.29
EPAct '92 (all other)	16.0	21.0	5.0	4.20
Subtotal	72.0	94.0	22.0	4.27
8 Product Notice of Proposed Rulemaking (1)	66.5	98.7	32.2	3.07
Refrigerator/ Freezer proposed standards for '98	8.2	11.6	3.4	3.41
Totals to 2030	146.7	204.3	57.6	3.55

Sources: All figures are taken or derived from DOE Technical Support Documents, EXCEPT for figures on "NAECA '88 (ballasts)," and "EPAct '92 (all other)," which were provided by Howard Geller, American Council for an Energy-Efficient Economy.

(1) As proposed in March 1994 for room air conditioners, water heaters, direct heating equipment, mobile home furnaces, kitchen ranges and ovens, pool heaters, fluorescent lamp ballasts, and television sets.

Q42. The following "success story" appears on page 178 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Ceramic Regenerator Matrix/Catalytic Exhaust Converters for Automobiles and Heavy-Duty Engines**
>
> **The Department of Energy research and development in ceramic turbine and materials programs is spawning an entirely new industry with many spinoff components. As an example, the Department's ceramic regenerator development work provided the technological 'roots' for a catalytic converter that is now commonly used to reduce automotive emissions. Current sales of such ceramic components for automobiles are $600 million per year worldwide and are expanding. Other component sales are projected at $1 billion and 10,000 jobs for the year 2000. Corning Incorporated holds the largest market share."**

Q42a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A42a. During the FY 1972 to FY 1978 time frame, DOE and its predecessor agencies (EPA and ERDA) supported automotive turbine R&D at Chrysler, including the application of the then new Corning ceramic regenerator technology. Approximate funding for regenerator cores was $0.7 million. During fiscal years 1978 to 1980, DOE supported ceramic regenerator durability development with Ford and, by subcontract, with Corning. The government cost share was approximately $1.9 million. The high temperature ceramic regenerator matrix later became the basis for Corning's automotive catalytic converter technology.

Q42b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A42b. The initial development of the ceramic regenerator technology was funded by Corning. Its budget estimates are:

1970 = $ 5 million
1971 = $10 million
1972 = $15 million
I 973 = $10 million
1974 = $5 million

This was somewhat offset by early parts sales to Ford under an Advanced Research Projects Agency (ARPA) contract, and later to Chrysler and Ford, as mentioned above. During fiscal years 1978 to 1980, the ceramic regenerator durability development effort was cost shared by Ford with $1.2 million.

Q42c. Does DOE hold the patents for this technology, and if not, why not?

A42c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q42d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A42d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q42e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A42e. See answers to sub-questions (c) and (d) . Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q42f. Please provide evidence that ceramic regenerator matrix/catalytic exhaust converters for automobiles and heavy-duty engines would not have been developed and commercialized without the DOE funding.

A42f. Dr. J. Paul Day of Corning has indicated that government funded, high-efficiency ceramic regenerator matrix development (parts purchases) made possible an early and quick start, and accelerated success, in its development of effective automotive catalytic converters. At the time, intensive worldwide competition was focused on the catalytic converter to help meet tightening U.S. emission standards.

Q43. The following "success story" appears on page 178 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Silicon Carbide Whisker-Reinforced Ceramics**
>
> **Silicon carbide whisker-reinforced ceramics developed by the Department of Energy have increased machining rates up to 800 percent and have dramatically decreased the frequency of cutting tool replacement. These advantages have allowed the United States to recapture a substantial international market share of the cutting tools industry. This composite material was developed in coordinated Department programs with a 7-year investment of $3.8 million; worldwide sales now exceed $30 million."**

Q43a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A43a. The recipients and DOE investment are provided in the table below:
(In Thousands of $)

Fiscal Year	University of Michigan	ORNL	Southern Illinois University	General Electric	Totals
1984	0	200	0	122	322
1985	0	345	0	130	475
1986	10	355	0	93	458
1987	174	322	20	0	516
1988	192	325	114	0	631
1989	127	360	172	0	659
1990	205	360	110	0	675
Totals	708	2,267	416	345	3,736

Q43b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A43b. Southern Illinois University provided a 39 percent cost share for each of the years shown above; the University of Michigan provided a 15 percent cost share for each of the years shown above.

Q43c. Does DOE hold the patents for this technology, and if not, why not?

A43c. The seven patents for this technology have been waived by DOE to Lockheed Martin Energy Research (LMER) Corporation. LMER, the M&O contractor that operates the Oak Ridge National Laboratory, has licensed the technology to several industrial companies. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for .which the Department's energy R&D was undertaken. Conveying patent and other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q43d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A43d. In the past, LMER signed licensing agreements for this technology with Arco Chemical, Cercom, Inc., Dow Chemical Company, Greenleaf, GTE, Hertel Cutting Technology, Inc., Valenite Corporation, Kennemetal, Inc., and Advanced

Composite Materials Corporation (ACMC). The ACMC license is the only active license.

Q43e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A43e. As indicated above, DOE has no licensing agreements with private sector firms. Royalties paid to LMER have been $1,275,000.

Q43f. Please provide evidence that the silicon carbide whisker-reinforced ceramics would not have been developed and commercialized without the DOE funding.

A43f. This technology is the result of an invention at Oak Ridge National Laboratory with DOE funding. There is no reason to believe that the invention would have occurred without DOE funds since, to our knowledge, no other organizations were working on the technology.

44. The following "success story" appears on pages 178 and 179 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Sintered Silicon Carbide Used as a Seal Face in Automotive Water Pumps**
>
> **The Department of Energy Transportation Materials Technology Program, with the Carborundum Company, has developed an improved sintered silicon carbide (ceramic) seal face for water pumps. These seals are used in 30 percent of new U.S. automobiles–up from 5% in 1993. Shipments will total 10 million seal faces this year for worldwide markets. A Department of Energy investment in mechanical characterization of approximately $500,000 over a 5-year period has resulted in a potential worldwide market for these seals in excess of 65 million units per year."**

Q44a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A44a. The recipients and DOE investment are provided in the table below:

(In Thousands of $)

Fiscal Year	University of Dayton	ORNL	Totals
1987	25	75	100
1988	50	0	50
1989	150	0	150
1990	125	75	200
Totals	350	150	500

Q44b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A44b. The University of Dayton bought equipment worth $400,000 to be used for this work during the FY 1987 to FY 1989 time period.

Q44c. Does DOE hold the patents for this technology, and if not, why not?

A44c. The development of the material composition was carried out by Carborundum. which owns the patent. DOE's role was in testing the material. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from federally-sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statutes to allow the contractor or inventor to retain the rights to any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the contractor or inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q44d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A44d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is Carborundum, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q44e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A44e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is Carborundum, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q44f. Please provide evidence that the sintered silicon carbide used as a seal face in automotive water pumps <u>would not</u> have been developed and commercialized without the DOE funding.

A44f. According to John Coppola, Vice President for Technology at Carborundum, the development required could not have been funded entirely with company funds.

Q45. **The following "success story" appears on page 179 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

> **"AC Electric Drive Train**
>
> **Under a cost-shared contract with the Department of Energy, the Ford Motor Company and General Electric have developed a new electric drive train. This drive train uses one design for a wide range of production vehicles. This new multivehicle design will reduce consumer costs and allow electric vehicles to enter the market sooner. Ford is testing this technology in 105 Ecostar electric vehicles operating around the country. The California laws mandating zero-emission vehicles will result in approximately $70 million in electric vehicle sales in 1998 (the only current solution to the California mandates), growing to $350 million by the year 2003. Should the New England states implement the California mandates, the market will grow to at least $1 billion by 2003."**

Q45a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A45a. The DOE investment in the most recent phase of AC drivetrain development, the Modular Electric Vehicle Program, was:

FY 1990 = $2,318,000
FY 1991 = $2,700,000
FY 1992 = $3,500,000
Total = $8,518,000

The major recipients of this funding were the Ford Motor Company and its subcontractor, General Electric, Inc.

Q45b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A45b. DOE can only provide the estimated data for the matching funds provided by Ford and General Electric at 20 percent cost share (actual expenditures by Ford and General Electric would have occurred later than the corresponding fiscal year). These funds are:

FY 1990 = $517,000
FY 1991 = $613,000
FY 1992 = $813,000
Total = $1,943,000

Q45c. Does DOE hold the patents for this technology, and if not, why not?

A45c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q45d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A45d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q45e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A45e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q45f. Please provide evidence that the AC electric drive train would not have been developed and commercialized without the DOE funding.

A45f. The Department of Energy conducted development work on the AC drivetrain from the early 1980s to 1992. As late as 1989 when the Modular Electric Vehicle Program was planned, there were no industry plans to commercialize the AC drivetrain. The commitments by the three major U.S. automobile makers to develop the AC drivetrain were basically made after 1989. By 1992, as a result of the 1990 California zero emission vehicle mandate, DOE noted that the industry would continue AC drivetrain development on its own, in part due to the results of DOE-supported work, and thus the DOE program was terminated. While each AC drivetrain is different, each incorporates key features from DOE's program, such as the microprocessor control, advanced semiconductor switches, and the use of low cost induction motors. Industry's response, including its recent agreement with California, was facilitated by the technology derived from DOE's program.

Q46. The following "success story" appears on page 179 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Ceramic Material Heat Engine Components

High melting temperatures, hardness, light weight, and other properties of ceramic materials promise to enable energy efficiency, emissions reduction, and durability improvements in automobile and truck engines. The Department has worked with industry to develop processes that have improved the properties and reliability of ceramics. In 1983, ceramic heat engine parts repeatedly broke. Ten years and $109 million of DOE cost-shared research and development has resulted in U.S. industrial ceramic materials that exceed the strength, durability, and reliability requirements for transportation applications. The Department has developed a process, with a U.S. company, to reduce the cost of producing silicon nitride ceramic powder from $30 per pound to slightly more than $10 per pound. The ultimate goal is $6 per pound. Manufacturers are beginning to use this material for a variety of parts in production engines. Allied Signal, for example, is manufacturing ceramic oil pump spacers for use in commercial aircraft, including Boeing, Gulfstream, and Airbus. As another example, more than 15,000 ceramic cotter pins have been sold for aircraft applications."

Q46a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A46a. The recipients and DOE investment are provided in the table below:

(In Thousands of $)

Year	DOE Funding	Participants
1983	2,415	Industry, National Laboratories, and Universities*
1984	4,850	Industry, National Laboratories, and Universities*
1985	5,671	Industry, National Laboratories, and Universities*
1986	8,426	Industry, National Laboratories, and Universities*
1987	12,680	Industry, National Laboratories, and Universities*
1988	13,445	Industry, National Laboratories, and Universities*
1989	14,953	Industry, National Laboratories, and Universities*
1990	14,636	Industry, National Laboratories, and Universities*
1991	14,478	Industry, National Laboratories, and Universities*
1992	14,580	Industry, National Laboratories, and Universities*
1992-1996	1,995	Dow Chemical Company
Totals	108,129	

*This program has involved a broad spectrum of participants through the years, i.e.: Industry: AlliedSignal, Carborundum, Coors Ceramic Company, Dow Chemical Company, Kyocera Industrial Ceramics, Norton.

Federal Laboratories: Argonne National Laboratory, U.S. Army Research Laboratory, NASA-Lewis Research Center, National Institute of Standards and Technology. Oak Ridge National Laboratory.
Universities: University of Dayton Research Institute, North Carolina A&T State University, University of Michigan, Southern Illinois University.

Q46b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A46b. Private sector investment is provided in the table below:

(In Thousands of $)

Year	DOE Funding	Industry Cost-Share
1983	2,415	242
1984	4,850	485
1985	5,671	567
1986	8,426	843
1987	12,680	1,268
1988	13,445	1,345
1989	14,953	1,495
1990	14,636	1,456
1991	14,478	1,672
1992	14,580	1,412
1992-1996	1,995	497 (Dow)
Totals	108,129	11,282

Q46c. Does DOE hold the patents for this technology, and if not, why not?

A46c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. Three patents for gelcasting were waived by DOE to Lockheed Martin Energy Research (LMER) Corporation, the Management and Operating (M&O) contractor at operates Oak Ridge National Laboratory (ORNL). [*Note: Appendix A is at the end of the answers to question 84.*]

Q46d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A46d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is LMER in this case, not DOE. There are three licensing agreements for the gelcasting technology developed under this effort. They are with AlliedSignal Ceramic Components; LTEC, Inc.; and Ceramic Magnetics, Inc. In addition, the "super grip" tensile testing system developed at ORNL was licensed to Instron Corp. for commercial production.

Q46e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A46e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q46f. Please provide evidence that ceramic material heat engine components <u>would not</u> have been developed and commercialized without the DOE funding.

A46f. Dr. Maxine Savitz, Director of AlliedSignal Ceramic Components, testified March 7, 1996. to the House Interior and Related Agencies Subcommittee of the Committee on Appropriations, on behalf of AlliedSignal Incorporated, concerning recent ceramic gas turbine activity at AlliedSignal. There are several pages of testimony with specific details about how important the DOE funding and collaborative efforts between industry, government, and national laboratories-particularly Oak Ridge National Laboratory (ORNL)--has been to significant advances made in ceramic engine design and silicon nitride material and fabrication technology development. Quoting from the testimony:

"AlliedSignal Ceramic Components is currently in production with three silicon nitride aerospace parts: components for air turbine starters, auxiliary power unit oil pumps and, just this month, seal runners for turbofan main engines. The oil pump parts are used on U.S. and foreign commercial aircraft such as the new Boeing 777 and Airbus A330/340; the seal runners are to be installed on engines which power business jets such as Citation, Learjet, Falcon. About 1,500 parts per month are now being manufactured. During the two years the gerotor rings have been in production, cost to manufacture these parts have been reduced 10-fold, yields have increased from 47% to 83%. Quality has been excellent–no parts have been returned–every Airbus has been retrofitted and all Boeing 777s use the ceramic gerotor rings. These and the seals are examples of the achievements of ceramic engineers at AlliedSignal Engines who have participated in the DOE ceramic ATTAP and Ceramic Demonstration project, and are familiar with the design, test, and advantages of ceramics. As a result of knowledge in materials and fabrication experience from the Engine Programs and the ORNL Ceramic Technology

Programs, AlliedSignal Ceramic Components was able to provide these parts in a short time, as an example, 20 days."

Q47. The following "success story" appears on pages 179 and 180 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Nickel Metal Hydride Cells, Modules, and Vehicle Batteries

Nickel metal hydride batteries are one of three midterm batteries being developed by the Department of Energy through the United States Advanced Battery Consortium. This battery technology is approaching all of the consortium's midterm goals, with the exception of cost. The consortium is now concentrating on developing lower cost materials and improved production processes. Given the performance of this technology, General Motors has formed a joint venture with the Ovonic Battery Company. Replacing the lead acid battery in the General Motors Impact car with this nickel metal hydride battery will increase the range of the vehicle from 70 miles to 140 miles between recharges. A conservative market estimate for this battery, as the result of the mandates for zero emission vehicles in California and the Northeastern States, is approximately $350 million in 2003."

Q47a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A47a. The research and development investment by the United States Advanced Battery Consortium (USABC) for nickel metal-hydride technology is as follows:

FY 1993 = $12,596,000
FY 1994 = $16,914,000
FY 1995 = $18,356,000
FY 1996 = $14,094,000 (estimated)

Under the cooperative agreement with USABC, the Department provided 50 percent of this investment. The principal recipients of this funding are the Ovonic Battery Company and SAFR America, the industrial developers. Argonne National Laboratory, Idaho National Engineering Laboratory, and Sandia National Laboratories have all received funding to test and evaluate nickel metal-hydride cells, modules, and batteries for USABC.

Q47b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A47b. Under the USABC cooperative agreement, private sector cost share is 50 percent of the total cost. Actual private sector cost share was higher beginning in FY 1994, since the automotive partners provided vehicles and conducted in-vehicle tests of the nickel metal-hydride batteries, above and beyond research and development done within the cooperative agreement.

Q47c. Does DOE hold the patents for this technology, and if not, why not?

A47c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q47d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A47d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q47e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A47e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q47f. Please provide evidence that nickel metal hydride cells, modules, and vehicle batteries <u>would not</u> have been developed and commercialized without the DOE funding.

A47f. Within the United States, the nickel metal-hydride advanced battery, for automotive applications, was developed by the United States Advanced Battery Consortium. When the Consortium was formed in 1991, the Department and the Congress agreed to provide financial assistance in order to develop advanced batteries for electric vehicles and to establish a domestic advanced battery industry in the United States. Without the Consortium and the Department's financial assistance, there would have been no industry incentive to develop this and other advanced electric vehicle batteries in this time frame. General Motors, Toyota, and Honda have all announced that they will use the nickel metal-hydride battery in their electric vehicles.

Q48. The following "success story" appears on page 180 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Biomass Feedstock Technology**
>
> **Hybrid poplar "supertrees," which are being commercially planted by six major pulp and paper companies in the Pacific Northwest, were developed through Department of Energy investment in research programs for producing biofuels feedstocks. This portion of the Department's Biofuels Feedstock Development Program, focused in the Northwest, has invested approximately $2 million over 17 years to produce genetically superior trees and improved agricultural production techniques. Acreage planted is expected to double from the 25,000 acres planted now to well over 50,000 acres within the next 2 years. Two mills are already using the fiber to produce paper as well as energy for their boilers, and two new nursery companies have emerged to supply high-quality cuttings to private industry and landowners. The Western Washington plantings established along rivers provide habitat to an endangered deer species and other wildlife. Each acre of hybrid poplars planted displaces the need to harvest 10 acres of Douglas Fir for fiber."**

Q48a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A48a. The DOE R&D investment in the development of genetically superior trees and improved cultural techniques for hybrid poplar in the Pacific Northwest was $2.2 million from fiscal years 1978 through 1995. The recipients of this funding, which varied from $ 100.000 to $200,000 per year, were the University of Washington, in Seattle, Washington and Washington State University, Puyallup, Washington. In addition, Crown Zellerbach received $135,000 in FY1986 to maintain ongoing research plots on industry land.

Q48b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A48b. The cost sharing by the University of Washington and Washington State University was $871,000 from fiscal years 1978 through 1995. Industry provided in-kind cost sharing in the form of land and labor to maintain field research plots. The value of the in-kind cost sharing is unknown.

Q48c. Does DOE hold the patents for this technology, and if not, why not?

A48c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q48d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A48d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M& O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q48e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A48e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the (M&O) contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q48f. Please provide evidence that biomass feedstock technology <u>would not</u> have been developed and commercialized without the DOE funding.

A48f. There is no direct evidence, but there is some indication that biomass feedstock technology would not have been developed and commercialized without DOE funding. It is the Department's position that the successful wide-scale use of biomass for liquid fuels production, electric power production, and chemicals will depend on integrated systems of highly productive, cost-effective biomass feedstock technologies and effective biomass conversion technologies. There were indications that the feedstocks would not be available, essentially becoming the "show stopper" for large-scale biomass energy use. In the 1970s, a few companies in the North Central and Southern United States were experimenting with the concept of short rotation woody crops. These experiments were soon abandoned because of difficulties experienced in establishing stands of trees and low yields, resulting in poor economics. The USDA Forest Service eliminated or reduced substantially its funding of woody crop research in the 1980s, but continued to participate in woody crop research only at those Forest Service stations receiving DOE funds. In 1978, when the Department initiated its biomass energy program, it was recognized that feedstock costs could be up to thirty percent of the cost of biomass energy systems, using wood as the feedstock, and that substantial cost reductions could be made by developing technologies specifically designed for energy applications, based on technical and analytical data. The development of genetically improved plants and management practices could overcome some of the shortcomings experienced by the private companies in the South and sector-funded research. During subsequent years, the Department undertook a focused and cost-effective program, using cost sharing and leveraging, to reduce risks and demonstrate the concept. The first commercial plantings occurred in the Pacific Northwest, where DOE-supported research achieved early-success in demonstrating the potential for fast-growing poplar trees. The company was able to make this decision by measuring the performance of the hybrids developed by the University of Washington on company test plots.

The first commercial harvest of the DOE/University of Washington hybrid poplar clones occurred in 1990-91 on James River Company land and, shortly thereafter, several other private companies in the region began commercial plantings using University of Washington plant materials and similar cultural techniques. New nursery companies have been formed to handle demand for high quality plant materials. By reducing the risk factors and demonstrating the concept, industry, with assistance from DOE, is now on the verge of exploiting the potential of the technology for fuels and fiber. Since 1990, twelve additional private sector projects have been initiated in all regions of the United States to test and commercialize short rotation woody crops, especially hybrid poplars. They are obtaining the plant materials from many of the University projects funded by DOE and seeking technical assistance and collaboration from the Department's Oak Ridge National Laboratory technical experts and DOE funded laboratory researchers. These materials and this expertise would not be available without the years of DOE investments in technology advancement.

Q49. The following "success story" appears on page 180 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"DYNA3D Finite Element Analysis Technology

The Department of Energy sponsored research that developed DYNA3D, a dynamic finite element analysis tailored to simulate high energy impacts, such as car crashes or aircraft collisions with birds. DYNA3D is available at near-zero cost to the public and has had a major impact on U.S. industry. It is used by more than 300 U.S. companies, including GE Aircraft Engines, General Motors, Chrysler, the Boeing Company, ALCOA, General Atomics, FMC Corporation, and Lockheed Missiles and Space Company. The technology is used by all U.S. car manufacturers and has sharply reduced the need for

costly vehicle crash testing. An independent study placed the savings to U.S. industry as a result of using the model at $350 million."

Q49a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A49a. Since 1977, the Methods Development Group at Lawrence Livermore National Laboratory (LLNL) has developed DYNA3D as one of the core computational mechanics capabilities. This code is used by 40 to 50 engineering analysts programmatically funded to assist the Laboratory to carry out its mission. Approximate code development effort levels has been as follows:

1977-1979 = 2.0 Full-time Equivalent (FTE) personnel per year
1980-1989 = 1.5 FTE per year
1990-1995 = 1.3 FTE per year

Beginning in 1980, DYNA3D was deposited, at periodic intervals of development, to the DOE Software Center, first at Argonne, and then in recent years to the Energy Science Technology Software Center (ESTSC) at Oak Ridge. DYNA3D was also provided to "collaborators" through "code in development" agreements allowed under DOE Order 1432D and ESTSC guidelines.

Q49b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A49b. No data is available on private sector investment in explicit nonlinear dynamic finite element technology.

Q49c. Please provide detailed documentation of the "savings to U.S. industry as a result of using the model at $350 million."

A49c. [*Note: DOE did not answer this question directly, but did provide some information in the answer to sub-question A49g.*]

Q49d. Does DOE hold the patents for this technology, and if not, why not?

A49d. DOE Software is not patentable.

Q49e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A49e. Since both the University of California (UC) and DOE considered such software in the public domain, only revolutionary new developments would have been copyrighted formally and licensed. No company was willing to pay a license fee for nonexclusive rights, and UC/DOE/LLNL were unwilling to concede anyone exclusive rights to a core technology needed for so many diverse applications; therefore, no royalties have been collected. As an independent value study indicated, royalties are not as important a measure of success as the value of the problems solved.

Q49f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A49f. See answer to sub-question (d).

Q49g. Please provide evidence that DYNA3D finite element analysis technology <u>would not</u> have been developed and commercialized without the DOE funding.

A49g. The code was developed by the Methods Development Group at DOE's Lawrence Livermore National Laboratory. By 1985, the French had developed a similar capability and began to make inroads into the U.S. auto industry (PamCrash by ESI). By 1987, another French company (started by the original ESI technical person) formed Mechalogue and the RADIOSS code. Ford Motor Company has used RADIOSS for many years while developing its code for automotive crash dynamics. In 1988, MacNeal Schwindler Corp. (MSC) acted on an implicit UC/DOE license to commercialize, and inaugurated MSC/DYNA. It is estimated that five or so man years were invested by them in interfacing DYNA to the MSC/NASTRAN suite before MSC acquired the explicit PISCES fluid code, merged it into the evolving MSC/DYNA, and since then has supported DYTRAN, with mixed market success. In 1989, John Hallquist, the original developer of DYNA3D from the Methods Development Group at Livermore, left the Laboratory and started a software service organization (LSTC), offering enhancements to public DYNA-3D. In 1990, as DOE began gradual tightening of access to the government code, Hallquist inaugurated LS-DYNA3D (based on the DOE 1989 version), and has provided an undetermined amount of development, mostly specialized user support to a much broader set of users than supported within the DOE complex. His commercial version is used heavily by General Motors, Chrysler, and other international automakers. Direct linkages can be established between this version and the foundation development work supported by DOE. An independent study. "Survey to Determine the Value of DYNA," by John W. Walter and David Bellshaw, UCRL-ID-112607, Lawrence Livermore National Laboratory, January 1993, placed $250 million of savings from auto industry estimates of crash tests not done because of industry use of explicit crashdynamic simulation with DYNA-like codes. Ford Motor Company uses half of its two Cray C-90 $30M computers for explicit crashdynamic simulation.

Q50. The following "success story" appears on page 180 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> "*Zymomonas Mobilis* Organism
>
> In 1994, research sponsored by the Department of Energy developed a new, genetically engineered organism, *Zymomonas mobilis.* This organism enhances the fermentation of cellulose, increasing the rate of conversion and yields of ethanol for use as fuel. It is estimated that this new technology, which was described in the prestigious journal, *Science*, and widely written about by the Associated Press, has significantly reduced the cost of ethanol from $3.60 per gallon to less than $1.00 per gallon, making ethanol a more competitive alternative fuel."

Q50a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A50a. The DOE R&D investment for genetically-engineered *Zymomonas* was $3.32 million from FY 1993 to FY 1996. Development of the organism to perform beyond the laboratory scale is continuing. Funding and recipient by fiscal year is:

FY 1993 = $502,000; National Renewable Energy Laboratory (NREL)
FY 1994 = $695,000 NREL
FY 1995 = $1,464,000 NREL
FY 1996 to date = $368,000 NREL.

FY 1994-1996: NREL subcontracts to support the development of the organism include $137,000 to the University of Toronto and $154,000 to Ohio State University.

Q50b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A50b. There has been no investment from the private sector in this technology.

Q50c. Please provide detailed documentation of the $1.00 per gallon cost of ethanol.

A50c. The estimated production cost of $1.00 per gallon is the result of a preliminary analysis completed by the Department's National Renewable Energy Laboratory, and is based on laboratory and bench scale data. The analysis looked specifically at the cost advantages of using the recombinant *Z mobilis* in the biomass to ethanol process. The revised process is simpler and less costly, and the overall process yields have been improved as well. Instead of using one organism to ferment the six-carbon sugar glucose and another organism to ferment the five-carbon sugar xylose, the revised process uses this single organism to perform the total job reducing capital cost by eliminating one fermentation reactor and associated equipment and smaller seed reactors required to grow one of the organisms. In addition, operating costs associated with these units are eliminated. Since the recombinant organism generally produces less by-products than other fermentation organisms, more of the sugars are converted to ethanol. The organism can be used most effectively in the conversion of sugars found in crop residues and other waste biomass sources that will be available at or below $10 per ton. The use of these low-cost materials coupled with the performance of the recombinant organism, forms the basis for the estimated costs of $1.00 per gallon.

Q50d. Does DOE hold the patents for this technology, and if not, why not?

A50d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q50e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A50e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q50f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A50f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q50g. Please provide evidence that *Zymomonas mobilis* <u>would not</u> have been developed and commercialized without the DOE funding.

A50g. The development of Z *mobilis* was a targeted breakthrough made possible by DOE funding. It is highly unlikely that this technology would have been developed in the near term without federal funds. Two laboratories had attempted this type of genetic engineering with *Zymomonas*, those being the University of New South Wales, Australia, and Forschungzentrum Julich, Germany, in 1988 and 1992, respectively. Both government-funded research groups were unsuccessful in their experiments and the work was discontinued.

The bacteria had been tested at large scale at both the University of Queensland, Australia, and the University of Toronto, Canada, and it was known its use could permit significant cost savings based upon use of the unimproved *Zymomonas*.

As a part of our effort to pursue research and development for the cost-effective production of ethanol from biomass, we discussed several approaches with industry, including Cargill, New Energy of Indiana, Grain Processing Corporation, and South Point Ethanol. Their response was that an improved *Zymomonas* could be beneficial but that the research was highly risky. and none of the companies contacted had research programs that focused on these activities.

Currently, DOE is continuing to test *Zymomonas* at NREL. This testing is a required step in the further development and commercialization of this biologically altered organism by industry.

Q51. The following "success story" appears on page 180 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Lightweight Materials Technology Development

Reducing vehicle weight through the use of lightweight materials promises to enable major energy efficiency improvements in full-size automobiles without compromising passenger comfort and safety. At the program's inception in 1992, lightweight metals such as aluminum could not compete with steel as the material of choice for automotive manufacturing because of their cost and forming time. After three years and $3 million of Department of Energy cost-shared R&D, advanced forming of aluminum sheets for auto body components achieved weight reductions of 43 percent, parts count reductions of 89 percent, forming time reductions of 77 percent, and cost reductions of 15 percent. Projected cost savings to auto companies are about $60 million per year by 1997."

Q51a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A51a. General Motors received $110,000 in FY 1992 and $390,000 in FY 1993 through a contract managed by the Oak Ridge National Laboratory. Through a Cooperative Research and Development Agreement, the Pacific Northwest National Laboratory received $404,000 in FY 1994; $116,000 in FY 1995; and $375,000 in FY 1996.

Q51b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A51b. The funding shown in sub-question (a) was 50/50 cost shared.

Q51c. Please provide detailed documentation of the "[p]rojected cost savings to auto companies are about $60 million per year by 1997."

A51c. The following calculations were used:

Estimated cost per part = $1,000.
Estimated cost savings as a result of part consolidation = 15% or $150 per part.
Number of parts per vehicle = 4.
Cost saving per vehicle = 4 parts x $150 per part = $600 per vehicle.
Estimated number of vehicles = 100,000.
Estimated total cost saving in first year = 100,000 vehicles x $600 Saving per vehicle = $60 million.

Q51d. Does DOE hold the patents for this technology, and if not, why not?

A51d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q51e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A51e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In those cases where DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q51f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A51f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights. which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant Federal statutes.

Q51g. Please provide evidence that lightweight materials technology development would not have been developed and commercialized without the DOE funding.

A51g. Advanced forming methods for aluminum components have existed for decades; however, the cost of the materials and processing has prevented the automobile manufacturers from using them. DOE funding in this area provided sufficient risk reduction to enable the industry/laboratory team to perform research and develop technologies to make these processes economically viable. In addition, DOE funding accelerated the development of these technologies. An industrial partner has stated, "DOE's cost-shared funding of the industry/government cooperative R&D programs in place helped accelerate the development of technology in advanced materials, such as metal matrix composites, and the fundamental understanding of iron manufacture and recycling."

Q52. The following "success story" appears on page 181 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Catalytic Distillation

The advanced catalytic distillation process developed by the Department of Energy nearly 15 years ago has become a major commercial success. It is used to produce gasoline additives such as methyl-tertiary-butyl-ether and tertiary-amyl-methyl-ether, thus helping U.S. refiners produce the reformulated gasoline mandated by the Clean Air Act Amendments of 1990. As of fiscal year 1994, 80 units were on order at the manufacturer, Chemical Research and Licensing, Inc., 19 units were operating in the United States, and 40 units were operating worldwide–28 percent of the world market. Advanced catalytic distillation saved 3.24 trillion British thermal units of energy in 1993 alone, at a rate of about $10 million per year."

Q52a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A52a. FY1980-FY1984: $1,467 M DOE
Recipients: Chemical Research and Licensing (CR&L)
10100 Bay Area Blvd.
Pasadena, Texas 77507

Q52b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A52b. FY1980-FY1984: $217 M Industry

Q52c. Please provide detailed documentation of the savings of "3.24 trillion British thermal units of energy in 1993 alone, at a rate of about $10 million per year".

A52c. MTBE (methyl tertiary butyl ether) can be made by reacting methanol with isobutylene over an acid resin catalyst. Isobutylene is present as a co-product from refinery Fluid Catalytic Cracking (FCC) units and ethylene plants. Under normal conditions, the reaction cannot proceed to completion because of a reversible reaction that approaches equilibrium.

The practical conversion limit for isobutylene is about 97%. Catalytic distillation relaxes this limit by removing the reaction products while simultaneously catalyzing the reaction. This approach minimizes the effect of the reverse reaction and allows the forward reaction to proceed to greater levels of conversion. Isobutylene conversion greater than 99% can be achieved by applying this technique-this is the basis for the energy savings benefit.

The energy savings calculation employed is as follows:

Barrels of MTBE produced, bbl/day
Barrel size: 259 pounds/barrel
Energy content of MTBE: 500 Btu/lb.

For 1993:

Units Installed in 1993:	23
Total Units Installed to Date:	32
Units Decommissioned:	0
Total Units Decommissioned to Date:	0
Average Size of Commercial Units:	2,234 bbl/day of MTBE

Calculation: (32 Units)(2,234 bbl/day)(350 days/year)(259 pounds/bbl)(500 Btu/pound) = 3.24 trillion Btu/year.

Using Fuel Value at $3/million Btu, $(3.24)(10^{12})(3)(10^{-6})$=$9.7 million, or "about $10 million."

Q52d. Does DOE hold the patents for this technology, and if not, why not?

A52d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q52e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A52e. See answer to sub-question (d). Licensing agreements are typically entered into by firms negotiating with the patent hold, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q52f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A52f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q52g. Please provide evidence that advanced catalytic distillation would not have been developed and commercialized without the DOE funding.

A52g. Chemical Research and Licensing was a 4-person startup company in 1980, with limited resources. The first commercial application of the catalytic distillation was in a Charter Oil refinery in 1981. DOE's role in this commercialization activity was to guarantee the catalyst that was used in the test unit. The first batch of catalyst was "poisoned," and DOE funded the second batch of catalyst, which operated successfully. Without DOE support the development of this new technology would have been terminated following the failure of the first test.

Q53. The following "success story" appears on page 181 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Ultralight Aerogels**
>
> **Scientists sponsored by the Department of Energy at two national laboratories have developed a new material, called aerogel, that has the lowest density, highest porosity, lowest thermal conductivity, and lowest sound propagation of any solid ever made. A 1-inch-thick layer of aerogel replaces 12 inches of fiberglass insulation. This feature is particularly valuable in appliances such as refrigerators and water heaters. While industry interest in better insulation is being explored, the unique properties of aerogel have opened other market opportunities for this emerging technology. Because of their high surface-to-volume ratio, these materials can be used as catalytic and**

adsorbent surfaces and as carbon ultracapacitors. Ultralight aerogels are being taken to the commercial market by Aerojet, a segment of GenCorp."

Q53a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A53a. There are two laboratories that have done work on aerogels, which is made up of a wide variety of material compositions. Lawrence Livermore has worked on organic and carbon aerogels for a number of years; the Office of Industrial Technologies (OIT) did not provide any of that funding. Silica aerogels were investigated at Lawrence Berkeley Laboratory by Dr. Arlon Hunt. This material is important because not only does it have outstanding thermal insulation properties, but it is also stable to 500°C and produces no gaseous emissions on exposure to heat. OIT funding for the Berkeley work was provided as follows:

FY 91	$300,000
FY 92	$320,000
FY 93	$300,000
FY 94	$317,000
FY 95	$100,000
FY 96	$0

OIT has no information about funding levels and sources of funds for Lawrence Livermore.

Both Lawrence Livermore and Lawrence Berkeley were provided funding from Aerojet General, Sacramento, CA, under terms of a Technology Reinvestment Program (TRP) grant from the Advanced Research Projects Agency, Department of Defense. The goal of the project was to commercialize aerogels of several kinds by construction of industrial scale production equipment. Lawrence Livermore received $500,000 in TRP funds and Lawrence Berkeley received $240,000 in FY 95. The total TRP grant was for $1,025 in ARPA funding, with $1,596 total industrial cost share.

Q53b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A53b. Aerojet provided $630,000 in cost share for the entire TRP project in 1994 and 1995, the remaining cost share was provided by the intended customers for the material. These are Aerojet Electronics, Boeing Commercial Aircraft, General Motors Cadillac Division, Benteler Industries, Admiral, and Glacier Bay. There was considerable investment by a small spin-off company, Thermolux in a previous effort to commercialize the silica aerogel, but amounts are not available at present because the knowledgeable parties are in Europe.

Q53c. Does DOE hold the patents for this technology, and if not, why not?

A53c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q53d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A53d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. In cases where DOE does hold the patent licensing is done per 35U.S.C.208 and the regulations issued by the Department of Commerce.

Q53e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A53e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q53f. Please provide evidence that ultralight aerogels <u>would not</u> have been developed and commercialized without the DOE funding.

A53f. In FY 1991, though aerogels were known to have outstanding thermal insulation properties, as well as properties suitable for many other applications, the production of the material was prohibitively expensive for most purposes. Funding to Lawrence Berkeley Laboratory enabled development of the process for extraction of solvents from silica aerogel by supercritical carbon dioxide. This is the key to commercial practicality. Even so, the ARPA funding to Aerojet, the Laboratories, and the other private sector companies was needed for commercial scale production. Without DOE funding for Lawrence Berkeley, the benefits of silica aerogels could never have been realized.

Q54. The following "success story" appears on page 181 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> "Aluminum Remelting Technology
>
> A $400,000 grant from the Department of Energy, through the National Industrial Competitiveness Through Energy, Economics, and Environment program to AAP St. Mary's of Ohio has resulted in a more efficient technology for aluminum remelting. By avoiding the second aluminum chip melt during recycling, real energy savings are 6.36 billion British thermal units annually–6,249 gallons of diesel fuel, and 155,000 gallons of coolant. Additionally, the new technology eliminates 59 tons per year of emissions and 64 tons per year of dross. Dollar savings equal $642,000 annually."

Q54a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A54a. No R&D funds were expended. The project was a demonstration project of new technology. Demonstration funds of $200,000 were expended in FY 1992.

Q54b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A54b. Private sector investment in the technology was $1,037,000 in FY 1992. The State of Ohio also contributed $30,000 to the project in FY 1992.

Q54c. Please provide detailed documentation of the energy savings of "6.36 billion British thermal units annually–6,249 gallons of diesel fuel, and 155,000 gallons of coolant", as well as elimination of "59 tons per year of emissions and 64 tons per year of dross" and "[d]ollar savings equal $642,000 annually."

A54c. The energy savings accrue from recycling aluminum and avoiding one melt. Prior to this project, the AAP St. Mary plant was shipping the aluminum-cutting scrap to a recycling plant near Cleveland, Ohio where it was remelted into ingot. The round trip was 600 miles. The improved process, uses an on-site melting, with a recovery of coolant oil using a centrifuge, and a submerged feed to the melting furnace which reduces dross generation and improves recovery of aluminum.

- The BTU savings are from saving the heat of melting at about 1000 BTU/lb of aluminum for 300 tons per month. The actual numbers currently are 350 tons per month yielding more than the quoted 6.36 billion British thermal units annually.

- The reduced diesel savings of 6,249 gallons are from elimination of the trucking of the aluminum tonnages to and from the remote remelting site 600 miles per round trip.

- The coolant savings are from a centrifuge unit installed to recover the cooling/cutting oils used in turning down the rough forging to make the finished aluminum wheel. The cooling/cutting oils are reused in the process.

- Prior to this process the oil was flared off in the melting process, accounting for the 59 tons of emission savings, part of it due to power plant emissions and part of it due to reduction of the volatile organic compound emissions and particulates associated with the burning of coolant oils.

- A submerged feed system for the aluminum chips was used to reduce the dross formation in the melter. 64 tons of dross was eliminated annually, and the yield of aluminum to recycle was correspondingly improved.

- Dollar savings of the above steps account for $624,000 annually.

Actual savings:
Annual material cost savings = $89,000
Annual process savings=$315,000
Annual coolant cost savings=$236,000
Annual Total=$640,000

In addition to the above benefits, better quality control of the process and reduced potential of liability from catastrophic failure of an aluminum wheel rim was achieved by not having to revalidate the alloy used in the wheels. When the alloy comes from a remelting facility, other alloys have gone into the mix, and the alloy has to be remixed to assure that the wheel will have the required strength. When only AAP St. Mary's aluminum scrap is used all the alloy is correct, and does not require a reformulation.

Q54d. Does DOE hold the patents for this technology, and if not, why not?

A54d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q54e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A54e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q54f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A54f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q54g. Please provide evidence that aluminum remelt technology <u>would not</u> have been developed and commercialized without the DOE funding.

A54g. We are unable to prove a negative, and it is possible that the technology would eventually have been developed, at St. Mary's or elsewhere. However, it would have been at least a year or two later. Remelting on this intermediate scale is found in other plants such as in the fabrication of aluminum pans. The incentives to be the first to implement a new technology are small and plants generally seek to not be the first to take a risk. " Everyone wants to be the first to be second" is a saying in industry. The competition for capital money in industry is very keen. The Federal Government being willing to partially fund a project is sometimes what it takes to make the project sufficiently attractive to undertake, instead of other uses for the money.

Q55. The following "success story" appears on page 181 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Vacuum Pressure Swing Adsorption**
>
> **By eliminating the nitrogen from air in glassmaking furnaces burning gas or oil, vacuum pressure swing adsorption technology has reduced furnace emissions of nitrogen oxides by 90 percent and particulates by 25 percent. Furnace energy requirements are reduced by 25 percent. Three companies, Praxair, Inc., (Tarrytown, N.Y.), Corning, Inc., (Corning, N.Y.), and Gallo Glass Company (Modesto, California) have commercialized this energy-efficient technology. Approximately 15**

percent of all glass made in the United States now employs this technology."

Q55a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A55a. Some background is essential before addressing the questions asked. Oxy-fuel combustion was demonstrated as part of an OIT project entitled "Oxygen Enriched Combustion Performance Study." The project was designed to assess the technical and economic feasibility of oxygen-enhanced combustion applied to large, commercial scale glass furnaces. The work involved: a) a technical and economic assessment, b) a market assessment, and c) laboratory testing followed by a full-scale testing of oxygen enhanced combustion using nearly pure, industrial oxygen. This is termed "oxy-fuel firing."

Separately, Praxair developed the Vacuum Pressure Swing Adsorption (VPSA) system for separating oxygen from air. No government funding was involved in VPSA development. VPSA technology is patented by Praxair.

The "success story" commingles two distinct systems: (1) oxy-fuel firing, and (2) the means to separate oxygen from the air. There are a number of ways to separate oxygen from air: cryogenic, pressure swing adsorption (PSA), and vacuum pressure swing adsorption. The first two are older, established technologies. An industrial-scale VPSA system became available during the course of the DOE project. VPSA is similar to PSA but has a lower operating cost because it is more energy efficient. It was ready for a full-scale test at the time of the oxy-fuel glass melter demonstration and was used for part of that demonstration. Cryogenically-produced oxygen was used for the remainder of the demo. VPSA is the economically preferred choice for 90% of the glass melters in the U.S. Both the VPSA and oxy-fuel firing were demonstrated during the DOE test. The former representing the oxygen source, the latter the oxygen use.

Q55b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A55b.

FY	DOE	Praxair
1988	$869,000	$343,031
1989	$166,460	$65,709
Total	$1,035,460	$408,740

All DOE funding was provided to Praxair.

Q55c. Does DOE hold the patents for this technology, and if not, why not?

A55c. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

VPSA was developed independently of the DOE project and is patented by Praxair. As a study/demonstration project, no new discoveries were made on the DOE project. Oxy-fuel firing is itself not patentable. Oxy-fuel burners have been developed and patented by a number of companies. Oxy-fuel systems are marketed by a number of companies.

Q55d. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A55d. See answer to sub-question (c). Licensing agreements, if any, are typically entered into by firms negotiating with the patent hold which is usually the management and operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q55e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A55e. See answers to sub-questions (c) and (d). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property, rights which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q55f. Please provide evidence that vacuum pressure swing adsorption technology <u>would not</u> have been developed and commercialized without the DOE funding.

A55f. Production oriented, operating businesses require data from a true-to-life demonstration before they can make a technical and economic choice, such as the decision to use oxy-fuel combustion. It is a case of "everyone wants to be second, but no one wants to be first." By sponsoring this demonstration, DOE has eliminated much of the technical risk to the glass manufacturer. Before the DOE demonstration there were no large-size glass furnaces using oxy-fuel. Subsequent to the DOE demonstration there has been a rapid expansion of this technology in the glass market.

Q55g. Praxair developed a technology. Did they patent additional technology coming out of the DOE work?

A55g. No additional technology resulted from the DOE project which involved only demonstration and testing. VPSA development was funded entirely by Praxair. No federal funds were used. (See A55c, paragraph 2.)

Q56. The following "success story" appears on page 182 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Electrochemical Dezincing of Steel Scrap

Department of Energy scientists have developed an electrochemical method of removing the galvanized coatings from steel scrap that would allow 10 million tons of this valuable resource to be used in steelmaking furnaces. This process would increase production yields and quality as well as decrease environmental problems and cost. By the year 2000, electrochemical dezincing could save 50 trillion British thermal units of energy, reduce raw material costs by at least $160 million per year, and reduce the need to import at least 75,000 tons per year of zinc, saving at least $77 million annually."

Q56a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A56a. Recipients include Argonne National Laboratory (ANL) and Metals Recovery Industries. Minor subcontracts have been awarded to a Texas consultant ($15,000), Capital Engineering ($150,000), and an Arizona design firm ($35,000).

Fiscal Year	DOE Funding
1991	$20,000
1992	$583,000
1993	$379,000
1994	$100,000
1995	$50,000
1996	$20,000 (Year to Date)

Q56b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A56b.

Fiscal Year	Cost-Share
1991	$55,000
1992	$675,000
1993	$428,000
1994	$263,000
1995	$32,000
1996	$0

Q56c. Please provide detailed documentation of the claim that "[b]y the year 2000, electrochemical dezincing could save 50 trillion British thermal units of energy, reduce raw material costs by at least $160 million per year, and reduce the need to import at least 75,000 tons per year of zinc, saving at least $77 million annually."

A56c. Energy savings of 50 trillion Btu/yr. The energy savings are based upon two factors: (a) a reduction in the energy required to produce hot metal from dezinced scrap rather than primary ore, and (b) estimates of the market for this technology. The market penetration is estimated to be 4.5 million ton or less than one half of the galvanized scrap available by the year 2000. The energy conserved by this technology are based on 16 million Btu/ton now required to produce hot metal from primary ore. The dezincing technology will require 5 million Btu/ton to produce hot metal from clean scrap: (16 million Btu/ton-5 million Btu/ton) = 11 million Btu/ton savings x 4.5 million tons market potential = 49.5 trillion Btu.

Reduce raw material costs $160 million per year. The estimate of raw material savings is now about $140 million based on a reduction in the price of raw materials in recent years. The dezincing technology will produce clean degalvanized scrap that can be used to produce hot metal rather than the use of primary ore. The market penetration rate is assumed to be 4.5 million tons and the cost difference between hot briquetted iron (HBI) and the price of prime grade automotive scrap is about $30/ton. The savings therefore is $30/ton x 4.5 million tons, or $135 million.

Reduce the need to import at least 75,000 tons per year of zinc. The U.S. imports about 700,000 tons/year of zinc. The zinc removed from the approximately 5 million tons of galvanized scrap is estimated to be 1.5% by weight or 75,000 tons. (Note: this is not an annualized term.) This estimate has now been increased to 100,000 ton based on recent studies of the market available.

Q56d. Does DOE hold the patents for this technology, and if not, why not?

A56d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q56e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A56e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q56f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A56f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q56g. Please provide evidence that electrochemical dezincing technology <u>would not</u> have been developed and commercialized without the DOE funding.

A56g. This technology has had difficulty finding venture capital at terms acceptable to owners of the technology. The sponsorship by DOE has been an attractor for obtaining outside capital. Degalvanizing was identified by ANL in 1987 as potentially a government project through the DOE-Office of Industrial Technologies Waste Reduction program. Private enterprise has always stated that the length of time to commercialization did not make this project profitable for the companies. No corporation would be willing to wait for payback (1987 to present). Private enterprise has always stated that success was contingent upon obtaining DOE funding (of near 50%) before venture capital would be made available.

Q57. The following "success story" appears on page 182 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"High-Efficiency Weld Unit

Improving power supply efficiency is key to achieving significant energy savings in welding processes. Conventional arc-welding power supplies use a low-frequency transformer, which makes them power-inefficient and unwieldy in weight and size. The Department of Energy developed a more efficient power supply with the Cyclomatics Company. The new system uses solid-state electronics known as inverter technology to shut off power to essentially all of the power source components when a unit is idling. This reduces electrical energy consumption by up to 45 percent compared to conventional power supplies. Nationwide, these units have saved

more than 13 trillion British thermal units of energy and can be credited with reducing emissions of carbon dioxide by 20,000 tons each year. Annual savings are $15 million."

Q57a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A57a. DOE provided $372,000 in 1980-1981 to Cyclomatics Industries, Inc. to develop this technology.

Q57b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A57b. Cyclomatics cost-shared $93,000 on this project and subsequent to the R&D phase provided an unknown amount of funds for product development and commercialization. DOE did not provide any funds for product development or commercialization.

Q57c. Please provide detailed documentation of the claim that "[n]ationwide, these units have saved more than 13 trillion British thermal units of energy and can be credited with reducing emissions of carbon dioxide by 20,000 tons each year. Annual savings are $15 million."

A57c. The high efficiency weld unit was commercialized in 1983 and has been tracked by DOE since that time. In 1994, the cumulative energy savings attributed to the high efficiency weld unit were 13 trillion Btus based on 44,000 units in commercial operation. In 1994 the annual energy savings rate for these units was 2.75 trillion Btus. At this energy savings rate, the total value of energy cost savings is $12.6 million. Because the high efficiency weld unit is lighter, smaller and more efficient than conventional arc welding, additional productivity improvements have been realized. Nationwide, these improvements have resulted in a non-energy annual cost savings of $2.64 million. Together with the energy cost savings of $12.6 million this provides an annual cost savings of about $15 million. Reductions in carbon dioxide emissions are calculated based on the energy that is saved for the type of fuel that would have been used.

Q57d. Does DOE hold the patents for this technology, and if not, why not?

A57d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this

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objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q57e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A57e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which in this case, is not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q57f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A57f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which in this case, is not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q57g. Please provide evidence that high-efficiency weld unit technology <u>would not</u> have been developed and commercialized without the DOE funding.

A57g. The industry which produces power tools, welding power supplies, and other machine tools is comprised mostly of small firms, with a few larger manufacturers. These smaller manufacturers typically have many areas which compete for R&D investments, and the funds available for long-term investments in high risk R&D are extremely limited. Many also operate with marginal discretionary funds and are often forced to divert R&D resources to make capital investments that help them meet immediate needs for regulatory compliance or equipment breakdowns. Today this technology is phenomenally successful, and has practically revolutionized the way welding is conducted in many operations across the U.S. However, despite its potential, it is highly unlikely that the developer of the high efficiency weld unit would have been able to develop this technology independent of government support due to the expensive and risky nature of the fundamental R&D needed to bring this technology from bench-scale to commercialization. Although not very large when compared with many government R&D projects ($372,000), government support provided the means to accelerate the development and subsequent commercialization of this important technology. It is important to note that government support ended in 1981, and that the additional support needed to bring the prototype technology to commercial production (which occurred in 1983) was provided solely by the developer.

Q58. The following "success story" appears on page 182 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Direct Steelmaking**
>
> **The Department of Energy supported post-combustion research in a Basic Oxygen Steelmaking Furnace, which led to the application of the technology in the electric arc furnace. The result is a savings of 40 to 50 kilowatt-hours per ton and a 6 to 7 percent increase in productivity. This work was performed by Union Carbide, now Praxair, under a subcontract from the American Iron and Steel Institute. Praxair is now marketing the technology worldwide. This technology can be applied in approximately 50 million tons of steelmaking annually, with an annual savings of $30 million."**

Q58a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A58a. The recipient of the funding for this project was the American Iron and Steel Institute. The pilot plant work was done in Pittsburgh, PA and additional research efforts were performed at various universities including MIT and Carnegie Mellon. The DOE expenditures for each fiscal year for this project is given below:

Fiscal Year	DOE Funds
1989	$4,943,000
1990	$12,303,000
1991	$8,416,000
1992	$10,401,000
1993	$6,796,000
1994	$3,522,000

Q58b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A58b.

Fiscal Year	Cost-Share
1989	$1,483,000
1990	$3,682,000
1991	$2,535,000
1992	$3,119,000
1993	$2,041,000
1994	$1,055,000

Q58c. Please provide detailed documentation of the "annual savings of $30 million".

A58c. The post-combustion of carbon monoxide off-gas from the furnace provides heat that can be used in place of some of the electrical power that is normally consumed during electric furnace steelmaking. Tests have shown that this energy savings is between 40 to 50 kilowatt-hours per ton of steel produced. If one uses the conservative end of this range, i.e., 40 kWh/ton and a conservative cost for electric power inside a steel plant ($0.015/kWhr) then the annual savings for applying this technology to the 50 million tons of electric arc furnace steel produced each year in the United States would be:

(40 kWh/ton)($0.015/kWh)(50 million tons) = $30 million.

Q58d. Does DOE hold the patents for this technology, and if not, why not?

A58d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q58e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A58e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q58f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A58f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q58g. Please provide evidence that direct steelmaking technology <u>would not</u> have been developed and commercialized without the DOE funding.

A58g. Direct Steelmaking technology was (and is) considered a "high-risk" technology by the conservative, capital intensive steel industry. Over the past 20 years, the integrated steel industry has focused its new technology capital investments on value-added end-products, such as hot-dip or electro-galvanized products. Since direct steelmaking is a generic front-end technology, no domestic steel company was (or is) willing to take the economic risk associated with this type of capital investment. Consequently, without DOE providing a significant portion of the cost in demonstrating the technical and economic feasibility of the process this technology would not have been developed.

Q59. The following "success story" appears on page 182 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Superplastic Metal Formation Technology

The superplastic metal forming process developed through research sponsored by the Department of Energy allows the manufacture of metal components into shapes very near final dimension. This results in several advantages. It minimizes machining material waste, eliminates the use of environmentally damaging solvents, and saves energy, time, and labor costs. Further, it allows the use of new materials such as lightweight alloys, and enhances design freedom by creating the opportunity to produce unique complex shapes. Manufacturers report a 20-percent savings in metal machining processes."

Q59a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A59a. The recipient of the funding for project was the Lawrence Livermore Laboratory. Additional participants included Caterpillar, North Star Steel, and Ladish. The DOE funding for each fiscal year for this project is given below:

Fiscal Year	DOE Funds
1989	$1,259,000
1990	$549,000
1991	$398,000
1992	$1,394,000
1993	$0
1994	$426,000

Q59b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A59b.

Fiscal Year	Cost-Share
1989	$465,000
1990	$4,000
1991	$184,000
1992	$211,000
1993	$331,000
1994	$178,000

Q59c. Please provide detailed documentation of the "20-percent savings in metal machining processes".

A59c. Because superplastic metal forming technology promotes the production of close tolerances and intricate shapes, savings in machining are maximized as normally only finish machining is required. Alternatively, the high carbon content of the superplastic material produces a microstructure with a high volume fraction of carbides, which results in very good wear and scoring resistance, but does increase machining costs. The near net shape reduces the machining requirements sufficiently that even with the high carbide microstructure, the reduction in machining costs is estimated to be in the neighborhood of 20%. The savings in machining include both the material that would otherwise be lost as chips and the energy associated with that material as well as the energy of the machining process itself.

Q59d. Does DOE hold the patents for this technology, and if not, why not?

A59d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q59e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A59e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the Management and Operating (M&O) contractor at the DOE site, not DOE. See Appendix A for details on applicable Federal statutes. If, in cases where DOE does not hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q59f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A59f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the M&O contractor, not DOE. Federal statutes normally do not require the reporting of this information when received by a non-M&O contractor. See Appendix A for details on relevant statutes.

Q59g. Please provide evidence that superplastic metal formation technology would not have been developed and commercialized without the DOE funding.

A59g. Superplastic metal formation technology was (and is) considered a "high-risk" technology by industry. Although superplastic aluminum and titanium have found significant application in the aerospace industry, it has always been viewed as a high priced, low production process, which was applicable to exotic applications, but not for routine commercial products. It is more difficult to produce superplastic steel than it is to produce superplastic aluminum or titanium and no individual company was (or is) willing to take the economic risk associated with this type of capital investment. Consequently, without DOE providing a significant portion of the cost in demonstrating the technical and economic feasibility of the process this technology would not have been developed.

Q60. The following "success story" appears on page 183 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Renewable Energy

The Department supports a balanced development and deployment effort on promising renewable energy technologies aimed at increasing the production and use of domestic energy resources, and is working with industry to strengthen the technology base leading to new products and processes for the commercial market. The number of private-sector partners willing to cost-share key research projects is evidence that the private sector has a legitimate interest in these technologies. Research and development on photovoltaics, solar thermal, wind, biomass, and geothermal energy will help strengthen the Nation's energy security, promote sustainable energy approaches, and increase U.S. industrial competitiveness. The goal in this program area is to triple the U.S. nonhydropower renewable energy capacity by the year 2000.

Continued cost reductions fostered by our strategic research, development, and deployment activities can ensure the United States a place in an emerging multibillion-dollar clean energy market. The establishment of footholds by U.S.-based firms in international sales activity is clearly vital. Currently, U.S. photovoltaic and geothermal companies are worldwide leaders as a result of Department of Energy investments in advanced technology development. More than 70 percent of U.S. photovoltaic manufacturing output is exported, resulting in more than $90 million in annual revenues. U.S. companies have installed more than 1,000 megawatts of geothermal facilities in other countries and have orders for an additional 2,000 megawatts, creating an annual income stream of $250 million."

Q60a. Please explain the statement that "[t]he goal in this program area is to triple the U.S. nonhydropower renewable energy capacity by the year 2000." Triple relative to what level, and what is the nonhydropower renewable energy mix?

A60a. This program goal for non-hydropower renewable energy capacity was predicated upon an aggressive and significantly expanded 5-year renewable energy deployment program as called for under the Climate Change Action Plan. Since the time the data and materials presented in the "Success Stories" was developed and printed, several factors have come into play that have necessitated a revision of this goal, including the FY 1995 funding recessions and the significantly reduced budgets allocated in FY 1996. These recent funding reductions and the likelihood of lower than previously projected future funding allotments have required us to revise our estimates. We now anticipate that domestic non-hydropower renewable energy capacity will increase by approximately 34% between 1995 and 2000. The non-hydropower renewable mix is projected as follows:

ACTUAL AND PROJECTED INSTALLED ELECTRIC CAPACITY FOR DOMESTIC RENEWABLE ENERGY TECHNOLOGIES (MEGAWATTS)						
Year	Biomass	Geothermal	Photovoltaics	Solar Thermal	Wind	Total
1995	7,500	2,700	50	454	1,770	12,339
2010	8,700	3,196	515	404	3,770	16,585

Q60b. Please document that statement that "[m]ore than 70 percent of U.S. photovoltaic manufacturing output is exported, resulting in more than $90 million in annual revenues."

A60b. A recent U.S. General Accounting Office analysis is of selected cases from a report containing DOE success stories (*Task Force on Strategic Energy Research and Development, Annexes 2-4*) determined that for photovoltaics, "DOE provided adequate documentation supporting the report's claims......"

The most recent information. on the U.S. photovoltaic industry is annually provided by the *PV News*, a monthly newsletter edited and published by Paul D. Maycock. The February 1996 Issue, Vol. 15 No.2, p. 4, indicates total shipments of 34.75 MW in 1995. It is estimated that the U.S. installations represented 10 MW, while exports represented 25 MW.

In addition, the Energy Information Administration/Renewable Energy Annual 1995 Draft Report based on EIA Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey," indicates exports represented 70% of output in 1993 and 68% in 1994.

Q60c. Please document that statement that "U.S. companies have installed more than 1,000 megawatts of geothermal facilities in other countries and have orders for an additional 2,000 megawatts, creating an annual income stream of $250 million."

A60c. U.S. companies have developed and are operating 755 megawatts of geothermal production in the Philippines and 170 megawatts in Indonesia. Smaller geothermal developments of 1 to 5 megawatts have been installed by U.S. companies in several other countries. In November 1994, four U.S. geothermal companies signed agreements with the Government of Indonesia for development of 1,420 megawatts of electrical power generation (*GRC Bulletin*, January 1995). These four agreements for geothermal power will require investment of (U.S.) \$3.46 billion. The power sales agreements for these geothermal plants have rates of 7.6 to 7.9 cents (U.S.) for initial 14 year periods and then decline. Due to a subsequent merger of two U.S. geothermal companies, the Indonesian Government canceled one of these contracts for 400 megawatts. Another U.S. Company signed a contract in 1994 for 1,000 megawatts of geothermal power in Indonesia (*GRC Bulletin*, December 1994). In 1995, U.S. companies were successful in obtaining contracts to develop geothermal power plants for an aggregate of 300 megawatts in the Philippines that will require an investment of \$500 million.

The geothermal power safe agreements average 7.75 cents/kilowatt hour. The addition of 2,000 megawatts of geothermal facilities will generate about 13,000 gigawatt hours of electricity (at 75% availability) for an annual revenue stream of \$1 billion. The annual income stream to the United States of \$250 million (about 25%) pays U.S. companies and buys U.S. goods and services for the projects, and it provides a rate of return of about 15 % to the U.S. investors (allowable by contract in Indonesia).

Q61. The following "success story" appears on pages 183 and 184 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Photovoltaics

Research and development supported by the Department of Energy has been instrumental in the discovery, synthesis, and development of state-of-the-art semiconducting and photonic materials and devices. Photovoltaic technology converts photons (light) into electricity. Today photovoltaic cells power a wide variety of devices, including spacecraft, watches, calculators, highway signs, navigational aids, emergency telephones, and relay stations; in developing countries, photovoltaic cells power entire remote villages. Photovoltaic systems are an ideal, environmentally sensitive technology for bringing people in remote sites such basic services and amenities as light, water, communications, power for businesses, and power for other productive uses.

Photovoltaic electricity costs dropped from 90 cents per kilowatt hour in 1980 to 20 cents per kilowatt hour today. Since 1988, photovoltaic output has doubled; photovoltaic output increased another 24 percent just from 1993 to 1994. Maintaining and expanding this phenomenal growth depends on continuous improvements in the performance and

cost-competitiveness of photovoltaic products, supported through cost-shared R&D between industry and the Department of Energy. At present, every $100 million in direct module photovoltaic sales helps support or create 3,800 U.S. jobs."

Q61a. Please document that statement that "[p]hotovoltaic electricity costs dropped from 90 cents per kilowatt hour in 1980 to 20 cents per kilowatt hour today."

A61a. In addition to the recent U.S. General Accounting Office analysis which determined that DOE provided "adequate support for all benefits claimed," documentation is provided by World Bank Technical Paper Number 240–Energy Series: January, 1994; "Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies," authored by Kulsum Ahmed. The author cites a cost of 158 to 317 cents per kWh from a report by Costello and Rappaport, 1980, "The Technological and Economic Development of Photovoltaics" in the Annual Review of Energy. The figure of 20 cents per kWh is derived from calculations cited in a Sacramento Municipal Utility District (SMUD) report documenting the results of its 1994 procurement of residential and commercial photovoltaic systems, which was summarized in The Solar Letter (edited and published by Allan L. Frank), June 24, 1994, Vol. 4, No.14, "Photovoltaic Bidders Please SMUD with Lower Prices than Last Year," pp. 145-6.

Q61b. Please document that statement that "[s]ince 1988, photovoltaic output has doubled; photovoltaic output increased another 24 percent just from 1993 to 1994."

A61b. Recent data from the DOE Energy Information Administration provide an independent confirmation of the increase in photovoltaic output. Their data yields a cumulative total of 87.811 megawatts from 1988 through 1993 for U.S. shipments. 1994 shipments totaled 26.077 megawatts representing an increase of 29.7% of photovoltaic output (Ref. 9, p. 23). Further, this data showed a 1993-1994 increase from 20.951 megawatts to 26.077 megawatts for an annual increase of over 24%. However one looks at this data, the market expansion of photovoltaics has been extremely significant over this period.

This information is contained in the Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Q61c. Please document that statement that "[a]t present, every $100 million in direct module photovoltaic sales helps support or create 3,800 U.S. jobs".

A61c. The source of this statement comes from a study conducted by the EA Engineering, Science, and Technology Energy Technology Group, in a report dated April 4, 1992, "Economic Impacts of a PV Module Manufacturing Facility." Page v shows the direct and indirect impacts of PV module sales, based on an input-output analysis of the Advanced Photovoltaic Systems (APS), Inc.'s Fairfield, CA, plant–a 10 MW amorphous silicon module production plant. The table shows that direct and indirect employment at this level of sales would equal 23,100 jobs. Dividing by 6 to reach jobs per $100 million equals 3850 jobs.

Q62. The following "success story" appears on page 184 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Wind Turbine Technology

Collaborative Department of Energy and industry research and development has created today's modern wind turbines, which are already providing sufficient electricity for 1 million Americans. Costs have been reduced from almost $.25 per kilowatt hour in 1980 to the current range of $.05 to $.07 per kilowatt hour in locations with good wind resources. New wind turbine blades, advanced materials development, and developments in airfoil technology are expected to further reduce the cost of wind-generated electricity to $.04 per kilowatt hour by 2000. In California alone, there are more than 1,700 megawatts of generating capacity. California's wind powerplants currently provide up to 8 percent of Pacific Gas and Electric's load and save the energy equivalent of 4.4 million barrels of oil each year while producing no air pollution. (In fact, wind power prevents the creation of 2.5 million tons of carbon dioxide and 15,000 tons of other pollutants per year.)"

Q62a. Please document the statement that "[c]osts have been reduced from almost $.25 per kilowatt hour in 1980 to the current range of $.05 to $.07 per kilowatt hour in locations with good wind resources."

A62a. The following reference supports this statement: Hock, S.M., Thresher, R.W., "Wind Systems for Electrical Power Production," Mechanical Engineer, p. 68, August 1994.

Q62b. Please document the statement that "[n]ew wind turbine blades, advanced materials development, and developments in airfoil technology are expected to further reduce the cost of wind-generated electricity to $.04 per kilowatt hour by 2000."

A62b. The following reference supports this statement: Hock, S.M., Thresher, R.W., Cohen, J.M., "Performance and Cost Projections for Advanced Wind Turbines," SERI/TP-257-3795, 1990.

Q62c. Please document the statement that "[i]n California alone, there are more than 1,700 megawatts of generating capacity."

A62c. The following reference supports this statement: Loyola, J., "Wind Project Performance - 1993 Summary," P500-95-001, California Energy Commission Staff Report, January 1995.

Q62d. Please document the statement that "California's wind powerplants currently provide up to 8 percent of Pacific Gas and Electric's load and save the energy equivalent of 4.4 million barrels of oil each year while producing no air pollution."

A62d. The following references support this statement:

"Integrating an Ever-Changing Resource," Utility Wind Interest Group brochure, July 1992.

American Wind Energy Association, "1994 Wind Energy Status Report," 1995.

Mark's Standard Handbook for Mechanical Engineers.

Q62e. Please document the statement that "wind power prevents the creation of 2.5 million tons of carbon dioxide and 15,000 tons of other pollutants per year."

A62e. The following reference supports this statement: "Environmental Emissions from Technology Systems: The Total Fuel Cycle," U.S. Dept. of Energy, 1989.

Q63. The following "success story" appears on page 184 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Geothermal Technologies

The commercially operated geothermal site at The Geysers in northern California reached peak electric power output of 2,000 megawatts in 1988. Inexplicably, a steady decline in output began in 1989. In 1990, a concerned geothermal industry asked the Department of Energy for assistance in determining the cause. Failure of power production at The Geysers would have a depressing effect on all potential markets for geothermal power. During fiscal years 1990 through 1994, the Department of Energy shared costs with a coalition of geothermal operators and made available both experts and expertise to help diagnose the problem. The cause proved to be reservoir fluid depletion, the result of inadequate reinjection practices and insufficient knowledge of reservoir management requirements. The lessons learned in this effort will continue to benefit geothermal reservoir development for years to come. With a $12 million Department of Energy investment–matched by $42 million from industry–a potential crisis for hydrothermal energy systems was overcome, reservoir practices leading to decades of stable operation were developed, and more than 300 jobs were directly preserved."

Q63a. Please detail, by appropriate fiscal year, the DOE R&D investment in The Geysers, including a listing of the recipients of this funding.

A63a. The Department's funding and recipients of that funding for The Geysers R&D Project for FY 1990 through FY 1996 follows:

DOE Funding for The Geysers R&D
(In Thousands of $)

Fiscal Year	Funding	Recipients
1990	1,000	Idaho National Engineering Laboratory (INEL), Lawrence Berkeley National Laboratory (LBNL), Stanford University, Lawrence Livermore National Laboratory (LLNL)
1991	2,500	INEL, LBNL, Stanford University, University of Utah, LLNL, U.S. Geological Survey (USGS), Oak Ridge National Laboratory (ORNL), University of California at San Diego (UCSD)
1992	2,264	Brookhaven National Laboratory (BNL), INEL, LBNL, Stanford University, University of Utah, LLNL, USGS, ORNL, UCSD
1993	2,524	BNL, INEL, LBNL, Stanford University, University of Utah, LLNL, New England Research Institute (NERI), USGS, ORNL, UCSD
1994	2,647	BNL, INEL, LBNL, Stanford University, University of Utah, LLNL, Sandia National Laboratories (SNL), NERI, USGS, ORNL, UCSD
1995	865	BNL, INEL, NERI, USGS, ORNL
1996	200	BNL, INEL, ORNL
Total	$12,000	

Q63b. Please detail, by appropriate fiscal year, private sector investment in The Geysers.

A63b. The geothermal industry's funding and participants in The Geysers for FY 1990 through FY 1996 follows:

Geothermal Industry's and Participants in The Geysers R&D
(In Thousands of $)

Fiscal Year	Funding	Participants
1990	3,000	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Mission Energy, Northern California Power Agency, Central California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
1991	7,500	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Mission Energy, Northern California Power Agency, Central California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
1992	7,500	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Mission Energy, Northern California Power Agency, Central California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
1993	7,500	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Mission Energy, Northern California Power Agency, Central California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
1994	7,500	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Mission Energy, Northern California Power Agency, Central California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
1995	8,900	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Northern California Power Agency, Pacific Gas and Electric, Barbara Nichols
1996	100	Unocal Geothermal, Calpine Corporation, Santa Fe Geothermal, Northern California Power Agency, Pacific Gas and Electric, Sacramento Municipal Utility District
Total	42,000	

264. The following "success story" appears on pages 185 and 186 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> "Mudpulse Telemetry for Measurement While Drilling
>
> One of the most important timesaving innovations used today in the drilling industry is the 'measurement-while-drilling' instrument. Before its invention, operators needing to determine drill bit direction had to cease drilling, remove hundreds or thousands of feet of drill pipe, and lower an instrument into the well. Readings would then be taken, the instrument retrieved, and drilling would recommence. In the 1970s, the Department of Energy helped Teleco, Inc., pioneer a wireless system that could transmit the location of a drill bit by sending pressure pulses through the drilling mud that circulated from the bit face to the surface. Today, mudpulse telemetry has gained wide acceptance in the drilling industry and is estimated to have saved the natural gas and oil industry at least $1 billion over the past 20 years."

Q64a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A64a. This technology was developed nearly 20 years ago. We cannot find records of the exact amounts invested by DOE, however, several of those involved in the project are still working at Sandia National Laboratories and, to the best of their recollection, DOE funded $2 million of the total $4 million for the two year project. All funding was received by Sandia.

Q64b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A64b. The private sector investment associated with the DOE program is estimated at $2 million. In addition, rig time was provided by six major oil companies and the Telecom parent companies Raymond Precision Industries and Societe National des Petroles d'Aquitaine.

Q64c. Please provide detailed documentation of the savings to the natural gas and oil industry of "at least $1 billion over the past 20 years".

A64c. More rigorous analysis has been completed since the original DOE analysis was done for mudpulse telemetry, which indicates that benefits from this technology are well in excess of $1 billion over the past 20 years. This new analysis is summarized below.

The five major applications of mud pulse telemetry are:

1) Bit Orientation: The position of the bit at any time can be obtained by measurements of the earth's magnetic field or by reference to gravitational acceleration. This real time survey permits the driller to know where the borehole is going without having to stop the operation. This saves drilling time, avoids the possibility of sticking the pipe while waiting on the survey, and with knowledge of present drill bit position can avoid the need for high angle correction runs. The mud pulse telemetry is responsible for sending the information to the surface.

2) Mechanics: The primary down hole mechanical parameters that can be measured are weight on bit, downhole torque on bit, downhole bending moments, and downhole accelerations. Acquisition of these parameters ensures that the optimal drilling rates can be achieved, as well as indicating whether the bit is worn out or that critical strength parameters are not being exceeded. The mud pulse telemetry is responsible for sending the information to the surface.

3) Logging While Drilling: The evaluation of formations in real time is a definite benefit to the geologist and reservoir engineer. The rock type, porosity, and fluid content can be ascertained before the mud has had a long time to invade the formation. This yields better values for evaluating the rock content and leads to better planning for completion and production. The mud pulse telemetry is responsible for sending the information to the surface.

4) Geosteering: The ability to change the well path in real time is a tremendous benefit to the operation. In extended reach and horizontal wells, the necessity of steering the well bore to stay within the target formation is the main requirement. Bit orientation, mechanical properties, and formation evaluation are integrated and used to confirm that the well is going where it was planned and corrected for changes in the program. If the velocity fields that were used in the seismic interpretation were in error, corrections can be made while the well is drilling to bring the well bore to the actual target formation. The mud pulse telemetry is responsible for sending the information to the surface.

5) Safety: The measurement of downhole conditions can warn the drillers of the possibility of a blowout long before the information would be discerned at the surface. The measurement of formation and annulus pressures needs to be in real time. The mud pulse telemetry is responsible for sending the information to the surface

Our statement that, "Measurement While Drilling Mudpulse Telemetry has resulted in savings to the natural gas and oil industry of at least $1billion over the past 20 years," is based on the following analysis of use of the technology on 715 offshore wells drilled in 1994. There were also benefits for onshore wells, but the benefits from offshore wells were higher because offshore wells are generally much more expensive.

1) Bit Orientation: Assume that the bit orientation saves two rig days in correction run. The savings would be $50,050,000 (2 days x $35,000 per day x 715 wells). This does not include the savings from circulation problems and pipesticking problems avoided.

2) Mechanics: The ability to keep the hardware in the hole and avoid downtime due to fishing or early bit runs is estimated at 3 days per well. The savings would then be $75,075,000 per year (3 days x $35,000 per day x 715 wells).

3) Logging While Drilling: Each well that is drilled must be logged over the pay section. Logging while drilling saves $79,000 per well or for 715 wells saves $56,485,000. This does not include the rig up and down time for the wireline unit of two days at $35,000 per day for 715 wells or $50,050,000. The total savings over the pay zone is $106,535,000 per year.

4) Geosteering: Use of this technology can make or break a well. Onshore, there are 2,506 leases which have been drilled since 1988 as horizontal wells. The May 1994 World Oil cites a case where geosteering a new well resulted in production of 2,800 BOPD with very little water. The other eight regular, vertical wells on the field produced a total of less than 2,000 BOPD while producing 16,000 barrels of water per day. The value here of using a tool with telemetry is approximately the value of 8 wells or $23,093,304 (8 x $2,886,663). If only one well in 50 out of 410 successful oil and gas wells saw this result, that would be an added benefit of $189,365,092 per year.

5) Safety: The use of remote telemetry to warn of gas bubbles and avoid blow outs is extremely valuable. A blow out is not only loss of time, but also potential loss of property and life as well as potential negative environmental impacts. The cost for cleaning up spills ranges from $55 to $3,859 per barrel for the offshore (Moller, Parker and Nichols, 1987). Using a weighted average of $1,000 and a rate of incidence of two per twenty years (Ixtoc I, 1979 and Alvenus, 1984), and a volume of 100,000 barrels, then the cost avoided is $200,000,000 per 20 years (2 x $1,000 x 100,000) or $10,000,000 per year. This neglects all injury or deaths to personnel, fishery death counts, the lost time and property on the rig, and the lost hydrocarbon resource.

Annual Savings and Benefit Summary due to use of Mud Pulse Telemetry with Other Technologies:

1) Bit Orientation	$ 50,050,000
2) Mechanics	$ 75,075,000
3) Logging While Drilling	$106,535,000
Subtotal of Avoided Costs	$231,660,000
4) Geosteering	$189,365,092
5) Safety	$10,000,000
Grand Total	$431,025,092

This is a yearly benefit. Over 20 years, this is $4.837 Billion dollars.

Considering the 20-year period that mudpulse telemetry has been available, new offshore wells averaged over 1200/year from the mid-70's to mid-80's. Since use of mudpulse technology would have been phased in over time, the figures based on 715 wells/year in 1993 may be an adequate "ballpark" estimate for this period. After the mid-1980's when oil prices fell, offshore drilling declined to 700-800 wells/year. Mudpulse technology was universally used by this time.

Geosteering benefits are a more recent phenomena, and are most significant in the past five years.

Based on these timeframes, benefits (1996$) for a 20-year period would be about $3 billion ($200 million/year for the first 15 years), plus $2 billion ($400 million/year for last 5 years), for a total of $5 billion.

To verify these metrics we had Mr. Pat Herbert, Baker Hughes Inc. (713-439-8600), review them. He indicated that the savings, "*were very conservative and were probably much greater.*"

Q64d. Does DOE hold the patents for this technology, and if not, why not?

A64d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development

These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q64e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A64e. DOE does not own the patent for this technology.

Q64f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A64f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q64g. Please provide evidence that mudpulse telemetry technology <u>would not</u> have been developed and commercialized without the DOE funding.

A64g. Federal government funding was a catalyst which, without question, accelerated the use of the technology by domestic producers.

Q65. The following "success story" appears on page 186 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Carbon Dioxide Sand Fracture Production Technology**
>
> **The Department of Energy's Morgantown Energy Technology Center developed, tested, and helped commercialize this technology for stimulating production from natural gas wells. A nondamaging treatment process, it won the natural gas industry's 1994 Best Technology in the Northeast Award. Of special importance to small, independent producers, the technology has been shown to increase production by 200 to 500 percent. At $2.00 per thousand cubic feet, a 3 to 9 million cubic foot well using carbon dioxide sand fracturing will generate $20 million more revenue over its productive life."**

Q65a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A65a. Total DOE investment from FY 1990 to date for the carbon dioxide/sand fracturing effort is $3.6 million (testing was delayed two years pending EPA approval). Petroleum Consulting Services and Advanced Resource International were the integrating contractors.

Q65b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A65b. Total Industry investment associated with the DOE program from FY 1990 to date for the carbon dioxide/sand fracturing effort is estimated at $8.3 million

Q65c. Please provide detailed documentation of the claim that "the technology has been shown to increase production by 200 to 500 percent. At $2.00 per thousand cubic feet, a 3 to 9 million cubic foot well using carbon dioxide sand fracturing will generate $20 million more revenue over its productive life."

A65c. Published production results from Society of Petroleum Engineers (SPE) Paper #29191 indicate that CO_2 Sand Fracture technology generated a 94 to 390 percent increase in production after nine months compared to conventional stimulation methods in the Pike County, Kentucky, study area where the carbon dioxide testing was performed. Incremental cumulative production to date (25 months) is now 27 million cubic feet (mmcf) per well compared to nitrogen stimulations and 46 mmcf per well compared to foam stimulations in the Pike county study area. Using decline curve analysis techniques, an average well would be forecasted to produce an additional 75 mmcf after seven years. At a natural gas price of $2.00 per thousand cubic foot, this means that a producer using carbon dioxide sand fracture technology will realize <u>increased</u> revenues of approximately $150,000 per well over the initial seven years of CO_2 Sand Fracture stimulation. This is a tremendous amount of increased revenue for marginally productive gas wells, which would normally bring in revenues of about $100,000 over the first seven years, and **resulted in DOE receiving the 1994 Hart's Oil and Gas World award for introducing the "Best New Technology in the Northeast."**

The technology is being tested in the Southwest, Rocky Mountain as well as in the Appalachian Regions, and is believed to be applicable to many wells in low and high permeability natural gas reservoirs nationwide. The applicable wells could reach thousands per year as increasing domestic natural gas demand requires increased production from unconventional sources. For every hundred wells for which this technology is applied, field results thus far suggest that there would be more than $15 million in increased revenues over the initial 5-7 years of CO_2 Sand Fracture stimulation.

Q65d. Does DOE hold the patents for this technology, and if not, why not?

A65d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q65e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A65e. DOE does not own the patent for this technology.

Q65f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A65f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q65g. Please provide evidence that carbon dioxide sand fracture production technology <u>would not</u> have been developed and commercialized without DOE funding.

A65g. It is difficult to estimate when the depressed US petroleum industry would have licensed the Canadian FracMaster technology and created a US service Industry. By successfully applying the process to over a dozen wells in Kentucky, the Department of Energy's Morgantown Energy Technology Center (METC) accelerated the acceptance and use of the technology in the US. In addition, as a result of METC efforts, CO_2 Sand Fracturing won the Hart's Oil and Gas World award in 1994 for **Best Technology in the Northeast.**

Q66. The following "success story" appears on page 186 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> "Hot Oiling Paraffin Treatment
>
> Buildup of paraffin in the wellbore and near-wellbore formation can cause severe reductions in production of waxy crudes and result in lifting equipment failures. Traditional batch treatments are expensive and can result in formation damage if sound hot oiling practices are not followed, that is, if melted paraffin solidifies before it reaches the bottom of the well and plugs the formation. The Department of Energy developed a computer model that optimizes hot oiling paraffin treatments and aids in determining good practices. The use of this software, to estimate downhole temperatures and effectiveness of hot oiling, helps both producers (especially independents) and service companies by reducing operating and maintenance costs. For example, application of the software by an independent producer in a West Texas field increased the efficiency of production equipment, reduced equipment failures, and resulted in about $1.00 per barrel-equivalent reduction in average lifting cost. Industrywide use of the software and good hot oiling practices could result in more than $150 million per year in reduced operating cost, and also reduce well abandonments."

Q66a. Please detail, by appropriate fiscal year, the DOE R&D investment in this software, including a listing of the recipients of this funding.

A66a. FY 1991 = $144,000; FY 1992 = $225,000; FY 1993 = $20,000; FY 1994 = $20,000; FY 1995 = $30,000. Sandia National Laboratories was the recipient of the funding.

Q66b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A66b. Private sector investment associated with the DOE program was from Petrolite Inc., who contributed an equal amount to the DOE's $439,000 funding. About a dozen different companies provided in-kind support to the project, e.g. use of their equipment and personnel as well as loss of production during tests. Petrolite continues to invest its own funds in the project. Just recently they developed a Windows version of the Hot Oiling Spreadsheet.

Q66c. Please provide detailed documentation of the claims of "$1.00 per barrel-equivalent reduction in average lifting cost. Industrywide use of the software and good hot oiling practices could result in more than $150 million per year in reduced operating cost, and also reduce well abandonments."

A66c. Documentation for these statements is contained in two information papers prepared by Sandia National Laboratories, *Stripper Well Program Helps Operator Implement Chemical Paraffin Control Program*, and, *Hot Oiling Practices Target Pilot Group.*

Q66d. Does DOE hold the patents for this software, and if not, why not?

A66d. No. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q66e. If DOE holds the patents for this software, what licensing agreements does DOE have with private sector firms? Which firms?

A66e. DOE does not own the patent for this technology.

Q66f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A66f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q66g. Please provide evidence that this software <u>would not</u> have been developed and commercialized without the DOE funding.

A66g. Paraffin buildup is a significant problem for stripper well operators, those whose wells produce 10 barrels or less of oil per day. The computer model developed by the Department of Energy helps these producers understand how to apply hot oiling paraffin treatments effectively and without damaging the reservoir. It is doubtful that this software would have been developed and commercialized without DOE funding. We believe service companies and paraffin treatment developers don't have the economic incentive to develop this software. They are in the business of selling paraffin treatments, not developing computer models to ensure that these treatments are applied properly or are appropriate for the formation or the operator's equipment. Moreover, the economics of stripper well production would not support a profitable commercial market for hot oiling paraffin treatment computer models. DOE provides these models free to producers and serves as an "honest broker," assuring producers that the model are accurate. By doing so, DOE enables producers to increase domestic crude oil production by more effectively using hot oiling paraffin treatment to improve the economics of marginal wells.

Q67. The following "success story" appears on page 186 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Insulating Doughnut for Steam Flood of Deeper Oil Wells

Steam injected into deeper heavy-oil wells can lose significant amounts of heat during the trip from the surface to the reservoir. In fact, a phenomenon known as wellbore refluxing can result in up to six times the heat loss in an uninsulated tubing string than would be normally expected. Sandia National Laboratories, working under a Department of Energy program, devised a 2-inch-long 'doughnut' of plastic insulation that, when inserted in the standard tubing coupling, prevents steam from contacting the thin outer coupling walls. Heat loss through refluxing is reduced substantially. This simple device is now standard in the industry, and the savings to the industry will amount to hundreds of millions of dollars over the next decade."

Q67a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A67a. As this work was conducted over 10 years ago and was part of a larger project, the exact costs are not available today. However, one staff member and one assistant were involved in the study, which included field studies in an oilfield and at a Sandia Test site. A reasonable estimate of total DOE investment is $1,250,000–an average of $250,000/year.

Q67b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A67b. There was no formal private sector partner associated with the DOE program. However, 4 field tests were conducted in 1982-83 at an oilfied in Canada at the invitation of Husky Oil Company. No DOE funds were used to cover Husky's expenses; rather, Husky bore the costs of shut-in production, workover operations, and personnel for data monitoring during these tests.

Q67c. Please provide detailed documentation of the claim that "the savings to the industry will amount to hundreds of millions of dollars over the next decade."

A67c. This statement was originally made in 1985. The estimate was based on level of activity and expected expansion of thermal EOR at that time. (For example, in 1982, steam drive and cyclic steam stimulation [both methods which could use this technology] accounted for 440,000 bbl/day, or 87% of the incremental oil produced by EOR according to the National Petroleum Council in 1984.) However, the bottom dropped out of oil prices shortly after this work was completed, greatly curtailing expansion of thermal operations and causing operators to forego injection well improvements. We still believe that when oilfield economics change and thermal EOR is applied to recovery of light oil in domestic depleted fields at typical depths >4000ft (approximately two-thirds of the oil is still there) then the knowledge of refluxing, and this insulating doughnut technology developed to prevent it, will result in the savings estimated above.

Q67d. Does DOE hold the patents for this technology, and if not, why not?

A67d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q67e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A67e. DOE does not own the patent for this technology.

Q67f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A67f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q67g. Please provide evidence that the "insulating doughnut for steam flood of deeper oil wells" would not have been developed and commercialized without the DOE funding.

A67g. In this project Sandia/DOE showed that wellbore refluxing occurred and was a serious loss of energy during steam injection. Further, we developed and demonstrated a simple, low-cost solution. Shortly thereafter, GE/Kawasaki Thermal Systems designed their own coupling insert and sold it with their line of insulated steam injection pipe. We believe that Baker Hughes also utilized this DOE developed technology in their services as well. In either case, industry was not aware there was a problem–or a simple solution to it–without the prior DOE-funded work that showed both the need for, and effectiveness of coupling inserts. This is an example of the catalyst effect of DOE sponsored R&D.

Q68. The following "success story" appears on page 186 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Improved Oil Recovery Technology for the Green River Formation**
>
> **An oil recovery field demonstration program cosponsored by the Department of Energy has shown that by properly applying improved water-flooding technology in the Uinta Basin in Utah's Green River Formation, additional oil can be produced from fields that might otherwise have been abandoned. The Department's test has turned around conventional thinking in the region, giving Utah producers a technology that was previously thought to be unusable in the region's complex geology. The initial field test has already added 2.4 million barrels of producible oil to the region's reserves. More importantly, neighboring operators have begun using the technology and will return more than $160 million in Federal taxes and royalties, well above the $112 million Federal investment to date. Ultimately, recoverable oil reserves in Utah could be expanded by 3.5 billion barrels because of the Department of Energy cost-shared project."**

Q68a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A68a. All funding went to Lomax Exploration Company. Lomax, in turn, subcontracted some of its work (and some of the DOE funding) to the University of Utah. DOE funding totaled $1.8 million broken down: FY 1992 = $800,000; FY 1994 = $1 million.

Q68b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A68b. Lomax, the only private sector firm associated with the DOE program, invested $1.13 million in FY 1992 and $1.42 million in FY 1994.

Q68c. Please provide detailed documentation of the claims that "[t]he initial field test has already added 2.4 million barrels of producible oil to the region's reserves. More importantly, neighboring operators have begun using the technology and will return more than $160 million in Federal taxes and royalties, well above the $112 million Federal investment to date. Ultimately, recoverable oil reserves in Utah could be expanded by 3.5 billion barrels because of the Department of Energy cost-shared project."

A68c. There are the two sources of information on the benefits listed below:

- Testimony on Technology Transfer before the Subcommittee on Renewable Energy, Energy Efficiency and Competitiveness of the U.S. Senate Committee on Energy and Natural Resources, November 30, 1993, by John D. Lomax.

- Interim Report for the National Research Council, Commission on Geosciences, Environment, and Resources, Board on Earth Sciences and Resources, January 17, 1995, by John D. Lomax.

The statement that "Ultimately, recoverable oil reserves in Utah could be expanded by 3.5 billion barrels" is inaccurate. The Success Story was based on a Fact Sheet prepared by the Office of Fossil Energy in March 1995. That Fact Sheet explains that the ultimate recoverable reserves of oil in the Uinta Basin are huge–approximately 3.5 billion barrels. The Lomax waterflood project, by adding new life to many of the reservoirs in this Basin, can be expected to make recoverable a substantial portion of the remaining oil in the Basin.

Q68d. Does DOE hold the patents for this technology, and if not, why not?

A68d. DOE does not hold the patents, if any, for this invention. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q68e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A68e. DOE does not own the patent for this technology.

Q68f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A68f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q68g. Please provide evidence that the improved oil recovery technology <u>would not</u> have been developed and commercialized without the DOE funding.

A68g. Despite the huge volume of recoverable reserves, production from the Uinta Basin has been limited due to the fluvial-deltaic character of the reservoirs as well as the basin's complex petroleum geochemistry. In recent years, most major oil companies involved in the Uinta Basin have pulled out or announced plans to leave. Smaller independent operators are becoming the dominant producers in the area. While these operators can tolerate lower operating margins, we believe they are more risk averse and more inclined to plug and abandon wells after primary production. We also believe that the smaller independent operators have neither the financial nor technical resources to develop and test improved oil recovery technologies. Accordingly, without DOE funding, it is very doubtful that this improved oil recovery technology would ever have been applied in the Uinta Basin.

Q69. The following "success story" appears on pages 186 and 187 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Carbon Dioxide Miscible Flooding Technology for Oil Recovery**
>
> **Three percent of all domestic crude oil (about 180,000 barrels per day) is produced by injecting carbon dioxide into aging reservoirs to force out oil that conventional production techniques cannot recover. The gas mixes with some of the remaining oil in the reservoir, and creates a miscible bank of fluid that pushes additional oil to production wells. In large part, industry gained confidence in carbon dioxide flooding technology through a series of eight field tests conducted in the 1970s and co-financed by oil companies and the Department of Energy and its predecessors. Because of the success of carbon dioxide-enhanced oil recovery, carbon dioxide pipelines have been built throughout west Texas and eastern New Mexico, the principal regions of successful carbon dioxide miscible flooding. With the completion of the LaBarge pipeline, carbon dioxide-enhanced recovery has also been extended to oil fields in Wyoming and could reach others in North Dakota. Today, roughly 68,000 Americans are employed directly and indirectly because of this oil recovery technology. Moreover, data developed through the Department's laboratory research has saved the domestic oil producers**

at least $10 million by allowing them to accelerate development of other recovery processes."

Q69a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A69a. (In Thousands of $)

Performer	Project Title	<90	90	91	92	93	94	95	96
BDM	Extraction Research	0	0	0	0	0	268	0	0
K&A	Mobility Control Agents	0	0	0	0	75	0	0	0
METC	Mobility Control of CO_2	500	500	500	465	347	0	0	0
Phillips	Class 2	0	0	0	0	0	881	6,120	0
Stanford	Scale up of Miscible Proc	0	0	0	350	350	350	0	0
Texaco	Class 1	0	0	0	0	5,539	0	2,985	0
New Mexico	Improved Efficiency	0	0	0	0	0	320	324	330
Gulf Oil	Little Knife Field	2,811	0	0	0	0	0	0	0
Shell Oil	Weeks Island	2,475	0	0	0	0	0	0	0
Pennzoil	Rock Creek	2,823	0	0	0	0	0	0	0
Columbia Gas	Granny's Creek	514	0	0	0	0	0	0	0
Guyan Oil	Griffithsville	1,200	0	0	0	0	0	0	0
Total		10,323	500	500	815	6,311	1,819	9,429	330

Q69b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A69b. (In Thousands of $)

Performer	Project Title	<90	90	91	92	93	94	95	96
BDM	Extraction Research	0	0	0	0	0	0	0	0
K&A	Mobility Control Agents	0	0	0	0	0	0	0	0
METC	Mobility Control of CO_2	0	0	0	0	0	0	0	0
Phillips	Class 2	0	0	0	0	0	1,191	0	12,946
Stanford	Scale up of Miscible Proc	0	0	0	0	0	0	0	0
Texaco	Class 1	0	0	0	0	10,015	0	5,395	0
New Mexico	Improved Efficiency	0	0	0	0	0	320	324	330
Gulf Oil	Little Knife Field	2,811	0	0	0	0	0	0	0
Shell Oil	Weeks Island	4,125	0	0	0	0	0	0	0
Pennzoil	Rock Creek	3,760	0	0	0	0	0	0	0
Columbia Gas	Granny's Creek	1,028	0	0	0	0	0	0	0
Guyan Oil	Griffithsville	2,046	0	0	0	0	0	0	0
Total		13,770	0	0	0	10,015	1,511	5,719	13,276

Q69c. Please provide detailed documentation of the claims that "[t]hree percent of all domestic crude oil (about 180,000 barrels per day) is produced by injecting carbon dioxide into aging reservoirs to force out oil that conventional production techniques cannot recover. . . . Today, roughly 68,000 Americans are employed directly and indirectly because of this oil recovery technology. Moreover, data developed through the Department's laboratory research has saved the domestic oil producers at least $10 million by allowing them to accelerate development of other recovery processes."

A69c. The *Oil & Gas Journal* (O&GJ) biennially surveys the industry for information on enhanced oil recovery (EOR) projects and publishes tables that details EOR projects including their production rate. The last survey, "EOR Dips in U.S. but Remains a Significant Factor," was published September 26, 1994. The survey identified 54 miscible carbon dioxide projects and 1 immiscible carbon dioxide project active January 1, 1994. The estimated incremental or enhanced production rate was 161,466 barrels per day and total project production was 322,687 barrels per day from just these responding projects. The enhanced production is that portion of production that cannot be produced by conventional methods. Since this is a purely voluntary survey, the results are probably under-reported by at least 10%.

The U.S. crude oil production rate in January, 1994 was 6,817,000 barrels of crude oil per day according to the Energy Information Administration's Monthly Energy Review. The total crude oil production from carbon dioxide projects is at least 3.48% of the U.S. crude oil production.

A high percentage of the carbon dioxide projects are in West Texas and the crude oil produced is usually a West Texas Intermediate grade. The average spot price for West Texas Intermediate in 1994 was $17.16/bbl. Based on a the O&GJ survey, revenues in 1994 from carbon dioxide projects would be about $2.02 billion ($1.88 billion in 1989 dollars). The Department Commerce's Economics and Statistics Administration publishes a *Regional Multipliers: A User Handbook for Regional Input-Output Modeling System (RIMS II)* which includes tables for the mining of crude oil and natural gas based on 1989 dollars. The following is a simplified example shows how these multipliers are used. The employment factor for the Texas oil extraction industry is 9.5 jobs for each $1 million in direct output (1880 x 9.5 = 17,860 jobs) plus 3.017 direct-effect multiplier for employment (3.017 x 17,860 = 53,580 jobs) or a total of 71,440 jobs. A weighting of regional multipliers based on the geographic distribution of production estimates 68,437 jobs. This estimate of jobs is consistent with this high-tech intensive recovery process and the number of jobs in the industry.

The DOE does not collect statistics on the impact of how our customers use the technology we supply but we do make conservative estimates of that impact. DOE has contributed to research that cuts the cost of carbon dioxide flooding and increases production through fundamental research at the National Institute for Petroleum and Energy Research (NIPER) and university-industry Consortium. A conservative estimate is 0.5% savings of total project revenue for 1994 or $10 million per year. A savings of 1% of incremental oil value over 12 years (1983 through 1994) is approximately $232 million.

Q69d. Does DOE hold the patents for this technology, and if not, why not?

A69d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q69e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A69e. DOE does not own the patent for this technology.

Q69f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A69f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q69g. Please provide evidence that the "carbon dioxide miscible flooding technology for oil recovery" <u>would not</u> have been developed and commercialized without the DOE funding.

A69g. The first carbon dioxide projects were conducted by Chevron, Amoco, Texaco and other major oil companies. Some of the fundamental research on petroleum fluid properties were conducted by the government to accelerate this technology but it is basically an industry initiated commercialization. The DOE has assisted in the develop of the technology and the deployment of the technology through fundamental research on the nature of miscibility and, through consortium, technologies for increasing recovery and reducing costs. The result has been an accelerated commercialization with incremental production.

Q70. **The following "success story" appears on page 187 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

> **"Computerized Oil Field Simulators**
>
> **Closely related to predictive models is a family of oil field simulation software developed by the Department of Energy. BOAST (Black Oil Applied Simulation Tool) was introduced in 1982 as a way to simulate the movement of oil, gas, and water through an oil reservoir. BOAST has been upgraded to operate on personal computers and expanded to assess larger areas, larger numbers of wells, and more solution options. More than 2,400 copies of BOAST PC software have been distributed by the Department. Several oil industry consulting firms have modified the program to their own specifications. More than 20 million barrels of oil have been produced as a result of using these simulators, and the return to the taxpayer is more than $1,000 for each $1 of Department of Energy investment. Universities are also using BOAST as a textbook for reservoir simulation instruction. A second simulator, UTCHEM, has been developed specifically for chemical flooding. The simulator is being used by approximately 20 oil companies to project the behavior of tracers, polymers, polymer gels, surfactants, and alkaline agents injected into oil reservoirs. Better management of reservoirs has saved these companies more than $23 million, $8 million of which will flow back to the U.S. Treasury. The Department developed a third simulator, MASTER, to assist the natural gas industry in evaluating miscible and nonmiscible gas-enhanced oil recovery processes. By 1994, more than 250 copies of the software package had been distributed. Studies indicate that use of these processes will generate a 3-billion barrel increase in potential reserves."**

Q70a. Please detail, by appropriate fiscal year, the DOE R&D investment in (i) BOAST, (ii) UTCHEM, and (iii) MASTER, including a listing of the recipients of this funding.

A70a. Information not available except that UTCHEM funding for FY79-95 for Univ. of Texas at Austin was $3,062,000 DOE funding. Collective memory is that Keplinger & Associates was paid $50,000 for BOAST publication rights.

Q70b. Please detail, by appropriate fiscal year, private sector investment in (i) BOAST, (ii) UTCHEM, and (iii) MASTER.

A70b. Private sector investment associated with the DOE program is not available except that UTCHEM cost-sharing for FY79-95 by the University of Texas at Austin was $1,248,000.

Q70c. Please provide detailed documentation of the claim "[m]ore than 20 million barrels of oil have been produced as a result of using these [BOAST] simulators, and the return to the taxpayer is more than $1,000 for each $1 of Department of Energy investment."

A70c. Statistics are not collected on how or when this product is used. We believe this number is extremely conservative for the following reasons: BOAST is distributed by sharing among a large number of industry, academic and government groups. If only 160 copies are used to design a single waterflood project on typical 640 acre leases that each contain 2.5 million barrels (OOIP) to improve ultimate recovery by only 5%, an additional 20 million barrels could be attributable to the original BOAST. Waterflood projects recover 5% to 30% of the original oil and success is very dependent on good placement of wells and proper water injection rates. If each copy were used twice on average to improve ultimate recovery by 3% on average, a much higher 360 million barrels is estimated. This second, higher estimate is just as plausible as the first.

In the annual TORIS run (Jan.-Mar. 1995), the corporate and personal federal income tax attributable to the production of a barrel of oil by EOR methods averaged $2.57/bbl for a referenced 40 degree API oil priced at $17.50/bbl. Therefore, $56.4 million federal tax revenue is estimated for the 20 million barrels from the use of BOAST. Local recollection is that the rights to BOAST cost the government $50,000 or $1,128 Federal revenue/$ for BOAST.

Q70d. Please provide detailed documentation of the claim that using UTCHEM results in "[b]etter management of reservoirs [and] has saved these companies more than $23 million, $8 million of which will flow back to the U.S. Treasury."

A70d. Statistics are not collected on how or when this product is used. We believe the following analysis might reveal the potential impact of this technology: About 20 companies are participating in the University of Texas at Austin UTCHEM project. If each of these 20 companies do only 15 well treatments that typically recover in the range of additional 10,000 barrels, an additional 3 million barrels is produced which at $17.50/bbl is $53 million in additional gross sales or $46 million net of royalties. Successful gelled polymer treatments return roughly $2 for $1 in increased production and savings from reduced fluid handling. The use of the sophisticated UTCHEM simulator should increase the performance of the typical treatment as well as reduce the number of unsuccessful treatments. Gelled treatments are just one potential application for this simulator. It is designed to accommodate full field simulations of waterflooding to trace tests.

Q70e. Please provide detailed documentation of the claim that "use of these processes will generate a 3-billion barrel increase in potential reserves."

A70e. The potential for carbon dioxide miscible recovery from domestic resources has been estimated numerous times. One recent estimate was published in *An Evaluation of Known Remaining Oil Resources in the United States* by the Interstate Oil and

Gas Compact Commission, DOE report number DOE/BC/14431-1. In Table V-1A, page V-4, estimated increment reserve additions from carbon dioxide miscible flooding, advanced technology case is estimated at 3.05 billion barrels with oil prices at $28/bbl. MASTER can also simulate hydrocarbon miscible and nitrogen miscible processes which have not been rigorously estimated. Since these two processes are amenable to offshore as well as onshore resource, the additional potential could double the target. Currently hydrocarbon and nitrogen miscible projects account for 632,000 barrels per day of crude production (O&GJ, Sept. 25, 1994) including 115,000 barrels per day of incremental enhanced production.

A70f. Does DOE hold the patents for (i) BOAST, (ii) UTCHEM, and (iii) MASTER, and if not, why not?

A70fi. No relevant patent exists. BOAST is a black oil reservoir computer simulator. DOE purchased the copyrights for the computer code from the developer with the understanding that the code would become public domain software. Prior to the release of BOAST, computerized reservoir simulation could only be done by the most sophisticated of operators that had financial depth. The availability of the black oil simulator BOAST to universities as a training tool as well as industry has made the use of computerized reservoir simulation more wide spread and less expensive.

A70fii. No relevant patent exists. UTCHEM is a sophisticated reservoir computer simulator that models the chemical interactions between injectants, the reservoir rock, and the reservoir fluids. It is a continually evolving simulator that incorporates advances in the fundamental understanding of interactions. The Department of Energy has served as a catalyst and major contributor to the University of Texas at Austin's research consortiums that generated the UTCHEM software code. While the University of Texas owns the copyrights to UTCHEM, DOE has use of the code and can pass the code to other contractors for DOE sponsored research. Making the software code public is a goal for a new project.

A70fiii. No relevant patent exists. MASTER is a composition simulator that was specifically designed to model miscible flooding processes. The development of the code was specifically commissioned by DOE to encourage the development of miscible flood projects by non-major operators. The computer code is in the public domain. This allows its use in Universities as a training tool and wide dissemination within the industry.

Q70g. If DOE holds the patents for (i) BOAST, (ii) UTCHEM, or (iii) MASTER, what licensing agreements does DOE have with private sector firms? Which firms?

A70g. Not Applicable–see above.

Q70h. If DOE has licensing agreements for (i) BOAST, (ii) UTCHEM, or (iii) MASTER with private sector firms, what licensing fees has DOE received from such licenses?

A70h. Not Applicable–see above.

Q70i. Please provide evidence that (i) BOAST, (ii) UTCHEM, or (iii) MASTER would not have been developed and commercialized without the DOE funding.

A70i. Please refer to the table above, which details private sector investment associated with the DOE program. A feasibility study was conducted about 1978 and three models were developed by 1983. The value of the models were first recognized during the National Petroleum Council's analysis of the potential for enhanced oil recovery in 1983 and 1984. The NPC commissioned the development of three additional models. These were used to generate a landmark study on the potential of EOR. The results of this study encouraged the domestic industry to incorporate EOR into their production development strategies until the oil price crash in 1986. The subsequent development of BOAST II, BOAST-VHS, et al, with DOE's cooperation and funding, was designed to provide technology needed by industry to assist in applying the results from DOE's oil recovery projects, and they are accomplishing that purpose. Although industry has developed some simulators, they still have not developed a complimentary, competitive or any other set of predictive models–they use DOE's.

Q71. The following "success story" appears on page 187 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Foam Fracturing of Gas Reservoirs**
>
> **Another technique for creating fractures in a gas reservoir is to inject foam under high pressure into the wellbore. Foam has an advantage over high pressure water injection because it does not create as much damage to the formation, and well cleanup operations are less costly. Before the mid-1970s, use of foam fracturing was limited almost exclusively to Canada and the Rocky Mountain region. The Department's research in the late 1970s extended the technology to the Eastern region of the country, where effective fracturing is required to produce commercial quantities of gas from shale formations. More than 50 stimulation tests were conducted to apprise oil and gas operators in 8 Eastern States of the technique's merit. Once it was shown that the process accelerates the rate of natural gas production from these wells by nearly 200 percent, the foam fracture process became the dominant stimulation technique for marginal gas wells in the United States."**

Q71a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A71a. This technology was developed nearly 20 years ago. Total DOE R&D investment in foam fracturing technology was $5.0 million. Columbia Gas, Mitchell Energy, Kentucky/West Virginia Gas, Thurlow Weed and Associates, and Muriel Welch Inc. were the original recipients of the funding.

Q71b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A71b. Total industry investment associated with the DOE program in foam fracturing technology associated with DOE's original investment was $10.0 million. Beyond the DOE's early cost shared demonstrations, the industry now spends 10's of millions of dollars annually using foam fracturing technology today.

Q71c. Please provide detailed documentation of the claims that "that the process accelerates the rate of natural gas production from these wells by nearly 200 percent."

A71c. The best evidence of positive improved production results is reflected in the fact that industry adopted foam fracturing as the preferred method of stimulation in tight low permeability gas formations throughout the United States. We believe DOE's R&D effort was instrumental in accelerating the introduction of foam fracturing technology for improving gas production in low permeability gas formations.

Q71d. Does DOE hold the patents for this technology, and if not, why not?

A71d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q71e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A71e. DOE does not own the patent for this technology.

Q71f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A71f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q71g. Please provide evidence that the foam fracturing of gas barriers technology would not have been developed and commercialized without the DOE funding.

A71g. We believe DOE funding contributed to the accelerated use of the technology's by the industry. The foam fracturing concept was a revolutionary, unproved advancement of traditional stimulation technologies which used water fracturing or gelled explosives. Federal government funding was a catalyst which, without question, accelerated the use of the technology by domestic producers. Reduction of risk and uncertainty related to the rapid cleanup and improved early production of gas convinced the operators and the availability of supply of capital from risk averse lending institutions was improved.

Q72. The following "success story" appears on page 187 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Enhanced Oil Recovery Predictive Models**
>
> **The Department of Energy, in partnership with the National Petroleum Council and Software/Intercomp, has developed easy-to-use, predictive computer models for numerous enhanced oil recovery techniques. More than 1,000 copies of the PC-based predictive models have been distributed to oil field operators, drilling and service companies, consultants, researchers, and several major oil companies. The use of these models has saved the industry $400 million by screening out uneconomical projects."**

Q72a. Please detail, by appropriate fiscal year, the DOE R&D investment in these computer models, including a listing of the recipients of this funding.

A72a. Information not available because the original computer codes were done between 1978 and 1984. Collective memory is $4.5 million by Gury Federal and InterComp.

Q72b. Please detail, by appropriate fiscal year, private sector investment in these computer models.

A72b. Detailed financial information about private sector investment associated with the DOE program is not available. National Petroleum Council contracted for three predictive models [polymer, in situ combustion and immiscible carbon dioxide flooding] about 1982-1984 which were given to the DOE's TORIS program. Venezuela contracted Scientific Software-Intercomp to write manuals for the predictive models in 1985 and 1986 and these document were given to DOE in exchange for Venezuelan use of the models.

Q72c. Please provide detailed documentation of the claim that "use of these models has saved the industry $400 million by screening out uneconomical projects."

A72c. Frequently, when a company obtains the predictive models, they use them to screen all their properties for additional consideration. Those properties that might be considered for Enhanced Oil Recovery would be subjected to a detailed study or a pilot project that might cost $100,000 to $1,000,000. Using $200,000 as an average, if each of the distributed models were used to prevent 2 of these studies, this would be $400 million not spent on uneconomic projects.

The $200,000 average cost avoidance per property is based on an analysis of the cost of EOR pilots and field-scale projects using published data that is maintained in the EOR project database (hundreds of projects) and from 27 DOE-industry cost shared projects completed in the mid-1980's. That data shows that pilot-scale EOR trials (size is 10 acres to 80 acres, except polymer flood pilots that are 600 acres) capital costs range from $1.5 million for polymer flooding to $6 million for thermal recovery. The $200,000 average cost avoidance per property is, therefore, an extremely conservative estimate of the industry savings associated with the use of EOR predictive models.

Q72d. Does DOE hold the patents for these computer models, and if not, why not?

A72d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q72e. If DOE holds the patents for these computer models, what licensing agreements does DOE have with private sector firms? Which firms?

A72e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q72f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A72f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q72g. Please provide evidence that these computer models would not have been developed and commercialized without the DOE funding.

A72g. The initial concept of the EOR predictive models was developed to answer DOE policy questions. A feasibility study was conducted about 1978 and three models were developed by 1983. The value of the models were first recognized during the National Petroleum Council's analysis of the potential for enhance oil recovery in 1983 and 1984. They commissioned the development of three additional models. These were used to generate a landmark study on the potential of EOR. The results of this study encouraged the domestic industry to incorporate EOR into their production development strategies until the oil price crash in 1986.

Q73. The following "success story" appears on page 188 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Integrated Gasification Combined Cycle**
>
> **Capitalizing on a successful gasification program, the Department of Energy has provided the foundation for an advanced power generation system that will be the powerplant of the 21st century. Advanced integrated gasification combined cycle (IGCC) technology will have system efficiencies ranging from 41 to 52 percent. Emissions of sulfur dioxide and nitrous oxide are limited to less than one-tenth of that allowed by New Source Performance Standards, carbon dioxide emissions are reduced by 35 to 45 percent, and solid waste is reduced by 40 to 50 percent. The IGCC powerplant is cost-competitive to build, in fact it is projected to be significantly less costly than conventional powerplants, while the cost of production would be reduced by 10 to 20 percent. At present, the Department's Clean Coal Technology program will provide the IGCC system entry into the global market as a top-ranking clean coal power generation technology with a potential global market of more than $400 billion in capital investment by 2030, and about $150 billion in the domestic market."**

Q73a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

Q73b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A73a and A73b. DOE and private sector investment associated with the DOE program by appropriate fiscal year is provided in the following Table. Also, in this Table, the major recipients are identified.

Estimated R&D Investment Related to IGCC Development*

Period FY	DOE ($ millions)	Industry ($ millions)	Major Recipients
1976	40	4	Battelle Memorial Institute (BMI), Bell Aero Space (BA), Bituminous Coal Research (BCR), CF Braun (Braun), Conoco Coal Development Co. (CCDC), Exxon Research & Engineering Co (Exxon), Institute of Gas Technology (IGT), Memphis Light, Gas & Water (MLGW), Foster Wheeler (FW), Westinghouse (West), Rockwell (Roc), Combustion Engineering (CE)
1977	45	5	BMI, BA, BCR, Braun, CCDC, Exxon, IGT, MLGW, FW, West, Roc, CE
1978	60	6	BMI, BA, BCR, Braun, CCDC, Exxon, IGT, MLGW, FW, West, Roc, CE
1979	55	6	BA, BCR, Exxon, IGT, MLGW, FW, West, Roc, MW Kellogg (MWK), CE
1980	46	5	BA, BCR, Exxon, IGT, MLGW, FW, West, Roc, MWK, CE
1981	52	5	Exxon, IGT, MLGW, FW, West, Roc, MWK, CE
1982	49	5	IGT, West, Roc, MWK, CE, TRW, General Electric (GE)
1983	35	4	IGT, West, TRW, GE, Avco, Advanced Fuel Research (AFR), Brigham Young Univ. (BYU)
1984	30	3	IGT, West, TRW, GE, Avco, AFR, BYU, North Dakota ERC (UNDERC), Brookhaven National Lab (BNL)
1985	24	2	IGT, TRW, GE, Avco, AFR, BYU, UNDERC, BNL, Roc, Kellogg-Rust-Westinghouse (KRW), Mountain Fuel Resources (MFR)
1986	32	3	IGT, TRW, GE, Avco, AFR, BYU, UNDERC, BNL, KRW, Allis-Chalmers (AC), United Coal Corp. Research Center (UCCRC)
1987	20	2	IGT, GE, AFR, BYU, UNDERC, BNL, West, Texaco, Calderon Energy Co. (Calderon)
1988	15	2	GE, AFR, BYU, UNDERC, BNL, West, Texaco, KRW, MWK, Calderon, Research Triangle Institute (RTI)
1989	12	1	GE, AFR, BYU, UNDERC, West, Texaco, Calderon, RTI Lawrence Livermore Labs (LLL)
1990	14	1	GE, AFR, BYU, UNDERC, West, Texaco, Calderon, RTI, LLL
1991	16	2	GE, AFR, BYU, UNDERC, West, Texaco, Calderon, RTI, LLL, Southern Company Services Wilsonville (SCS), MTCI

Estimated R&D Investment Related to IGCC Development* (Continued)

Period FY	DOE ($ millions)	Industry ($ millions)	Major Recipients
1992	12	1	GE, AFR, BYU, UNDERC, West, Texaco, Calderon, RTI, SCS, MTCI, CRS Sirrine (GPIF)
1993	20	2	GE, AFR, BYU, West, UNDERC, RTI, SCS, GPIF
1994	27	3	GE, AFR, BYU, West, UNDERC, RTI, SCS, GPIF, MWK
1995	28	3	GE, AFR, BYU, West, UNDERC, RTI, SCS, GPIF, MTCI
1996	22	3	GE, RTI, UNDERC, SCS, Hampton University (HU), SRI International (SRI), Ames National Lab (Ames)
1997	24	3	GE, RTI, UNDERC, SCS
Total	678	71	

*Investment does not include funding for the Clean Coal Technology and Synfuel Corporation demonstrations which were funded under separate appropriation.

Q73c. Please provide detailed documentation of the claims that "a potential global market of more than $400 billion in capital investment by 2030, and about $150 billion in the domestic market."

A73c. New Energy Information Administration projections have become available since the numbers for this success story were developed. These new projections show a slowdown in new domestic coal plant construction, especially in the next 15 years. Nevertheless, the projected potential overall market is still large and consistent with the claim that the IGCC technology represents a major emerging success story. Projected capital investment through the year 2030 is summarized in the following table. These numbers indicate a domestic market (sales in U.S. and abroad) through 2030 of $117 billion ($34 billion discounted), out of a total worldwide market of $479 billion ($119 discounted).

IGCC CAPITAL INVESTMENT SUMMARY		
	$1996, Billions	
	As Spent $	Discounted $ at 7%
U.S. IGCC Plants	97.6	29.6
U.S. IGCC Exports	19.1	4.4
Total U.S. Investment	116.7	34.1
Total World (Incl. U.S.)	479.2	118.6

Assumptions:

- Based on program goals, IGCC capital cost (1996$) estimated at $1,200/kw in 2000 and $1,050/kw in 2010.

- IGCC begins to enter market in 2005 with a 10% market share of new coal-fired market demand, and consistent with its projected superior economics and environmental performance relative to existing coal-fired options, grows linearly to

100% of new coal-fired demand by 2015. Demand does not include retirements or repowering.

- Between 2015 and 2020, IGCC ramps linearly to capture baseload U.S. gas-fired power demand. This is based on the assumption that gas prices continue to increase after 2015 consistent with the 2010-2015 increase shown in EIA's 1996 Annual Energy Outlook. From 2020 to 2030, IGCC captures total fossil-fired baseload market.

- IGCC begins to enter remaining world market in 2005 with 10% market share of new coal-fired market demand, growing linearly to 100% of new coal-fired demand by 2015. After 2015, IGCC captures 100% of new coal-fired demand. Export market is 25% of world market. U.S. captures 20% of export market. Demand does not include retirements or repowering.

- U.S. domestic market through 2015 is based on Energy Information Administration (EIA) 1996 Annual Energy Outlook, which is also the basis for 2015-2030 U.S. extrapolations.

- World market through 2010 is based on EIA 1995 International Energy Outlook, which is also the basis for 2010-2030 world extrapolations.

Q73d. Does DOE hold the patents for this technology, and if not, why not?

A73d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q73e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A73e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q73f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A73f. See answers to sub-questions (e) and (f). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q73g. Please provide evidence that the integrated gasification combined cycle technology would not have been developed and commercialized without the DOE funding.

A73g. IGCC is in later stages of a 25 to 30 year R&D-to-commercial cycle. The "developmental cycle" begins with applied research addressing concept validation, followed by an R&D cycle that leads to demonstration-scale projects and initial commercialization which requires continued support addressing product improvements such as reducing capital and operation costs, and enhanced performance leading to a more economically competitive technology. The developmental cycle has very low industrial investment during the high-risk R&D phase, and considerable investment in the demonstration phase. However, it appears Texaco gasification technology is making its way into commercial markets. The Texaco gasification technology has recently been installed at an El Dorado, Kansas refinery to gasify petroleum coke and other refinery wastes. The gas produced in the gasifier is blended with natural gas to fuel a combustion turbine. Texaco has announced five (5) Italian refineries are planning to construct gasification projects to gasify heavy residue from the refineries to produce power, chemicals, fuels and industrial gases. Even though these identified projects do not use coal feed, the knowledge gained from the plants will enhance the commercialization of IGCC.

The DOE has successfully addressed and resolved many technical barriers, thus allowing the development of a high efficiency power generation plant with much reduced environmental emissions of pollutants such as sulfur dioxide, nitrogen oxides, carbon dioxide and solid waste. Historically, industrial support of R&D concepts does not extend beyond a 5 year horizon, and support of high-risk R&D activities is minimal. Documentation is provided by examination of the IGCC funding profile addressed in sub-question (b) above. Prior to the initiation of the Clean Coal Technology program, industrial cost share has been around 10 percent or less during the R&D development cycle. When government funding was reduced or eliminated, industry did not continue development.

Presently, Destec, Texaco, and KRW advanced IGCC power systems are just starting or nearing startup of commercial scale IGCC demonstrations under the DOE/FE Clean Coal Technology Program. Although Texaco gasification technology was demonstrated at the coolwater demonstration plant at Daggett, California in a nominal 100 MW IGCC plant in the 1984-1989 time frame, the relatively high capital and operating costs discouraged the utility industry from commercializing the technology. These three projects are possible as least cost electric supply options only because of DOE cost sharing for these large capacity first-of-a-kind plants being built and initially operated under the CCT program. After the 3 to 5 year demonstration period, it is expected that these CCT plants will be operated commercially for their remaining plant life. Maximum DOE funding is 50 percent of demonstration cost.

The advanced, high efficiency subsystems and components included in these plants would not be available nor would the technology of the projects have been sufficiently mature to meet the CCT selection criteria without DOE funded R&D. DOE funding ranged from 80% to 100% of developmental cost depending on maturity level and industry's competitive willingness to co-fund the R&D.

More DOE funding is required to stay-the-course of the remaining 5 to 10 years of IGCC's commercial success cycle. The next 10 year period requires government leadership in product improvements that will lower capital cost and additionally improve plant efficiencies. If the U.S. were to ignore the needs of this product cycle and abandon IGCC at this critical time, other governments will intercede at a relatively low cost to harvest the U. S. IGCC investment. If DOE is not funded to retain technology leadership, Government aided foreign industries will surely capture today's emerging foreign markets and penetrate much of the future U.S. markets at the expense of U. S. jobs.

Q74. The following "success story" appears on page 188 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Super 9 Chrome Alloy

During the 1980s, Department of Energy research and development was instrumental in the development of a superstrong alloy called Super 9 Chrome, which is now used worldwide as an industry standard for improving the safety and reliability of equipment in coal-fired powerplants. This 9 percent chromium and 1 percent molybdenum alloy improves the life and performance of equipment under the severe operating temperature, pressure, and corrosion conditions typical of fossil fuel plants. Department of Energy scientists received the prestigious R&D 100 Award for this technology, which has since been incorporated into American Society of Mechanical Engineers Boiler and Pressure codes and transferred directly to industry for commercial applications. Sales of this product exceed $100 million to date. Use of this alloy has enabled an increase in coal-fired powerplant efficiency of more than 3 percent, which results in a savings of more than $1.7 million per year in fuel costs in a typical 500 MW powerplant. The higher efficiency also results in reduced emissions of sulfur dioxide, nitrogen oxides, and particulates, as well as reduced production of carbon dioxide by 280,000 tons per year."

Q74a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A74a. See attached table. [*Note: DOE did not provide this table.*]

Q74b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A74b. See attached table, which presents private sector investment associated with the DOE program in this technology. [*Note: DOE did not provide this table.*]

Q74c. Please provide detailed documentation of the claims that "[s]ales of this product exceed $100 million to date. Use of this alloy has enabled an increase in coal-fired powerplant efficiency of more than 3 percent, which results in a savings of more than $1.7 million per year in fuel costs in a typical 500 MW powerplant. The higher efficiency also results in reduced emissions of sulfur dioxide, nitrogen oxides, and particulates, as well as reduced production of carbon dioxide by 280,000 tons per year."

A74c. The referenced sales and cost savings estimates are included in the section entitled "Super 9 Chrome Alloy," and that section is stated here to assure proper context, viz:

> "During the 1980s, Department of Energy research and development was instrumental in the development of a superstrong [steel] alloy called Super 9 Chrome, which is now used worldwide as an industry standard for improving the safety and reliability of equipment in coal-fired power plants. This 9 percent chromium and 1 percent molybdenum alloy improves the life and performance of equipment under the severe operating temperature, pressure, and corrosion conditions typical of fossil fuel plants. Department of Energy scientists received the prestigious R&D 100 Award for this technology, which has since been incorporated into American Society of Mechanical Engineers Boiler and Pressure [Vessel] codes and transferred directly to industry for commercial applications. **Sales of this product exceed $100 million to date**. Use of this alloy has enabled an increase in coal-fired power plant efficiency of more than 3 percent, which results in a **savings of more than $1.7 million per year in fuel costs in a typical 500 MW power plant**. The higher efficiency also results in reduced emissions of sulfur dioxide, nitrogen oxides, and particulates, as well as reduced production of carbon dioxide by 280,000 tons per year."

The bases for the estimated sales of the so-called Super 9 Chrome alloy, which is often referred to as T91 in tubing and as P91 in piping, were restricted to publicly available information enumerated in References 1-3, below, which resulted in a conservative, i.e., low, estimate of the dollar value of the sales. Additional proprietary information was obtained from producers and fabricators of the alloy, but was not used in the estimate, nor will it be used here except to state that this information confirmed the conservatism of the estimate.

The earliest sale considered in the estimate was for 37 tons and was made by the Babcock and Wilcox Company to Southern California Edison Company in 1984. In 1988, Sumitomo Metal Industries, a Japanese steel company, and Mannesmann Aktiengesellschaft, a German company, sold components of this alloy for use in a coal-fired power plant, the J. M. Stuart Station in Aberdeen, Ohio, owned and operated by Dayton Power & Light Co. The total weight of the components made from this alloy was 540 tons, or 1,080,000 pounds. This was one of the bits of data used in making the estimate of total sales. Vallourec Industries, a French supplier of the alloy, has reported in its publication, *The T91 Book*, 1990, that by 1990, over 5000 tons of Alloy 91 had been used in boilers throughout the world. Vallourec Industries' first sale in 1986 was for 60 tons of T91 to Bharat Heavy Electrical Ltd. in India. Several other companies, including Mitsubishi Heavy Industries of Japan and Wyman Gordon Forgings, are also major suppliers of the alloy or components made from the alloy. For example, Wyman Gordon Forgings (formerly Cameron Forged Products Division of Cooper Industries) has made significant sales of the alloy including sales to a Korean utility for six 500 MWe power plants. However, the basis for the sales estimate used in *Success Stories* was limited to the 540 tons used in the Dayton Power & Light Co. plant and the supply by Vallourec Industries of the alloy to sixty six plants by 1994. Depending on the component purchased, the price of the alloy varies somewhat, but a cost of $2.00 per pound was used as the basis for the estimate.

To obtain an estimate of minimum total sales of the alloy, the weight of the alloy used in the J. M. Stuart plant, 540 tons, was multiplied by the number of plants, sixty seven, identified as having been supplied this alloy by <u>only two</u> of the suppliers, to obtain a conservative tonnage figure of 36,180 tons. The cost per ton, $4,000 was obtained simply by multiplying the price per pound figure, $2.00/lb, referenced above by 2,000 lb, the number of pounds in a ton. The product of the minimum tonnage multiplied by the referenced price per ton is $144,720,000 million. **For the purposes of the *Success Stories*, sales of the product were stated to "...exceed $100 million to date." This estimate has been confirmed through proprietary discussions with industrial sources to be very conservative, with actual sales greatly exceeding this figure. Subsequent to the notification of a possible General Accounting Office audit of *Success Stories*, several producers and fabricators were contacted to determine if sales figures would be provided; as a result, nonproprietary information (see Reference 4, above) has been received from three companies regarding their production. Vallourec Inc., has produced 9000 metric tons (1 metric ton = 2,205 lb); Sumitomo Metal Industries, Ltd. has produced 10,087.3 tons, and Ellwood Quality Steels Company has produced 7,200 tons. The total sales for these three companies is 54,416,000 lb. Sales prices vary from $2.00-$2.50/lb depending on product form, but using $2.00/lb, the revenues from the sales by the three companies would be $108,832,000.00. There are several other major producers such as Mitsubishi Heavy Industries, Inc., and Wyman Gordon Forgings that have not provided nonproprietary information at this time. We have obtained**

proprietary data from one other company that indicate sales of 500 metric tons in 1994 and 3,300 metric tons in 1995, or about $18 million for the two years.

References

1. Irving, Bob, "A Promising Chrome-Moly Steel Returns to American Shores," pp. 35-40 in *Welding Journal*, Vol. 70, Number 12, December 1991.

2. Vallourec Industries, France, *The T91 Book*, 1990; *The P91 Book*, 1992.

3. Blum, R, "Materials Development for Power Plants with Advanced Steam Parameters)–Utility Point of View," pp. 15-30 in *Materials for Advanced Power Engineering, 1994, Part I*, D. Coutsouradis, et al., eds., Kluwer Academic Publishers (1994).

4. Brown, K., Vallourec Inc., Houston, Texas, personal communication dated October 30, 1995, to V. K. Sikka, ORNL; Iseda, A., Sumitomo Metal USA Corporation, personal communication dated November 1, 1995, to Vinod Sikka; and Martonik, M. C., Ellwood Quality Steels Company, personal communication dated November 1, 1995 to Vinod Sikka.

With regard to efficiency improvements and the concomitant increases in efficiency, fuel savings, and pollutant decreases, several sources were used to justify the point of view that this alloy was responsible for these improvements, but for the purposes of the *Success Stories*, a reference source was used. That source was R. Blum, "Materials Development for Power Plants with advanced Steam Parameters)Utility Point of View," pp. 15-30 in *Materials for Advanced Power Engineering, 1994, Part I*, D. Coutsouradis, et al., eds., Kluwer Academic Publishers, 1994. This author, an employee of the Danish electric utility, ELSAM, stated that increases in efficiency of coal fired steam power plants over the 42-45% possible using the best (other than T91) conventional steels required material with a higher creep strength for thick section components. Further, Blum stated that "Following approval of the ferritic steel grade T91, developed by the Oak Ridge National Laboratory in the U. S. as a construction material for power plant superheater tubes, pipes, and forgings, it became possible to increase the steam temperature and pressure up to approximately 580°C and 300 bar." Plants operating at these conditions, according to Blum, have efficiencies of 47%. For *Success Stories*, the mid point efficiency, 43.5%, of the best of the earlier plants was compared with the 47% possible using T91, yielding an efficiency increase of 3.5%, or as stated in *Success Stories*, "...more than 3%."

In the calculation of fuel savings for a "typical" 500 MW power plant, an initial efficiency of 35%, which is near the average for modern U.S. plants, was assumed with an increase to 38%, i.e., the 3% increase discussed above resulting from the use of Alloy 91. Additional assumptions included the use of a bituminous coal with a heating value of 12,000 Btu/lb, coal cost of $16/ton, and plant operation at full power for 75% of the year to account for planned and unplanned outages, power reductions, etc. Based on these assumptions, such a plant would burn 5,142 tons of coal per day or 1,407,623 tons of coal per year at 35% efficiency. At 38% efficiency, such a plant would burn 4,737 tons of coal per day or 1,296,754 tons per year. Thus, total savings of fuel (coal) would be 110,869 tons of coal per year, which would translate to a savings of $1,773,904 per year in fuel costs, or "...**savings of more than $1.7 million per year in fuel costs....**" in *Success Stories*, based on the assumption of a cost of coal of $16/ton, which is itself a conservative figure.

Assumptions that formed the basis for the statement that this "...higher efficiency also results in ... reduced production of carbon dioxide by 280,000 tons per year" included the use of a bituminous coal with 69% carbon content. One mass unit of carbon when burned will create 3.67 mass units of carbon dioxide. Thus, the reduction in coal usage, i.e., the fuel (coal) savings, of 110,869 tons translates to a reduction of carbon emissions of 76,500 tons, i.e., 69% of the coal reduction, and this in turn translates to a reduction in carbon dioxide emissions of 280,500 tons per year, or a "...reduced production of carbon dioxide by 280,000 tons per year" as stated in *Success Stories.*

Q74d. Does DOE hold the patents for this technology, and if not, why not?

A74d. No. Although invention disclosures were prepared and submitted, at the time the invention was made, to DOE's operating contractor, Union Carbide Corporation, of Oak Ridge National Laboratory, no patent application was ever made. The philosophy of the DOE at that time was to file for patents on only those inventions related to major DOE missions. That philosophy changed with the passage of the Bayh-Dole and Stevenson-Wydler acts, and with the change in operating contractor (from Union Carbide Corporation to Martin Marietta Energy Systems) for the Oak Ridge National Laboratory.

Q74e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A74e. Not applicable since neither DOE nor Lockheed Martin Energy Research Corporation holds patents on the alloy.

Q74f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A74f. Not applicable since neither DOE nor Lockheed Martin Energy Research Corporation holds patents on the alloy.

Q74g. Please provide evidence that the Super 9 chrome alloy would not have been developed and commercialized without the DOE funding.

A74g. The alloy had previously been developed for a major DOE mission, the liquid metal cooled fast breeder reactor. That development was a joint effort of, primarily, Oak Ridge National Laboratory and Combustion Engineering, Inc. Since development of the liquid metal cooled fast breeder reactor was abandoned by the U. S., the alloy has not been used in the U. S. for that application. The DOE Fossil Energy development effort was specifically to confirm, demonstrate, and facilitate ASME Code approval of the Super 9 chrome alloy for fossil energy applications.

The AR&TD Materials Program investment and the complementary private sector investments were directly responsible for the development of data that led to ASME Code approval for coal-fired power generation and the world-wide use of the alloy in coal-fired power plants. All of the sales reported in "Success Stories" were for coal-fired power generation applications.

75. The following "success story" appears on pages 188 and 189 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Atmospheric Fluidized Bed Coal Combustor

The most significant advance in coal-fired boiler technology in more than half a century, the Fluidized Bed Coal Combustor has been the commercial success story of the last decade in the power generation business. This state-of-the-art, low-polluting combustion system technology has progressed into even larger scale utility applications. To date, more than $6 billion in domestic sales and $2 billion in foreign sales have been achieved through this Department of Energy investment. Domestic sales alone translate into nearly 250,000 jobs. Every major U.S. boiler manufacturer now offers a fluidized bed combustor in its product line."

Q75a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A75a. The following is the yearly funding levels ($83 million total from 1981-1995):

Fiscal Year	Dollars (Millions)	Major Recipients
1981	10.328	Foster Wheeler
1982	9.549	Combustion Engineering
1983	4.771	Combustion Power
1984	1.368	Keeler Dorr-Oliver
1985	18.545	TVA (B&W, CE, others)
1986	16.614	Pyropower (Colorado-Ute)
1987	3.263	Donlee
1988	3.375	MTCI
1989	2.688	EPRI
1990	3.128	Riley Stoker
1991	2.383	MIT, EER
1992	4.102	Donlee
1993	0.097	Donlee
1994	1.975	MTCI
1995	0.990	Donlee
Total	83.176	

Q75b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A75b. Private sector investment associated with the DOE program in this technology cannot be determined. Most companies consider it a trade secret and do not wish to share this information.

Q75c. Please provide detailed documentation of the claims that "[t]o date, more than $6 billion in domestic sales and $2 billion in foreign sales have been achieved through this Department of Energy investment. Domestic sales alone translate into nearly 250,000 jobs."

A75c. According to The U.S. Fluidized Bed Boiler Directory (1995 Edition), at the end of 1994, at least 5,870.1 MWe of fluidized bed boilers were sold in the U.S. Adding the sales in 1995 and assuming an average sale cost of $1,000 per kilowatt (the current price is $1,200 or more per kilowatt installed), the total domestic sales will be well over $6 billion. This fact was also confirmed by Mr. Jason Makansi, Editor-in-Chief of Power Magazine.

K&M Engineering and Consulting Corporation of Washington provides market assessments for a number of international clients. K&M agreed to share its findings, in part, with the Department of Energy. According to its data base, 2,549 MWe capacity of circulating fluidized bed combustion boilers were sold in 1995. Assuming an average cost of $1,000 (the cost for labor and materials may be cheaper overseas) per kilowatt, the total sale will be more than $2 billion dollars.

The statement of the translation of the 6 billion dollars in domestic sales into nearly 250,000 jobs is based on a published multiplier. DOE arrived at this number by using a regional input-output model multiplier published by the Bureau of Economic Analysis, Department of Commerce (40,000 jobs per billion dollars of investment) and applying the multiplier to the $6 billion domestic sales. Our data base indicates that our major competitors in other countries have also sold a respectable amount of circulating fluidized bed combustion boilers.

Q75d. Does DOE hold the patents for this technology, and if not, why not?

A75d. Many contractors have been involved in development and demonstration of this technology, and pursuant to federal statutes and policies governing ownership of patents, these contractors have generally been allowed to retain any invention rights. DOE does own several related patents, e.g., USP 4,867,079, and at least two DOE-owned patents were allowed to expire after licensing interest failed to materialize.

Q75e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A75e. The related DOE-owned patents have not been licensed.

Q75f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A75f. None.

Q75g. Please provide evidence that the atmospheric fluidized bed coal combustor technology would not have been developed and commercialized without the DOE funding.

A75g. All indications are that fluidized bed coal combustors would not have been commercialized in a cost-effective manner to the extent that it has to date without DOE funding, and most certainly it would not have been commercialized as rapidly. The basic AFB technology has been around since the 1940's with expertise in various areas such as boiler manufacturing, combustion technology and material processing residing in different European countries. The U.S. companies are credited with putting the best of these technologies together integrating the systems for successful combustion of coal for the power producing industry. This integration would not have taken place without U.S. Government support.

Many of the key players in fluidized bed coal combustion did not have the resources to support needed levels of research in a variety of technically challenging areas, which included solid feeding, ash withdrawing, pollution control, post-combustion pollution control, waste disposal and utilization. DOE made a significant investment in high risk R&D that successfully identified, addressed and resolved many technical barriers, thus allowing the development of an environmentally friendly technology that could use a variety of coals, including in smaller-scale applications, to meet emerging national needs.

Q76. The following "success story" appears on page 189 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Low Nitrogen Oxide Burner**
>
> **With nitrogen oxides targeted for reduction by the 1990 Clean Air Act Amendments, Low Nitrogen Oxide Burner technology developed by the Department of Energy and Altex Technologies Company has rapidly found its way into the power market. Domestic sales to date total more than $250 million, supporting 1,800 U.S. jobs. For wall-fired boilers, nitrogen oxide reduction levels of 35 to 40 percent are achieved at a capital cost of about $20 per kilowatt hour and a levelized cost of about $280 per ton of nitrogen oxide removed. For tangentially fired boilers, the same degree of nitrogen oxide reduction is achieved at a capital cost of $15 to $20 per kilowatt hour and a levelized cost of $220 to $350 per ton of nitrogen oxide removed. These costs are significantly lower than other options."**

Q76a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A76a. Note: Funding not allocated by Fiscal Year.

Southern Company Services, subcontractor - Foster Wheeler
Project Duration: 1988-1996
DOE Funding: $5.5 million
Burner Configuration: wall fired

Southern Company Services, subcontractor - Asea Brown-Boveri
Project Duration: 1988-1994
DOE Funding: $4.4 million
Burner Configuration: T-Fired

EER, subcontractor - Foster Wheeler
Project Duration: 1990-1995
DOE Funding: $2.4 million (estimated from total integrated project of $8.9 million contributed by DOE)
Burner Configuration: wall-fired

B&W
Project Duration: 1990-1995
DOE Funding: $5.4 million
Burner Configuration: Low NO_x Cell Burner

Total DOE Funding: $19.7 million

Q76b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A76b. The following table presents private sector investment associated with the DOE program.

Note: Funding not allocated by Fiscal Year.

Southern Company Services, subcontractor - Foster Wheeler
Project Duration: 1988-1996
Private Sector Funding: $8.2 million
Burner Configuration: wall fired

Southern Company Services, subcontractor - Asea Brown-Boveri
Project Duration: 1988-1994
Private Sector Funding: $4.7 million
Burner Configuration: T-Fired

EER, subcontractor - Foster Wheeler
Project Duration: 1990-1995

Private Sector Funding: $2.4 million (estimated from total integrated project of $8.9 million contributed by private sector)
Burner Configuration: wall-fired

Public Service of Colorado, subcontractor - B&W
Project Duration: 1990-1996
Private Sector Funding: $2 million (estimated from total integrated project of $13.7 million contributed by private sector)
Burner Configuration: wall-fired burner utilized in a down-fired boiler configuration

B&W
Project Duration: 1990-1995
Private Sector Funding: $5.8 million
Burner Configuration: Low NO_x Cell Burner

Total Private Sector Funding: $22.0 million

Q76c. **Please provide detailed documentation of the claims that "[d]omestic sales to date total more than $250 million, supporting 1,800 U.S. jobs. For wall-fired boilers, nitrogen oxide reduction levels of 35 to 40 percent are achieved at a capital cost of about $20 per kilowatt hour and a levelized cost of about $280 per ton of nitrogen oxide removed. For tangentially fired boilers, the same degree of nitrogen oxide reduction is achieved at a capital cost of $15 to $20 per kilowatt hour and a levelized cost of $220 to $350 per ton of nitrogen oxide removed. These costs are significantly lower than other options."**

A76c. Note: $/kilowatt hour has no meaning relative to capital investment for this technology. $/kilowatt is a more appropriate measure of investment costs.

It is not believed that Altex Technologies Corporation supplies Low NO_x Burners for the Utility Market, but their technology is applicable to the industrial sector (e.g., pulp and paper mill). However, the technology that is discussed under A and B was demonstrated under the DOE Fossil Energy Clean Coal Technology Program. The DOE funding support of the Low NO_x burner technologies has significantly contributed to the rapid market penetration and commercialization into the electric utility sector by the following companies.

Babcock & Wilcox (B&W) reports that it has sold the DRB-XCL burner for 101 boiler units (55 domestic and 46 international), representing 1829 burners or 23,664 MWe of electric generating capacity, plus another seven contracts (all domestic) for its Low NO_x Cell Burner™ technology, representing 172 burners or 4,900 MWe of generating capacity. The total value of these sales, according to B&W, is $267 million, with an estimated employment impact of 7000 job-years.

Other vendors manufacture and market Low NO_x burners, including Foster Wheeler. While Foster Wheeler will not divulge its sales figures to DOE, it is estimated that sales of Foster Wheeler Low NO_x burners total $20 million. Using a factor of 40 job-years for each $1 million of domestic sales, an employment impact of 800 job-years is arrived at for Foster Wheeler low NO_x burners. DOE believes that this sales estimate is reasonable, as is the assumption that other companies have made significant sales of low- NO_x burners and related technologies.

Q76d. Does DOE hold the patents for this technology, and if not, why not?

A76d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q76e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A76e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q76f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A76f. See answers to sub-questions (e) and (f). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q76g. Please provide evidence that the low nitrogen oxide burner technology <u>would not</u> have been developed and commercialized without the DOE funding.

A76g. All indications are that Low NO_x Burners would not have been commercialized as rapidly without DOE funding.

The Clean Air Act Amendments of 1990 required the utility industry to quickly meet significant NO_x reduction control capability in a comprehensive and reliable manner so that the full consideration of the cost and performance issues could be placed in perspective of the ensuing regulatory process. The timely demonstrations under the DOE Fossil Energy Clean Coal Technology program allowed some electric utilities to satisfy the requirements of the Clean Air Act with low NO_x burner technology.

Q77. The following "success story" appears on page 189 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Pure Air Scrubber**
>
> **The first utility in the United States to meet new Clean Air Act standards for sulfur dioxide control did so using an advanced technology supported by the Department of Energy, the Pure Air Scrubber. The capital cost per unit was half of previous air scrubbers, and it produces a commercially marketable gypsum material, rather than the waste sludge commonly produced by older scrubbers (which causes landfill problems). In one year, the Pure Air Scrubber is eliminating 50,000 tons of sulfur dioxide emissions, turning an air pollutant into enough wallboard to construct nearly 19,000 homes. The project earned Power Magazine's 1993 'Power Plant of the Year' award."**

Q77a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A77a. Funding for the Pure Air project flowed not from the Fossil Energy/Coal R&D program, but rather from the Fossil Energy/Clean Coal Technology demonstration program. Actual project expenditures through FY 95 for DOE and the participant, are summarized below. The participant of record is Pure Air on the Lake, L.P. (a project company of Pure Air which is a general partnership between Air Products and Chemicals, Inc., and Mitsubishi Heavy Industries America, Inc.) but the co-funder and beneficiary of the project is Northern Indiana Public Service Company.

Fiscal Year	Dollars	Participant	Total Cost
1990	$10,274,170	$10,720,940	$20,995,110
1991	19,981,895	20,059,194	40,041,089
1992	18,500,171	24,979,403	43,479,578
1993	3,658,616	9,061,674	12,720,290
1994	4,497,683	7,890,785	12,388,468
1995	3,177,302	11,314,393	14,491,695
Total	$60,089,837 (41.7%)	$84,026,389 (58.3%)	$144,116,230

Project costs included design and construction, as well as three years of demonstration operations.

Q77b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A77b. Please refer to the table above, which details private sector investment associated with the DOE program.

Q77c. Please provide detailed documentation of the claims that "[t]he capital cost per unit was half of previous air scrubbers, and it produces a commercially marketable gypsum material, rather than the waste sludge commonly produced by older scrubbers (which causes landfill problems). In one year, the Pure Air Scrubber is eliminating 50,000 tons of sulfur dioxide emissions, turning an air pollutant into enough wallboard to construct nearly 19,000 homes."

A77c. In a paper entitled "Advanced Simplified Wet FGD Designs" by Dalton et al. (1988), the Electric Power Research Institute used a figure of $281/kW when baselining the cost of a conventional wet limestone 1982 design scrubber. That paper also identified a series of design improvements for incorporation in advanced scrubber systems. The Pure Air scrubber incorporated all of the suggested improvements except one (i.e., use of chemical additives) and featured a capital cost of approximately $165/kw, or 41.3% less than the conventional design. It should be noted that the cost of scrubbing has continued to decline with further design improvements and increased competition among vendors, to an estimated range of perhaps $120-$130/kW.

During the three-year DOE project demonstration period, SO_2 removals and gypsum production were as follows:

	SO_2 Removed	Gypsum By-Product
Year 1	79,248 tons	212,972 tons
Year 2	74,007	199,363
Year 3	76,782	210,536
Total	230,037 tons	622,871 tons

All of the gypsum by-product produced by the Pure Air scrubber has been sold commercially, primarily for wallboard manufacture at the U.S. Gypsum Company's East Chicago plant. This is in contrast to older scrubber designs that produced a sludge requiring significant landfill space and expense.

With an average annual gypsum production of 207,624 tons, the Pure Air scrubber should yield approximately 200 million square feet of wallboard annually. Assuming that a new house requires 6,144 square feet of wallboard, the scrubber produces enough gypsum by-product to supply the construction of 32,500 homes annually.

Q77d. Does DOE hold the patents for this technology, and if not, why not?

A77d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q77e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A77e. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q77f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A77f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q77g. Please provide evidence that the Pure Air Scrubber <u>would not</u> have been developed and commercialized without the DOE funding.

A77g. The Clean Coal Technology demonstration of the Pure Air scrubber probably accelerated commercialization of the technology. The Pure Air scrubber began operations in June of 1992–three years ahead of the Phase I SO_2 compliance requirements under the Clean Air Act Amendments of 1990. Indeed, Northern Indiana Public Service Company, the host utility for the Pure Air scrubber, has on numerous occasions affirmed that it would not have utilized the advanced, and therefore higher risk, features that were demonstrated under the Clean Coal Technology program.

For example, during the 1970s and 1980s, scrubbers commonly utilized a spare module to back up the original scrubber, which was often unreliable. By the late 1980s that practice had changed overseas, but U.S. utilities remained largely unconvinced that scrubbers could operate reliably enough when using high-sulfur coals in a U.S. operations environment. In fact, the scrubber system installed by Cincinnati Gas & Electric at its Zimmer station in 1991 utilized five 260 MWe scrubber modules plus one spare module. That was the most recent scrubber installation in the United States prior to the Pure Air scrubber. Apparently, Cincinnati Gas & Electric did not believe that large, reliable scrubbers had been demonstrated adequately for U.S. applications.

By contrast, the Pure Air scrubber featured a single, nominal 600 MWe scrubber module, with no spare or back-up vessels. During the three-year DOE Clean Coal demonstration, scrubber availability averaged 99.8%. The project was so successful that single, large, reliable scrubber vessels have since become the norm for utility bid specifications throughout the United States. Similarly, Pure Air's novel "own and operate" concept was mimicked in the form of better, longer equipment guarantees by competing scrubber vendors.

These and other scrubber features demonstrated under the Clean Coal Technology program have been widely adopted. The net effect of these Clean Coal projects, their advanced features and the increased competition that they have engendered has been significant savings to electric consumers (e.g., industrial, commercial and residential) in the form of lower Clean Air compliance costs. These cost savings are estimated to be billions of dollars.

To wit, 20,024 MWe of scrubber capacity has been ordered or installed since (and including) the Pure Air scrubber, at an average capital cost of approximately \$233/kW. Using the 1982 conventional design cost of \$281/kW, a total capital savings of \$961 million is projected, ignoring inflation. Last year, the Institute of Clean Air Companies estimated that an additional 12,000 to 20,000 MWe of scrubbing capacity will be installed under Phase II (1995-2004). Using the mean of 16,000 MWe and a capital cost of \$165/kW as demonstrated by Pure Air, would yield an additional \$1.865 billion in capital cost savings. But the story does not end there. Assuming a reduction in operating and maintenance (O&M) costs of 0.5 mills/kWh (along with a 65% power plant capacity factor and a projected life of 20 years), the O&M cost savings would be \$1.140 billion for Phase I units and an additional \$911 million for Phase II units.

Admittedly, these calculations may be overstated from the standpoint that not all of this nearly \$5 billion cost savings can be attributed solely to the Pure Air project, nor to the Clean Coal program. However, that project was a landmark, as evidenced by two national awards that it received–the National Society of Professional Engineers Outstanding Achievement Award for 1992 and Power magazine's 1993 Powerplant Award. Its advanced demonstration features have been widely followed, if not copied, by numerous utilities, and it helped to usher in an era of intense price competition among scrubber vendors.

Q78. The following "success story" appears on page 189 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"MicroMag Sulfur Removal Process

Application of the MicroMag sulfur removal process removes 80 percent or more mineral-bound sulfur in coal. Scientists supported by the Department of Energy received a Federal Laboratory Consortium annual award for excellence for developing and transferring this technology to the private sector. This technology is central to a \$900 million coal preparation and slurry pipeline energy project in China. The China project alone, developed by Custom Coals Corporation, will support 6,300 U.S. jobs."

Q78a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

Q78b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A78a and A78b. Both the DOE R&D investment and the private sector investment associated with the DOE program in this technology are shown in the following table by fiscal year.

Micro-Mag Sulfur Removal Process Funding and Investment by Fiscal Year
(In Millions of $)

	FY88	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	TOTAL
DOE R&D INVESTMENT										
PETC IN-HOUSE R&D--LAB/BENCH SCALE TESTING	0.094	0.169	0.268	0.156					0.226	0.744
CUSTOM COALS CONTRACT- BENCH SCALE TESTING AT PETC					0.528		0.631			1.159
CUSTOM COALS CCT COOPERATIVE AGREEMENT-FULL SCALE DEMO						1.346	13.275	10.336	13.038	37.994
PRIVATE SECTOR INVEST.										
CUSTOM COALS INDIVIDUAL LIMITED PARTNERS				1.000	1.950	2.302	0.600			5.852
CUSTOM COALS BENCH SCALE CONTRACT-COST SHARING					0.104					0.104
DUQUESNE LIGHT COMPANY (1990-91)			1.250	1.250						2.500
CUSTOM COALS CCT DEMO COST SHARING						1.964	13.275	10.383	23.770	49.392

Q78c. Please provide detailed documentation of the claims that "[t]his technology is central to a $900 million coal preparation and slurry pipeline energy project in China. The China project alone, developed by Custom Coals Corporation, will support 6,300 U.S. jobs."

A78c. The technology is central to the Custom Coals $900 million coal preparation and slurry pipeline because it is one of the technologies that allows Custom Coals to offer a unique solution to China's huge energy needs and severe pollution problems, as compared to other coal processing companies. The pipeline will transport coal with a maximum particle size of 1 mm, which means that there will be a large quantity of fine coal that must be cleaned before it is pipelined. Custom Coals' suite of technologies, consisting of their own patents as well as the DOE-licensed Micro-Mag Process, provides for a low-cost, highly efficient, deep cleaning process for coal particles down to several microns. In a September, 1995 presentation at the 4th

Annual Clean Coal Technology Conference in Denver, Custom Coals presented a paper on their Chinese slurry pipeline project. They stated that "a central aspect of our plan is the assumption that the incremental cost of deep cleaning is almost always less than the cost of transporting and burning raw coal. We will therefore employ the deep cleaning technology we have developed with the help of the Department of Energy in the United States." The Chinese government obviously agrees with their assumption and the importance of the technology, as they have agreed to pay a royalty to Custom Coals for this cleaning plant/pipeline project. Furthermore, according to the president of Custom Coals, "the Chinese government has asked to negotiate on $165 million worth of additional coal cleaning plants employing the Micro-Mag technology." He also states that "the Coal Ministry is on record as wanting 17 pipelines."

With respect to estimation of job creation, updated figures indicate that approximately 16,000 job-years would be created for each $1 billion of exports. The president of Custom Coals estimates that the U.S. is currently competitive on prices and quality for $250 million in capital equipment for the first pipeline (out of what is now a smaller $500 million project viewed as the first of many in China.) Based on this figure and using the factor mentioned above, this first pipeline will actually support about 4000 job-years of U.S. employment. However, as mentioned in the preceding paragraph, China appears to have a serious interest in many more cleaning plants and pipelines. Custom Coals proposes that much of the fabrication and construction be done in the U. S. on a modular basis, with the modules then shipped to China for final assembly. This obviously could be a continuing source of even more U. S. jobs.

Q78d. Does DOE hold the patents for this technology, and if not, why not?

A78d. Yes, DOE does hold the patent for this technology. It is U.S. Patent No. 5,022,892 entitled "Fine Coal Cleaning via the Micro-Mag Process," issued June 11, 1991. The inventors were Mark S. Klima, Carl P. Maronde, and Richard P. Killmeyer of the Pittsburgh Energy Technology Center.

Q78e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A78e. DOE has an exclusive patent license agreement with Genesis Coals Limited Partnership (the licensee) and Custom Coals International (the sublicensee). It was signed on January 12, 1993.

Q78f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A78f. To date, DOE has received an initial royalty fee of $12,500.

Q78g. Please provide evidence that the Micro-Mag sulfur removal process would not have been developed and commercialized without the DOE funding.

A78g. While it is impossible to prove that anything would not have happened anyway, the best evidence that the Micro-Mag Process would not have been developed without DOE funding is that it was invented, reduced to practice, and licensed by the DOE's own Pittsburgh Energy Technology Center. The best evidence that it would not have been commercialized without DOE funding is the belief by Custom Coals officials that they would not have built the 500 ton/hour Laurel demonstration plant without the 44% funding provided by DOE's Clean Coal Technology program. In addition, DOE's funding for the Laurel plant demonstration helped the technology gain international credibility, particularly in Poland and China, where commercial projects are being developed.

Q79. The following "success story" appears on pages 189 and 190 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"Ceramic Composite Filters for Hot Gas Cleanup**
>
> **The Department of Energy developed a process that produces continuous fiber ceramic composite filters that will reduce tons of pollutants and save millions of dollars in cleanup costs at hundreds of fossil fuel powerplants across the U.S. and elsewhere. Subsequently, Department of Energy scientists developed a chemical vapor infiltration and deposition process to produce filters many more times more resistant to thermal and mechanical shock than conventional filters. 3M is now beginning to market the filter technology worldwide. The annual market share for the filters is estimated to be $200 million per year."**

Q79a. Please detail, by appropriate fiscal year, the DOE R&D investment in this technology, including a listing of the recipients of this funding.

A79a. See table below:

DOE R&D Investment: Ceramic Filter Development
(In Thousands of $)

	Task Title				
Fiscal Year	Ceramic Fiber Filter Fabrication (3M)	Filter Failure Assessment (Acurex)	METC-sponsored filter development (ORNL)	AR&TD Scoping Study (ORNL)	Subtotal
1985	0	0	0	30	30
1986	0	189	0	0	189
1987	0	41	0	0	41
1988	0	4	200	0	204
1989	222	0	200	0	422
1990	0	0	200	0	200
1991	87	0	0	0	87
1992	110	0	0	0	110
1993	80	0	0	0	80
1994	0	0	0	0	0
1995	99	0	0	0	99
1996	0	0	0	0	0
Subtotals, DOE	598	235	600	30	1,463

Q79b. Please detail, by appropriate fiscal year, private sector investment in this technology.

A79b. See table below: All private-sector funding was provided by 3M Company
(In thousands of $)

1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Total
0	0	0	0	51	0	20	25	580	500	599	300	2,075

Q79c. Please provide detailed documentation of the claims that "continuous fiber ceramic composite filters . .. will reduce tons of pollutants and save millions of dollars in cleanup costs at hundreds of fossil fuel powerplants across the U.S and elsewhere. . . The annual market share for the filters is estimated to be $200 million per year."

A79c. The market estimate is included in the section entitled "Ceramic Composite Filters for Hot Gas Cleanup" and that section is stated here to assure proper context, viz:

> "The Department of Energy developed a process that produces continuous fiber ceramic composite filters that will reduce tons of pollutants and save millions of dollars in cleanup costs at hundreds of fossil fuel power plants across the U.S. and elsewhere. Subsequently, Department of Energy scientists developed a chemical vapor infiltration and deposition process to produce filters many more times resistant to thermal and mechanical shock than

> conventional filters. 3M is now beginning to market the filter technology worldwide. **The annual market share for the filters is estimated to be $200 million per year.**"

The validity of the claim that this was a DOE development that was transferred to the industrial sector may be verified through reference to United States Patent Number 5,075,160 dated December 24, 1991, entitled *Ceramic Fiber Reinforced Filter*, which was assigned to Martin Marietta Energy Systems, Inc., of Oak Ridge, Tennessee, the operating contractor of the Oak Ridge National Laboratory. The 3M Company obtained a limited exclusive license for the invention in 1994.

The basis for the market value of the development includes several publicly available documents referenced below with respect to their pertinence in the statement made in *Success Stories*. It is noted that for conservatism in the estimate, only two applications were considered, namely, integrated coal gasification combined cycle and pressurized fluidized bed combustion power generation plants. Numerous other applications such as incineration and chemical processing will boost the market for these filters. In fact, the 3M license includes incineration as an application.

References

1. Research Management Consultants, Inc., Washington, D. C., in Report Number DOE/OR-2002, dated February 1994 and entitled *Continuous Fiber Ceramic Composites Program: CFCCs for Low Cost Energy and a Cleaner Environment*, prepared for the U. S. Department of Energy. On page 10 of that report in a section entitled "Hot Gas Filters," at a subsection entitled "Market Potential," it is stated that "Hot gas filters have a potential international market of $7 billion over the next 10-15 years. The U. S. market for this [sic] hot gas filters is estimated to be around $200 million in 1998, and a 20% penetration for CFCCs is anticipated, or $40 million and 400 industrial sector jobs."

2. Epstein, M., "Overview of Dust Filtration From Coal-Derived Reducing Gases at High Temperature," in *Proceedings: Second EPRI Workshop on Filtration of Dust from Coal-Derived Reducing and Combustion Gases at High Temperature*, Bedick, R. C., Epstein, M., and Brown, R. A., eds., Electric Power Research Institute, Palo Alto, CA, March 11-13, 1992. In that paper, Brown estimates that for a 300 MWe power plant operating on Eastern bituminous coal with a filtration velocity of 3 cm/sec, that the number of filter elements required for an air blown coal gasification combined cycle plant, an oxygen blown coal gasification combined cycle plant, and a pressurized fluidized bed combustion plant, would be 3,200, 1,660, and 16,000, respectively.

3. Bajura, R. A., Bechtel, T. F., Schmidt, D. K., and Wimer, J. G., "Repowering Flexibility of Coal-Based Advanced Power Systems," in *Proceedings: Thirteenth EPRI Conference on Gasification Power Plants*, October 19-21, 1994, Electric Power Research Institute, Palo Alto, CA, October 1994. In that paper, these authors estimate that "...the market for power systems over the next 15 years is estimated to be about 279,000 megawatts (MW), but could range from as much as 484,000 MW to as little as 153,000 MW....Over the next 15 years, the replacement market is potentially much larger than the expansion market because of the large base of aging power plants in the U. S."

4. Smith, R. G., 3M Company, personal communication dated October 2, 1995, to R. R. Judkins, ORNL.

On the basis of the information contained in these referenced documents, the following assumptions were made to estimate the annual market share for ceramic composite filters. From Reference 3, above, the estimate for new power system requirements of 279,000 MWe was divided by 300, the reference plant size in Reference 2, above, to determine the number of 300 MWe plants to meet the requirement. That number is 930. It was then assumed that approximately 20%, or 186, of these plants would be air blown coal gasification, oxygen blown gasification, and pressurized fluidized bed combustion plants, in the ratio of 1:1:1. Then, from Reference 2, above, the average (mean) number of filters required per 300 MWe plant is 6,954. For 186 plants, then, the total number of filters required would be 1,293,444. Further, it was assumed that ceramic composite filters would garner 30% of this market or 388,033 filters. Depending on the number of filters in an order, 3M Company prices the filters at $750-$850/filter. In the estimate, the mid-range price, or $800/filter, of the 3M filter was used to obtain a market value of $310,426,560. The final assumption was that with market growth and the requirement for replacement filters, two thirds of this market would recur annually, which resulted in an annual market of $206,951,040, which was rounded to $200,000,000 to estimate the annual sales as reported in *Success Stories.* As a check on reasonableness of this estimate, it is noted that estimated sales in Reference 1 were $7 billion over the next 10-15 years with a 20% market for ceramic composite filters. Assuming a linear growth of sales over fifteen years with the aggregated sales totaling $7 billion and ceramic composite filters representing 20% of the market, sales of hot gas filters would be $746 million in the fifteenth year, and the market share for ceramic composite filters would be $187 million per year. Based on the assumption that the $7 billion in aggregated sales occurs within ten years and that growth occurs linearly, annual sales of hot gas filters would be $1.12 billion, and the ceramic composite filter market would be $280 million per year. Thus, based on the Reference 1 estimate, sales of ceramic composite filters would range from $187-$280 million per year, or a mean value of $233.5 million per year.

In summary, the estimate of $200 million as an annual international market for ceramic composite filters is believed to be conservative. It is based on requirements for only two power generation technologies, IGCC and PFBC, that will require hot gas filters, and there are numerous other applications, such as incineration and chemical processing, for the filters. **The 3M Company has stated that its internal market estimates are proprietary, but have acknowledged the independent estimates of Reference 1, and have stated that "Because the 3M ceramic composite filter is the first of its kind to enter the market and is superior to existing competitors, it stands to gain a large share of both the U.S. and world markets."** [Reference 4]

Q79d. Does DOE hold the patents for this technology, and if not, why not?

A79d. No. Pursuant to a joint waiver, USP 5,075,160 has been assigned to the operating contractor of the Oak Ridge National Laboratory, now Lockheed Martin Energy Systems, which has licensed the patent to the 3M Company.

Q79e. If DOE holds the patents for this technology, what licensing agreements does DOE have with private sector firms? Which firms?

A79e. See answer to sub-question d.

Q79f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A79f. No DOE licensing agreement and no licensing fee to DOE.

Q79g. Please provide evidence that the ceramic composite filter technology would not have been developed and commercialized without the DOE funding.

A79g. It is inappropriate to state unequivocally that the ceramic composite filter technology would not have been developed and commercialized without the DOE funding.

However, at the time this project was initiated, we knew of no ceramic composite filter work was in progress with private sector or government funding. The ceramic composite filter technology was the result of a long-term development process at the Oak Ridge National Laboratory, one of the pioneers in ceramic composite R&D. The idea of a ceramic composite filter and a novel approach to the fabrication of the filters were conceived by ORNL researchers, witness the patents that were granted based on their novelty. The work at 3M Company was initiated through a competitive procurement to all interested companies, with eight proposals being received. Not one of those companies was pursuing the development of ceramic composite filters on its own initiative and with its own funding. This was due in large measure to the risk of the investment in a novel technology, and DOE funding was necessary to reduce the risk. In spite of 3M's successful development and demonstration of the ceramic composite filter concept, no other private sector companies have developed competitive products to date. Thus, the lack of initiative of private sector companies to pursue the development of ceramic composite filters without supplemental DOE funding suggests that they would not have been developed and commercialized without DOE funding.

Q80. The following "success story" appears on page 190 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Slagging Advisor Software Model

The Slagging Advisor Software Model, the result of an industry, university, and Department of Energy team in laboratory coal science, is being marketed worldwide by PSI Powerserve. By optimizing control of boiler fouling, the software improves efficiency and cost in both conventional and advanced systems. Potential industrywide savings are hundreds of millions per year. For example, the software has saved more than $1 million annually for one utility alone."

Q80a. Please detail, by appropriate fiscal year, the DOE R&D investment in this software, including a listing of the recipients of this funding.

A80a.

DOE funding:	FY 86	$ 1,000,000
	FY 87	700,000
	FY 88	600,000
	FY 89	493,993
	FY 90	533,000
	FY 91	1,010,000
	FY 92	43,209
		$4,380,202

Funding Recipient: PSI Powerserve (PSI)

Q80b. Please detail, by appropriate fiscal year, private sector investment in this software.

A80b. See below.

Private sector investment:	FY 90	$112,500
	FY 91	150,000
	FY 92	37,500
		$300,000

Q80c. Please provide detailed documentation of the claims that "[p]otential industrywide savings are hundreds of millions per year. For example, the software has saved more than $1 million annually for one utility alone."

A80c. Slagging Advisor™ has saved money for utilities by shortening the length of test burns needed to qualify new coals. A test burn is a period in which a utility evaluates a new coal or coal blend on a particular unit. The minimum cost of a test burn is on the order of $15,000/week (corresponding to the cost of maintaining a test crew on site). For units which are not ordinarily base-loaded (e.g., cycling units), the cost of a test burn can be as high as $100,000 per day if the unit must be run at full load during the test burn.

For example, Slagging Advisor™ has reduced the length of test burns for two utilities that have used it. These utilities conduct 4-6 test burns per year. Previously, test burns required as much as 4 weeks. Now, after using the methods embodied in Slagging Advisor™, the length of test burns has been reduced to one week for a total savings of a minimum of $250,000 per year per utility.

Slagging Advisor™ provides a way of avoiding test burns with coals that would be troublesome for a particular boiler because of boiler slagging. Test burn failures, i.e., test burns that have to be aborted due to slagging in the boiler, have been eliminated. Severe slagging can require shutdown of a boiler and revenue from electricity production is lost. Shutdown of a 500 MW boiler equates to revenue losses from 12 million kilowatt hours (kWh) per day, and at 7.1 cents per kWh, lost revenue is $850,000 per day. This assumes that the utility does not have spare capacity at the time the unexpected shutdown occurs.

Q80d. Does DOE hold the patents for this software, and if not, why not?

A80d. DOE does not hold the patents, if any, for this technology. Numerous Federal statutes and Presidential policy statutes govern the ownership or control of intellectual property arising from federally-sponsored research and development These rights vary with different circumstances. In general, it is the broad interest of these Federal statutes to convey the rights of any invention to the contractor. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purposes for which the Department's energy R&D was undertaken. Conveying patent and other rights to the inventor furthers this objective. See Appendix A for details on Federal statutes and the Presidential policy statements. [*Note: Appendix A is at the end of the answers to question 84.*]

Q80e. If DOE holds the patents for this software, what licensing agreements does DOE have with private sector firms? Which firms?

A80e. See answer to sub-question (d). Licensing agreements are typically, if any, entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce.

Q80f. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A80f. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q80g. Please provide evidence that this software would not have been developed and commercialized without the DOE funding.

A80g. The technical skills and experimental capabilities required to create the underlying body of data, and understanding necessary to create the software were substantial. It is highly unlikely that a single organization would have had the required resources. The approach taken here was multi-disciplinary and involved a number of organizations. The Univ. Arizona, Cal. Tech., MIT, Univ. Kentucky were all PSI subcontractors. Furthermore, technical collaboration with Brookhaven National Laboratory, Sandia National Laboratories and the Univ. North Dakota EERC was also a key to program success. Furthermore, while the problem of ash slagging is significant and has the potential to impact all coal users, it was not clear at the onset of the project (because of the enormous technical challenges involved) that the effort would produce a commercially-viable product.

Q81. The following "success story" appears on page 192 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

"Phosphoric Acid Fuel Cells

A Federal investment in the 1980s and early 1990s yielded a radically new approach for commercial power generation, the fuel cell, and positioned the United States as the world leader in fuel cell technology. Relying on electro-chemistry rather than combustion, the fuel cell is attractive for both heavily polluted urban areas and remote applications.

The phosphoric acid fuel cell was the first technology to emerge from one joint public-private, cost-shared program sponsored by the Department of Energy. Seventy-five 200-kilowatt commercial onsite cogeneration systems have been sold throughout the world, including 31 in the United States, by International Fuel Cells Corporation of South Windsor, Connecticut. One of these fuel cells, operated by Southern California Gas, set a record last year for uninterrupted operation at more than 80 percent efficiency. Phosphoric acid fuel cells have also been successfully developed by the Department for transportation applications. A fuel-cell-powered bus, now undergoing field testing, demonstrates significant energy benefits (twice the fuel economy of comparable diesel buses) and environmental benefits (emissions reduced by more than 99 percent compared to diesel buses). The projected annual sales of fuel cell technologies could total more than $1 billion by 2020, a market that could create as many as 100,000 U.S. jobs."

Q81a. Please detail, by appropriate fiscal year, the DOE R&D investment in phosphoric acid fuel cell technology, including a listing of the recipients of this funding.

A81a. Total DOE/FE funding for phosphoric acid fuel cells for stationary applications from 1977 through 1996 is 288.3 million. (Total since program inception in 1976 is $292 million.) Major recipients were United Technologies Corp, and their subsidiary International Fuel Cells Corp. ($124M); Westinghouse Electric Co. ($102M); Engelhard Corp.; and Energy Research Corporation. Funding is shown below by year appropriated ($ millions).

1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
18.1	30.8	19.5	23.5	21.0	20.6	17.6	28.8	28.9	20.4

1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
15.5	13.2	9.5	8.3	8.8	3.9	0	0	0	0

The DOE R&D investment in phosphoric acid fuel cell technology for transportation applications has been limited to the fuel cell bus program and is shown below:

FISCAL YEAR	DOE FUNDS $, MILLION	FUNDING RECIPIENTS
		The following organizations received the amount shown
1987	1.0	during the Phase I period (FY87-90):
1988	1.6	Booz, Allen & Hamilton $1.28M
1989	2.0	Energy Research Corp. $1.27M
1990	2.0	Argonne National Lab $0.96M
		The following organizations received the approximate amount shown during the Phase II period (FY91-95): H-Power Corporation $8.26M
1991	2.0	*Sub-contractors to H-Power included: Booz Allen & Hamilton,*
1992	2.0	*Bus Manufacturing, U.S.A., Fuji Electric Co, Soleq Corp., and*
1993	2.0	*Transportation Manufacturing Corp.*
1994	0.9	Argonne National Lab $1.80M
1995	1.8	Other DOE Contractors
TOTAL	**15.3**	(NREL, ESM, etc.) $1.76M

Note: Additional funding was provided to the Fuel Cell Bus Program by the Department of Transportation/Federal Transit Administration, South Coast Air Quality Management District and H-Power Corporation (~ 20% cost share)

Q81b. Please detail, by appropriate fiscal year, private sector investment in phosphoric acid fuel cell technology.

A81b. Estimated private sector investment associated with the DOE program in research and development of phosphoric acid fuel cell technology for stationary applications is shown below.

($ in millions)

thru 1989	1990	1991	1992	1993	1994	1995	1996	Total
383	6.6	7.1	3.1	No DOE/FE funding after FY1992				399.8

Q81c. Please provide the details of the ownership of International Fuel Cells Corporation of South Windsor, Connecticut.

A81c. International Fuel Cells Corporation reports ownership of approximately 90% by United Technologies Corporation and 10% by Toshiba Corporation.

Q81d. Please provide detailed documentation of the claim that "[a] fuel-cell-powered bus, now undergoing field testing, demonstrates significant energy benefits (twice the fuel economy of comparable diesel buses) and environmental benefits (emissions reduced by more than 99 percent compared to diesel buses). The projected annual sales of fuel cell technologies could total more than $1 billion by 2020, a market that could create as many as 100,000 U.S. jobs."

A81d. The buses referred to in the testimony were manufactured by H-Power of Belleville, New Jersey. These thirty-foot long, twenty-five passenger buses meet all applicable standards for transit buses, including wheelchair lifts and air conditioning. The buses use a 50-kW phosphoric acid fuel cell to supply all of the vehicle's energy needs.

Energy Benefits: Formal performance tests were conducted on the first of these buses at the Aberdeen Proving Grounds in Aberdeen, MD. The fuel cell operated on methanol fuel at over 42% thermal efficiency. Fuel economy for the bus over the standard Transit Coach Duty Cycle was 2.1 mi/gal on methanol, or 4.7 mi/gal diesel equivalent, about twice that of a similarly sized conventional bus with diesel engines. The fuel cell bus' greater fuel economy results from the fuel cell's efficiency being significantly greater than that of a diesel engine. This is especially true at the low-power and low-speed operation that are characteristic of a bus. The fuel cell bus' hybrid electric drive train also permits the recovery of braking energy and further benefits from the fuel cell's low energy losses during stop/idle periods which constitute a large fraction of bus operation.

Environmental benefits: A comparison of the fuel cell bus powerplant's measured emissions (in grams/brake-horsepower-hour) with the 1998 heavy-duty vehicle emission standards is as follows:

Criteria Pollutant	1998 Standard	Fuel Cell Measured	% Reduction
nitrogen oxides	4.0	0.01	99.7%
carbon monoxide	15.5	0.35	97.7%
hydrocarbons	1.3	0.00	99.9%
particulate matter	0.05	0.00	99.9%

Q81e. Does DOE hold the patents for phosphoric acid fuel cell technology, and if not, why not?

A81e. DOE holds eight patents for phosphoric acid fuel cell technology developed with DOE support by Engelhard Corporation. DOE acquired these patents when Engelhard discontinued commercialization activities and patent rights reverted back to DOE. Other patent rights have been waived by DOE to other contractors in consideration of cost share investments by the developers and to accelerate commercialization. DOE retains rights to use of patents and "march in" rights if commercialization is not pursued.

Q81f. If DOE holds the patents for phosphoric acid fuel cell technology, what licensing agreements does DOE have with private sector firms? Which firms?

A81f. DOE has granted a request from Fuji Electric Company Ltd. for a nonexclusive sublicense of eight patents mentioned above, with restrictions that the products must be substantially produced in the U.S.

Q81g. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A81g. Licensing fees of $250,000 have been received from Fuji Electric.

Q81h. Please provide evidence that phosphoric acid fuel cell technology would not have been developed and commercialized without the DOE funding.

A81h. The large investment required and the long time before payback greatly reduced the availability of private sector funding. Developers unsuccessfully sought private funding within their own corporate structures as well as all domestic sources of such funds. Even the international arena was unable to provide such funds. This has been true in other countries as well. There is no established fuel cell industry and infrastructure anywhere in the world and the entire industry has been largely regarded by the investment community as high risk and long term.

There were at one time up to four major phosphoric acid fuel cell R&D contractors in the DOE program for stationary applications. Following the reduction to two major contractors (UTC/IFC and Westinghouse), the others were free to continue development on their own, but did not. When the commercial offering of a phosphoric acid fuel cell power plant was made by UTC/IFC in 1992, and DOE stopped funding further development, the remaining developer (Westinghouse) terminated commercialization activities and sold the technology rights to a newly formed company. That company has not been successful in commercialization efforts to date.

Q82. **The following "success story" appears on pages 192 and 193 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:**

"Advanced Gas Turbine Components

The Department of Energy is cost-sharing an 8-year development program to produce a leapfrog advanced gas turbine technology that will ensure continued U.S. leadership in the global market. While the entire turbine system will not be completed until the year 2000, key components have already emerged from the development effort and are being used in commercial turbines. In late 1994, Westinghouse Corporation announced a new type of industrial gas turbine, the 501G, the most fuel-efficient machine in its class. Advanced technology from the Department's R&D program is incorporated into the turbine. Closed-loop steam cooling of blades and rotors, techniques developed in the joint government-industry program, have effectively eliminated efficiency losses caused by earlier methods of air cooling. Although the United States dominates the global turbine market, foreign vendors are closing the gap. The leapfrog turbine emerging from the Department's program is expected to maintain U.S. dominance in a multibillion dollar world market."

Q82a. **Please detail, by appropriate fiscal year, the DOE R&D investment in advanced gas turbine technology, including a listing of the recipients of this funding.**

A82a. The DOE Fossil Energy appropriations for the Advanced Turbine Systems Program are as follows:

Dollars in millions–excludes participants cost-share

1992	1993	1994	1995	1996 (est)
$0.72	$9.84	$20.47	$37.86	$36.77

The major recipients of this funding ($ in millions) are:

Major Developers	Prior FY95	FY95	FY96 (est.)
Allison Engine Co.	3.5	3.8	---
ABB	0.1	1.6	0.4
General Electric	5.4	11.0	15.0
Solar	3.8	---	---
United Technologies	0.1	---	---
Westinghouse	4.8	8.8	11.1
Technology Base Research			
South Carolina Energy R&D Center	6.4	4.8	4.3
Oak Ridge National Lab	1.0	1.0	1.4
METC	3.6	2.5	2.8
Alternate Fuels (AFR/BYU, GE, West., Hague)	1.3	3.1	---
Technology Research (TBD)	---	---	1.4
Other (gen. reductions, program mgmt., etc.)	1.0	1.3	0.3

Q82b. Please detail, by appropriate fiscal year, private sector investment in advanced gas turbine technology.

A82b. The amount of private sector investment associated with the DOE program or cost-sharing provided by the Advanced Turbine Systems Program participants by fiscal year is as follows:

Dollars in millions–cost share for DOE/FE funded ATS

1992	1993	1994	1995	1996 (est.)
$0.04	$1.92	$3.92	$14.29	$22.75

Percentage cost-share requirements of the major program participants was 25% for the initial phases of the program and will increase to more than 70% during the pre-commercial demonstration phase of the program.

DOE has approached the gas turbine manufacturing community to obtain actual figures for their gas turbine technology investment outside of the Advanced Turbine System program. However, they have declined to breakout these costs due to the competitive nature of this information.

Q82c. Does DOE hold the patents for advanced gas turbine technology, and if not, why not?

A82c. No, DOE does not hold the patents for advanced gas turbine technology. The major gas turbine companies participating with DOE have received advanced patent waivers for the technology developed in the Advanced Turbine System program.

These companies are providing significant amount of cost share to be eligible for this waiver.

Patents resulting from research performed by universities under the Advanced Turbine Systems (ATS) Industry/University Consortium are granted to the Universities in accordance with federal legislation. This legislation automatically grants title to inventions developed by small businesses and universities conducting research under sponsorship by the federal government. Numerous Federal statutes and Presidential policy statements govern the ownership or control of intellectual property arising from Federally sponsored research and development. These rights vary with different circumstances. In general, it is the broad intent of these Federal statues to allow the contractor or inventor to retain the rights of any invention. Moreover, it is DOE's objective to encourage private development and deployment of new and advanced energy technologies that might contribute to the national interest and the public purpose for which Department's energy R&D was undertaken. Conveying patent and other rights to the contractor or inventor furthers this objective.

Q82d. If DOE holds the patents for advanced gas turbine technology, what licensing agreements does DOE have with private sector firms? Which firms?

A82d. See answer to sub-question (d). Licensing agreements, if any, are typically entered into by firms negotiating with the patent holder, which is usually the contractor, not DOE. If DOE does hold the patent, licensing is done per 35 U.S.C. 208 and the regulations issued by the Department of Commerce

Q82e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

A82e. See answers to sub-questions (d) and (e). Any licensing fees or royalties stemming from an invention would go to the holder of the intellectual property rights, which is usually the contractor, not DOE. Federal statutes normally do not provide authorities to the government to require the reporting of this information when received by a non-M&O contractor.

Q82f. Please provide evidence that advanced gas turbine technology <u>would not</u> have been developed and commercialized without the DOE funding.

A82f. Without DOE funding, we believe gas turbine manufactures would continue to making upgrades in performance and incremental improvements that produce modest gains in turbine efficiency and emissions reductions but not the high-risk, "Leap-Frog" advances in the efficiency and environmental performance of these systems. However, we do recognize the U.S. manufacturers either have their own allied high technology turbine businesses such as aircraft engines and ship propulsion systems, or have technology partnerships with other firms that give them access to turbine R&D resources that contribute toward advancement of power systems technology. Leveraging investment of the Federal Government and the private sector to share the risk of developing the ATS enables the domestic gas turbine industry to achieve ATS goals and maintain U.S. global leadership in the gas turbine marketplace. U.S. leadership will enhance exports of domestic products that will support high wage U.S. jobs. This position was documented in a series of workshops held at Clemson University in 1991-1992 to define the goals of the ATS program.

Q83. The following "success story" appears on page 193 in Annex 3 of the *Final Report of the Task Force on Strategic Energy Research and Development* of the U.S. Department of Energy's Secretary of Energy Advisory Board:

> **"High Energy Batteries for Consumer Products**
>
> **Investigations supported by the Department of Energy of nonaqueous electrolytes such as propylene carbonate provided the fundamental information needed to develop batteries based on electrolytes. High-energy primary (nonrechargeable) lithium batteries, which were not available prior to this research, are now in widespread commercial use. New generations of these electrolytes are also employed in secondary (rechargeable) lithium batteries now under development and in early stages of commercialization. The commercial use of such high-energy batteries has accompanied and enabled the explosive growth of the multi-billion dollar portable electronics industry, which includes laptop computers and portable tools. The technology can also be used in home and auto security systems, electronic tools, robotics, and medical instruments."**

Q83a. Please detail, by appropriate fiscal year, the DOE R&D investment in lithium battery technology, including a listing of the recipients of this funding.

Q83b. Please detail, by appropriate fiscal year, private sector investment in lithium battery technology.

Q83c. Does DOE hold the patents for lithium battery turbine technology, and if not, why not?

Q83d. If DOE holds the patents for lithium battery technology, what licensing agreements does DOE have with private sector firms? Which firms?

Q83e. If DOE has licensing agreements with private sector firms, what licensing fees has DOE received from such licenses?

Q83f. Please provide evidence that lithium battery technology <u>would not</u> have been developed and commercialized without the DOE funding.

[Note: DOE did not answer this question.]

Q84. **Appendix D, included as pages D-1 through D-6, of the *Final Report of the Task Force on Strategic Energy Research and Development* volume entitled *Energy R&D: Shaping our Nation's Future in a Competitive World* contains an analysis by the Department's Office of Industrial Technologies (OIT). Please provide the detailed documentation, including assumptions, to support the following claims:**

Q84a. **Cumulative Federal appropriations for the entire OIT program from 1976 through fiscal year 1994 were $1,098,454,000 (page D-2).**

A84a. Estimated appropriations developed from various DOE office files were used. The appropriations assumed are as follows:

Year	Annual Funding (In Millions of $)
Prior to FY 1985	432.3
FY 1986	42.3
FY 1987	35.0
FY 1988	33.1
FY 1989	30.5
FY 1990	82.1
FY 1991	91.1
FY 1992	108.5
FY 1993	111.1
FY 1994	132.5
Total	1,098.5

Q84b. **Cumulative energy savings for the OIT technologies currently tracked are approximately 614 trillion Btu, representing a net production cost savings of about $1.6 billion (page D-2).**

A84b. Cumulative energy savings for the OIT technologies currently tracked are approximately 614 trillion Btu, representing a net production cost savings of about $1.6 billion, (page D-2).

Energy savings have been tracked by the Office of Industrial Technologies (OIT) for about the last 15 years through quarterly surveys. The purpose of this system has been to continuously track and record information on technologies developed through cost-shared R&D projects with industry. The tracking process considers technologies which can be classified as commercially successful, mature, or emerging. When at least one full-scale commercial unit of a technology is operational in private industry, that technology is considered commercially successful and is on the active tracking list. When a commercially-successful technology unit has been in operation for ten years, that particular unit is then considered a mature technology and is no longer actively tracked. Emerging technologies are those in the late development or early commercialization stage of the technology life cycle (roughly within one to two years of commercialization). While preliminary information on emerging technologies is collected, they am not placed on the active tracking list until they are commercially available to industry.

The active tracking process involves the collection of technical and market data on each commercially-successful technology, including details on: number of units sold, installed, and operating, in the U.S. and, abroad (including size and location); units decommissioned since the previous year, energy saved by the technology, environmental benefits, improvements in quality and productivity achieved through the use of the technology; impacts of the technology on employment, marketing issues and barriers. Information on technologies is gathered through direct contact with either vendors or end-users of the technology. These contacts provide the data needed to calculate the unit energy savings associated with an individual technology, as well as the number of operating units. Unit energy savings are unique to each individual technology. Technology manufacturers or end-users usually provide unit energy savings, or at least enough data for a typical unit energy savings to be calculated. The total number of operating units is simply equal to the number of units installed minus the number of units decommissioned or classified as mature in a given year–information that is usually based on sales data or end-user input. Operating units and unit energy savings can then be used to calculate total annual energy savings for the technology. On the other hand, cumulative energy saving encompass energy savings of all units for the total time the technology has been in operation (including previous savings from now-mature units as well as decommissioned units). They represent the accumulation of energy saved every year since the technology was tracked.

Appendix D cited in the question contains a detailed listing of each technology tracked by OIT and its contribution to the total energy savings claimed.

Net production cost savings are calculated by subtracting the Cumulative Appropriations curve cited in Appendix D from the Cumulative Production Cost Savings. This provides an estimate of the direct net economic benefit of the OIT program since its inception. The method to compute net economic benefits is based on several factors:

<u>Cumulative energy savings</u>.–the accumulated energy savings (Btus) produced by OIT-supported technologies that have been commercialized and tracked since the program began. As of FY 1994, this figure was 614 trillion Btu.

<u>OIT Appropriations</u>.–cumulative R&D dollars provided by OIT for commercialized and tracked technologies since the program began. As of FY 1994, this number was $1,098 million.

<u>Weighted average cost of industrial energy</u>.–the average fuel price (dollars/Btu) that would have been paid to purchase energy, usually an average of industrial energy prices over the last ten to twenty years, weighted by the mix of industrial fuels saved by ORT commercialized and tracked technologies. For 1994, the weighted average cost of industrial energy was about $4.00 per million Btu.

Levelized cost of industrial energy efficiency.–the average "efficiency" fuel price (dollars/Btu) that was paid based an a 1988 study of 43 OIT-supported technologies. Estimation of this factor takes into account differences between the OIT technologies and the technologies they replace. For each technology, differences in annualized capital costs, operating and maintenance costs, and non-energy production-costs are summed and then divided by the annual energy savings to yield a net "price" per million Btu of energy benefits. This net levelized cost for each technology is then multiplied by the cumulative energy savings for that technology to yield cost savings per year. The sum of these cost savings for all 43 technologies, divided by the cumulative energy savings for all 43 technologies, then provides the final levelized cost of industrial energy efficiency, which is $0.71 per million Btu. To ensure that a conservative result is achieved, the cost-benefit analysis doubles this cost to $1.40 per million Btu.

Average energy cost savings rate.–the difference between the weighted average cost of industrial energy and the levelized cost of industrial energy efficiency. Thus, for 1994, the average energy cost savings rate was $4.00 minus $1.40 per million Btu, or $2.60 per million Btu.

Net Production Cost Savings.–the average energy cost savings rate of $2.60 per million Btu is multiplied by the cumulative energy savings of 614 million Btu to obtain the net production cost savings, $1.6 billion.

Q84c. These savings represent a net economic benefit of about $480 million for fiscal year 1994.

A84c. These savings represent a net economic benefit of about $480 million for fiscal year 1994. $480 million is the difference between approximately $1.6 billion in net production cost savings and, the cumulative Federal appropriations for the program, approximately $1.1 billion.

Appendix A: Patents, Licenses and Royalties

Overview

Ownership of new inventions arising from the research, development or demonstration activities of the Department of Energy is governed by statute. Where not inconsistent therewith, guidance is also provided by the Presidential Memorandum to the Heads of Executive Departments and Agencies on Government Patent Policy issued February 18, 1983 and Executive Order No. 12591 issued April 10, 1987. The Presidential guidance directs each agency to follow the philosophy the Bayh-Dole Act, 35 U.S.C. 200 et seq, for all government contractors engaged in research development or demonstration to the extent permitted by law.

1.0 Agreements with Non-Laboratories, Small Business & Nonprofit Contractors After 1981

For all government agencies, since 1981 ownership of new inventions made under funding agreements with small businesses and nonprofit organizations are governed by 35 U.S.C. 202 (the Bayh-Dole Act) which provides, with certain exceptions, for contractor retention of title to new inventions. In 1984, 35 U.S.C. was amended to provide the same right to retain title to new inventions not arising from weapons related funding to small business and nonprofit contractors under agreements for the management and operation of DOE facilities. Except for a funding agreement for the operation of a DOE facility, 35 U.S.C. 202 (c)(7) requires royalties received by a nonprofit contractor to be first shared with the inventor, with the balance after expenses to be retained by the contractor and used to support scientific research and education. Neither the statute nor the government-wide standardized contract provisions implementing this statute provide for the reporting to the government of any royalties received by the contractor. Therefore, for small business and nonprofit contracts entered into after 1981, not operating DOE facilities, for which information is sought, DOE can only identify whether a new invention was reported to DOE and whether the contractor chose to retain title to the invention.

2.0 Agreements with All Other Non-laboratory Contractors Not Covered under Section 1.0

For all agreements not subject to 35 U.S.C. 202, which includes all agreements with small businesses and nonprofits not for the management and operation of a facility entered into before 1981, the Government was required to take ownership of new inventions pursuant to section 152 of the Atomic Energy Act of 1954, 42 U.S.C. 2182, and section 9 of the Federal Nonnuclear Energy Research and Development Act of 1974, 42 U.S.C. 5908. Both of these acts provide that the Secretary of Energy may waive the government's right of ownership to such inventions to the contractor. Waivers are generally dealt with on a contract by contract basis and in recent years have been readily granted. Only rarely have waivers required contractors to share royalties with the government. Neither Bayh-Dole permitted nor the Presidential Statements suggested that royalty sharing with the government was appropriate. Where royalty sharing has been required, it has usually been done as part of programmatic direction (clean coal) or congressional direction (the United States Advanced Battery Consortium). Therefore, for all agreements not subject to 35 U.S.C. 202, for which information is sought, DOE can identify whether the contractor reported to DOE a new invention as having been made under the contract, whether a waiver was granted to the invention, whether the contractor or the government chose to retain title to the new invention, whether royalties were required to be shared, and whether any royalty payments have in fact been made.

3.0 Agreements with All M&O Laboratories (GOCOs)

For funding agreements with small businesses and nonprofits for the operation of a DOE facility, which since 1984 have provided the contractor with the right to elect to retain title to new non-weapons funded inventions, 35 U.S.C. 202(c)(7) provides that after payment of expenses, and payments to inventions, 100 percent of the balance of royalties received during any year, up to five percent of the annual operating budget of the facility shall be used by the contractor for scientific research, development, and education consistent with the mission of the facility. Any royalties in excess of the five percent are to be split between the contractor and the Treasury.

In 1989, Congress enacted the National Competitiveness Technology Transfer Act of 1989 which directed DOE to make technology transfer a mission for each contractor managing and operating a DOE laboratory engaged in substantial research and development. In response to this Congressional direction, DOE chose to extend the philosophy embodied in Bayh-Dole and the above referenced Presidential statements to its for-profit contractors managing and operating DOE facilities. All management and operating contracts follow the invention ownership and royalty sharing provisions of Bayh-Dole. Contractors can request waivers to weapons funded inventions on a case by case basis. If the request is granted, the royalty sharing and use provisions of Bayh-Dole are followed. Therefore, for all agreements for the management and operation of DOE facilities for which information is sought, DOE can identify whether the contractor reported to DOE a new invention as having been made under the contract, whether the contractor or the government has chosen to retain title to the new invention, whether any royalty payments have in fact been made to the laboratory and the amount of such payments.

4.0 Agreements with All Government Owned -Government Operated (GOGO) Laboratories

For inventions made by government employees at government owned - government operated (GOGO) Facilities, such as PETC and METC, Executive Order 10096 as amended Executive Order 10930 governs the disposition of title to inventions. For inventions made in the normal course of business, the government retains title. In 1986, the Federal Technology Transfer Act allowed the Laboratory Director the authority to license inventions and provided for the use of any royalties earned.

Mr. Michael C. Lynch
Research Affiliate
Center for International Studies
Massachusetts Institute of Technology

Answers to Followup Questions

**HEARING OF THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES**

on

U.S. Energy Outlook and Implications for Energy R&D

Thursday, March 14, 1996

Followup Questions Submitted to

**Mr. Michael C. Lynch, Research Affiliate
Center for International Studies
Massachusetts Institute of Technology**

Q1. On page 3 of your written testimony you say that DOE's forecast for non-OPEC Third World oil production has been consistently pessimistic and has been consistently raised.

Do you believe that EIA's Annual Energy Outlook 1996 has corrected adequately for its previous pessimism?

A1. The current international oil market forecasts from EIA's Annual Energy Outlook appears to repeat the problem described in my written testimony. Non-OPEC production is predicted to be relatively flat, with some increase in the Former Soviet Union and (in the long run) the United States. However, the non-OPEC Third World and the North Sea are both shown as peaking within a few years. Given that the non-OPEC Third World especially is extremely immature as an oil province, it is hard to understand why they would be expected to be peak so soon.

It should be noted that most forecasts which are still published (the number has declined dramatically in recent years) agree with the EIA view of the world. However, these forecasts have been repeatedly wrong, while my more optimistic ones have proven correct.

Q2. How does your most recent forecast, shown in Exhibit 5 on page 9 of your prepared testimony, compare with EIA's most recent forecast? What are the most significant differences?

A2. My forecasts and the EIA's are fairly dissimilar. My oil price forecast is much lower, and my demand forecast is much higher for the Third World, as is my non-OPEC supply forecast. Given that EIA projects relatively high oil prices, their lower demand forecast is internally consistent. However, the fact that their high oil prices yield a lower oil production than in my forecast implies that there is a substantive disagreement between us.

My belief is that their non-OPEC production forecast is much too low, as it has been for some time now, and that correcting this would tend to support a lower oil price forecast. Note, however, that our forecasts of OPEC oil production are relatively similar, because my higher demand projection mostly offsets my higher non-OPEC production forecast.

Q3. On page 6 of your written testimony you state the following:

> **"One of the most glaring errors in petroleum forecasting has been the post-1980 need to revise supply upward while lowering price projections. The fact that lower price expectations have resulted in higher demand expectations is logical and consistent with basic economic theory. But lower prices and higher production are not normally consistent with basic economic theory, and are a strong indication that the underlying premises are incorrect."**

It would seem to me that classical microeconomic theory tells us that lower prices should lead to less production. Why is there this apparent contradiction?

A3. Lower prices should lead to lower production in theory. However, in the current world oil market, falling prices do not affect private companies significantly, since most of the drop is absorbed by the host governments who lower their taxes and royalties. Lower prices reduce cash flow, which impacts investment, and in the U.S., the 1986 price collapse reversed the production increase of the early 1980's.

In forecasting, the fact that forecasters like DOE have reduced their long-term price forecasts by 50-75% while increasing their projections of competitive energy production (like U.S. natural gas and non-OPEC oil production) shows that their methodology for predicting production is inaccurate and biased in a pessimistic direction. The fact that their demand forecasts have tended to be too low since 1986 is consistent with their price forecasts being too high, but if their model were correctly structured, then their high price forecast would yield production forecasts which are too high as well.

Q4. How does your most recent forecast, shown in Exhibit 5 on page 9 of your prepared testimony, compare with EIA's most recent forecast? What are the most significant differences?

A4. This question is identical to question 2.

Q5. On page 11 of your written testimony you say that "[r]educing oil consumption or developing alternative supplies has a very minor impact on the possibility that an oil supply disruption will lead to higher prices."

Could you please elaborate on this statement?

A5. The possibility that a disruption in oil supplies will led to higher prices is primarily dependent on the degree to which the disrupted supplies are replaced. In 1967 and 1990, for example, when oil supplies were lost, other producers increased production and offset the losses, minimizing the effect of the disruption. Price changes were minimal.

The availability of replacement supply depends on the amount of replacement capacity and the willingness of those who hold that capacity to use it. Replacement capacity is a combination of OPEC surplus capacity and strategic reserves, such as the U.S. Strategic Petroleum Reserve.

Cutting consumption has a minimal impact on replacement capacity, since OPEC countries can adjust their capacity in response, especially over the long term. If the oil market is weak due to low demand for oil (for whatever reason), most OPEC nations will simply cut back their investment programs. As a result, in a future disruption, slightly lower consumption in the U.S., for example, will leave the amount of surplus capacity at approximately the same level (all else being equal), because OPEC countries will have reduced their investment programs and thus, should have approximately the same amount of surplus capacity as if U.S. oil demand and/or imports were higher.

This is not to ignore the economic impact of higher prices during a disruption which leads to higher prices, but preventing the price increase through utilizing capacity is the first step and obviates the need for other measures.

Q6. **On page 11 of your written testimony you also say that "the cost of reducing oil imports by 10% over a long period is probably much higher than say, the impact of a 50% increase for one year."**

Could you please elaborate on this statement?

A6. Reducing U.S. oil imports by 10% over a long period would require very significant economic intervention in the market, whether by taxes on oil, subsidies on other fuels or energy-savings programs, or widespread command-and-control regulation. The least disruptive of these policies would distort the economy and have significant costs, although research at the precise level is mixed. Also, as discussed in the previous question, merely reducing the level of imports would not prevent an oil crisis, although it would moderate the impact.

Given that commodity prices generally fluctuate and supply shocks frequently occur for all of them (frosts often drive up coffee or orange juice prices for example, and the price of corn is currently 70% higher than a year ago), it must be asked why the government should intervene only in the case of oil. Granted oil is the most important commodity, but manipulating markets has not worked particularly well historically. Most agricultural stabilization programs have primarily raised prices, not stabilized them.

An oil crisis involving a short-term price spike, such as occurred in 1990, is obviously much less costly than the ones we experienced in the 1970s, and the level of economic damage was much smaller as well. It appears as if the government might be better off accepting the small-scale volatility from minor disruptions (like 1990), while trying to minimize them through use of the Strategic Petroleum Reserve, than to implement long-term, large-scale programs to reduce consumption as a way of improving our energy security.

This is not to suggest that R&D on energy efficiency, for example, should be terminated, but to recognize that the goal should be to create products which are economically viable during normal markets, rather than ones which must be imposed on it in the belief that the nation's energy security will be improved.

Q7. Finally, on page 11 of your written testimony you stated the following:

> **"Clean coal technology, fusion power, or photovoltaics will not prevent another oil crisis from occurring, and are likely to provide only a slight moderating effect on the crisis which do occur. This is not to say that R&D in these areas should not go forward, just that they need to be justified in some other way."**

What other ways of justification would you suggest?

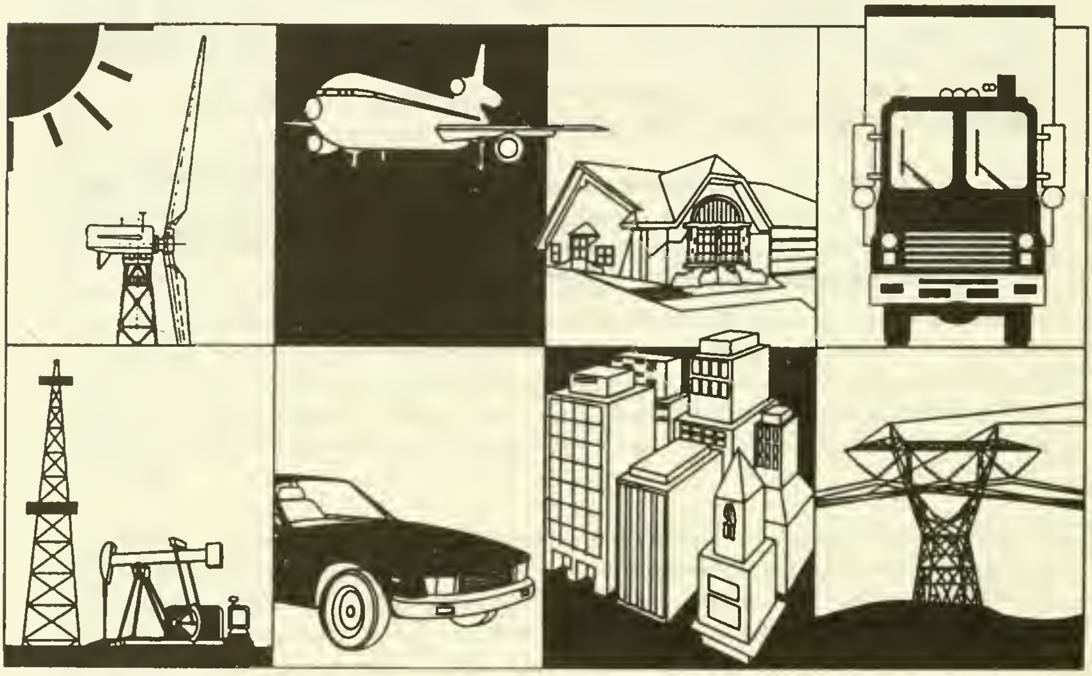
A7. Like other non-defense R&D, energy R&D should not be justified on security grounds. Basic research should always be justified on the possibility of increasing knowledge. Applied research should be primarily justified on the expectation of tangible benefits. Although intangible benefits are hardly ignored, they are often exaggerated by self-interested individuals or groups and must be considered carefully.

Thus, a new method of converting coal into easily an usable, clean product which is cheaper than imported oil would provide significant economic benefits to the nation. Funding R&D on a clean coal technology which provides coal that is more expensive than alternative fuels, even imported alternative fuels, would be wasteful.

Annex 3

Success Stories:
The Energy Mission in the Marketplace

A Portfolio of
Successful Investments in Applied Energy Research and Development
by the U.S. Department of Energy



Helping To Make America
Clean, Efficient, Competitive, and Secure

U.S. Department of Energy

Prepared by
Office of Policy
U.S. Department of Energy
Washington, DC 20585

Success Stories: The Energy Mission in the Marketplace

Energy Mission

The Department of Energy's mission and its civilian energy research and development (R&D) programs are motivated by a number of important and enduring public policy objectives. These objectives are rooted in national security, economic, environmental, and scientific leadership considerations. They reflect the pervasive role that energy plays in modem society. They are underpinned by a respectful understanding of history and of the unique vulnerabilities that our Nation faces with regard to certain aspects of long-term energy supply and end-use.

Role of Federal R&D

Accordingly, the Department's applied energy R&D programs fill an important gap in the United States' R&D continuum. This gap is where it is clearly in the *public interest* to pursue certain technological opportunities, especially those that are long-term or high-risk, but where for economic reasons it is not in the *market's interest* to do so.

The reasons for this gap are many. One is that the public benefits, such as national security or environmental quality, are simply not fully reflected in market prices. Another is that private firms are finding it increasingly difficult to recoup their R&D costs by appropriating exclusively to themselves the true benefits of the R&D. In today's highly competitive global market, technical secrets are short-lived and too easily stolen, scientists are hired away, and inventions are slightly modified in order to circumvent intellectual property rights. More fundamentally, the R&D itself is often too challenging, requiring large interdisciplinary teams of scientists, working year after year on expensive and unique laboratory equipment. Finally, the structure of certain industries is often too fragmented, or the firms too small, to mount the sustained R&D campaign necessary for success.

Within this context, the proper role for the U.S. Department of Energy's applied R&D programs is *not* to subsidize or displace private sector responsibilities for R&D, but to complement them selectively in ways that will help achieve important long-term public policy objectives and that are justified by one or more of the special market circumstances outlined above.

What Successes?

So, after nearly two decades of investing in such R&D at the U.S. Department of Energy, is it fair to ask "What benefits have accrued to the U.S. economy?"

Yes, it is—and the answer is impressive. Many outputs of the Department's R&D, conducted in pursuit of its public policy objectives, not only have had substantial economic success in the marketplace, but also have proven to be fundamentally important in one technical area after another in positioning U.S. industry at the forefront of global competition. In today's markets, winning products are often those with technically driven advantages in performance and price, and the Department's R&D has contributed significantly to many of these winning products.

Among such products is the electronic ballast for fluorescent lighting fixtures that has become the lighting technology-of-choice. It has already saved U.S. electricity consumers $750 million, a saving that grows every day. Another technology, low-emissivity window coatings, has gained a 34-percent market share of all new double-glazed residential windows.

And, the economic benefits of the Department's programs will continue well into the future. Four technologies in one building technologies R&D program are expected to net more than $16 billion in economic savings to U.S. taxpayers by the year 2015, far outstripping the total past and projected Department of Energy investments in this area of R&D.

These statistics may surprise some critics of the Department's R&D programs. Many of the Department's most important R&D contributions lie in the "precompetitive" stages of technology development, or in important intermediate technology components, and such contributions are often hidden in the final product. Many people might recognize the technological sophistication of modern commercial trucks and diesel engines, Boeing 757 and 767 aircraft, and high-efficiency lights, windows, and appliances; but few would realize that Department of Energy technology is inside those products and is responsible, in part, for their fast-growing global market shares.

To be sure, the Department has embarked on some R&D activities without yet achieving the desired results, and some of these are highly visible and costly. As with most high-risk ventures, targets cannot always be met, both in private and public sector R&D programs. The purpose of the Department's R&D programs is to explore these high-risk technical possibilities.

Many of the bold experiments in energy demonstration projects of the late 1970s, motivated by global conflict and national security concerns over oil, are now seen in hindsight as having been too ambitious. Some expensive technology pushes are no longer supported—for example, synthetic fuels, the Clinch River Breeder Reactor, magnetohydrodynamics, and the Stirling automobile engine—because they were not economically successful, even though they produced a wealth of scientific knowledge and engineering experience. But these are only a part of the picture.

Improved R&D Productivity

More fundamentally, the Department's record of R&D productivity has steadily improved over nearly two decades of R&D investment. Management techniques for R&D have become more sophisticated and less congressionally directed. They are now squarely rooted in competition, driven by technical merit and scientific peer review, and aligned with the needs of cost-sharing industrial partners.

Economic Successes

This report compiles a brief list of some of the more significant Department-sponsored technology developments that have already had, or will have in the next year or so, significant impacts on the U.S. economy. It omits hundreds of scientifically and technically important developments and focuses only on examples of successes with major economic significance.

As a word of caution, please note that the pathway of scientific discovery, from basic research to product development, is often complex and multifaceted. Bringing a new product to market involves many players, and credit for their existence should be shared broadly. The final stages of development are almost always, as they should be, private sector interests. The products that consumers see rarely have any overt indication of an underlying Federal or Department of Energy R&D role.

This does not mean, however, that the R&D was not important, or that it would have been developed anyway if just given enough time. The examples in this report show that the Department of Energy's R&D programs played a key and enabling role in the resulting technology development. The Department does not claim credit for the final design and production of the commercial products. Nor does it wish to understate the critical importance of the private sector's role. It does want to emphasize, however, the collaborative nature of scientific discovery and technology development, with private and public actors each playing distinct and complementary roles.

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R&D Management Principles

The Department's programs support high-risk, precompetitive research. The Department's applied energy R&D investments are guided by a set of R&D management principles, which limits and carefully guides the use, and guards against the misuse, of public funds for R&D. The Department supports R&D if and when serious shortfalls occur in areas of R&D otherwise important to society.

R&D Considerations

The Department of Energy's decisionmaking on investment in R&D takes into consideration the following factors:

- The overall significance of the potential benefits of the R&D to the Nation.
- The level of technical difficulty of the task and whether the overall risk of the R&D is such that private industry will not undertake the development on a timely basis.
- The nature of the R&D and whether or not an individual firm might recover its research costs by appropriating to itself the benefits of the knowledge (a "public good") it creates.
- The nature of the industry and whether the fragmented structure of an industry might work against sufficient levels of R&D spending because its firms are too small to undertake certain kinds of R&D projects.
- The distance from commercialization, where certain proprietary sensitivities otherwise might adversely affect private sector competition.

Deficit Reduction or Revenue Enhancement?

Given these considerations, the Department's funding of applied energy R&D is a well-founded, complementary public investment in the advancement of science and technology in areas critically important to the Nation's future. Upon this enabling foundation of precompetitive research and knowledge, corporate America can build and market its own commercial products, which is the proper domain of the private sector.

These successes result in new products and processes that compete successfully in global competition and employ U.S. workers in high value-added jobs, who pay taxes on their income. These technologies reduce costs to businesses and consumers, which stimulates the economic growth of the Nation and adds to corporate taxable profits, all of which return revenue to the Treasury.

Accordingly, a case can be made that an investment in the Department's applied energy R&D programs should not be viewed as a current operating expense on the deficit side of the Federal budget account, but rather as a high-risk portfolio of capital investments in the Nation's future, with a predictable portion resulting in significant economic paybacks that are already adding net revenue to the income side of the Federal ledger. These R&D investments not only produce public benefits, but make money for the U.S. Treasury.

Increasing Energy Efficiency

Energy-efficiency improvements in homes, commercial buildings, transportation, and industry can contribute significantly to offsetting increased energy demand while freeing up capital for use elsewhere. Benefits from demand reduction include avoiding costly capital investments in electric capacity, lessening reliance on imported energy supplies, and reducing harmful emissions.

The Department of Energy aims to develop cost-effective energy-efficiency technologies that protect the environment and support the Nation's economic competitiveness. To achieve this goal, the Department emphasizes carefully targeted cost-shared collaborations with public and private enterprises. U.S. industry is increasingly involved in developing and using these technologies, thanks to the efforts of the Department.

Our programs in these areas carry out the Department's responsibility under the Energy Policy Act of 1992 (EPACT) and other major pieces of authorizing legislation. The benefits of the Department's efficiency programs—to industries, homeowners, and commercial firms—can be measured in cost savings, productivity gains, new high-value jobs created, and improved productivity and competitiveness for U.S. industry. The following paragraphs highlight some of the successes that have flowed from these programs.

Building Technologies

Residential and commercial buildings consume more than one-third of all U.S. primary energy and about two-thirds of the Nation's electricity. To help realize the energy security, economic, and environmental benefits of improved energy efficiency in buildings, the Department supports research and development on building systems, envelope, and equipment.

Fluorescent Lamp Electronic Ballasts

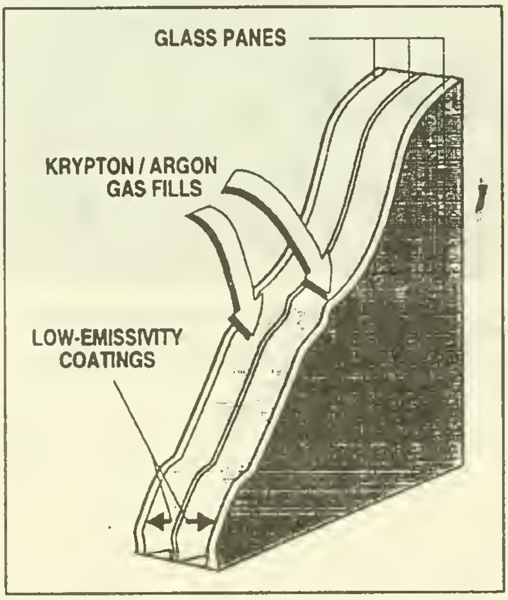
Department of Energy research and development created the current state-of-the-art electronic fluorescent lighting ballast, which was unknown in the mid-1970s. The electronic ballast not only improved lighting quality, but has **saved consumers $750 million in consumer energy bills** from a $3 million research and development investment. This new industry's sales totalled $275 million in 1992,

Electronic ballasts (upper) have saved consumers $750 million. In foreground is a lab prototype electronic ballast for low power electrodeless lamps (for example, the sulfur lamp).

accounting for 25 percent of total ballast sales. Electronic ballasts are expected to replace magnetic ballasts in at least 75 percent of applications by 2015.

Advanced Energy-Efficient Windows

A 20-year Department of Energy research and development partnership with industry culminated in the development at Lawrence Berkeley Laboratory of an advanced energy-efficient window that uses low-emissivity coatings to block heat gain or loss. **No U.S. manufacturer had invested in this technology before the Department's R&D investment. Cumulative consumer energy savings attributable to using low-emissivity windows are $1.8 billion.** This enormous savings was leveraged and catalyzed by a Department of Energy investment of just $3 million through the early 1980s. The Department teamed with five window manufacturers (Andersen, Cardinal IG, Owens-Corning Fiberglass, Pella, and Southwall Technologies) and the Bonneville Power Administration to convert the concept into commercial prototypes. Today, every **major glass and window manufacturer offers low-emissivity products.** Their market share is one-third of all residential windows.



Energy-efficient window.

Sulfur Lamp

In October 1994, the Department of Energy and a small Maryland company, Fusion Lighting Inc., unveiled the sulfur lamp, or S-Lamp, a revolutionary new type of light system in which microwaves are used to heat a sulfur core. The S-Lamp is a scientific and technological breakthrough, considerably more efficient than even fluorescent lights, with fewer associated environmental problems. The quality of light is vastly improved, more nearly approximating natural sunlight, and the installation costs are one-sixth that of conventional lighting. At present, the new system is being demonstrated at the Department's Headquarters, where it lights the outdoor entrance to the building, as well as at the Smithsonian Air and Space Museum. **Two S-Lamp bulbs have replaced 240 mercury bulbs, providing four times the light at one-third the cost.** Unlike other high-efficiency lamps, the Sulfur Lamp uses no mercury and produces 50 percent less ultraviolet light. The United States uses 520 billion kilowatt hours annually for lighting. The S-lamp is expected to have enormous potential commercial and residential applications.

Computerized Analytical Tool for Energy-Efficient Building Design

Department of Energy research and development has created a powerful analytical software tool, DOE–2, for reducing energy use in buildings. DOE–2 calculates hourly building energy use and cost from information on the building's construction, climate, operation, heating, ventilating, and air-conditioning systems, and utility rate schedule. At least 5 percent of commercial buildings today are designed with DOE–2. **Use of the software accounts for $1.9 billion in energy savings for buildings constructed through 1993.**

High-Efficiency Refrigerator/Freezer Compressor

From 1978 through 1980, the Department of Energy, through Oak Ridge National Laboratory, sponsored a contract with Columbus Products Co. to develop a high-efficiency compressor for household refrigerators. The resulting product achieved a 44-percent improvement over the compressor technology used in refrigerators at the time. The availability of high-efficiency compressors was a major reason that refrigerator energy use dropped from about 1,300 kilowatthour per year in 1980 to about 900 kilowatthour per year in 1990. Use of the improved compressors pioneered by this research effort has saved consumers at least **$6 billion in energy costs from 1980 through 1990.**

Flame Retention Head Oil Burner

In the early 1970s, concern with oil supply and price volatility increased interest in improving the efficiency of oil use. The Department of Energy sponsored field testing by the Oil Heat Research and Development Program at Brookhaven National Laboratory, which established the energy conservation benefits of the retention head oil burner. A second Department effort published the findings in a consumer-oriented information booklet. In several years the retention head burner achieved total dominance of the market for new and replacement oil burners. **Consumer energy cost savings to date from this innovation total more than $5 billion.**

Flame Quality Indicator

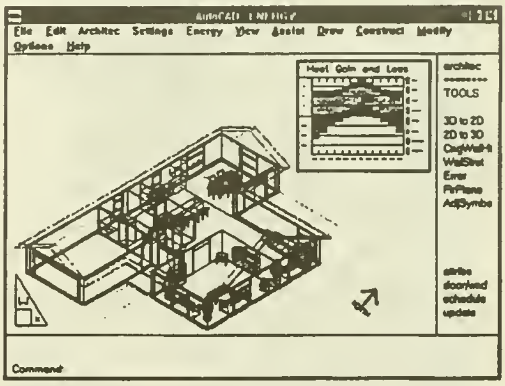
The flame quality indicator, developed by the Oil Heat Research and Development Program at Brookhaven National Laboratory, has been called the most significant advance in oil heating technology since the introduction of the flame retention head burner in the 1980s. The flame quality indicator ensures that the burner operates at peak efficiency throughout the year by monitoring the brightness of the oil burner flame and warning the consumer when the burner needs maintenance. From a Department of Energy investment of slightly more than $1 million, this technology potentially can **reduce oil use by 290 million gallons per year, which represents $3 billion to consumers over 10 years.** Currently, three licensed manufacturers have entered the market. **The flame quality indicator received the 1992 R&D Magazine R&D 100 award and the 1993 "Best of What's New" from Popular Science magazine.**

Compact Fluorescent Lamps With Convective Venting

Compact fluorescent lamps produce less light and operate at reduced efficiencies at the elevated temperatures often associated with constricted environments (such as within recessed fixtures). A Department of Energy laboratory has received a 1994 Federal Laboratory Consortium Award for Excellence for developing a convective venting method to alleviate this problem. The cooling action produced by the convective venting yields an approximate 18-percent increase in lumen output, **while increasing lamp service life from 750 to 10,000 hours.** This approach has been adopted by several large fixture manufacturers (Delray Lighting, Lithonia, Kurt Versen, and Prescolite).

Softdesk Energy Building Software

A collaboration among the Department of Energy, the University of Oregon, and Softdesk, Inc., resulted in Softdesk Energy, a software building design system that incorporates energy-saving features into computer-based building designs. The program integrates specialized software, computer-aided drafting tools, and commonly used manual tools for energy-use estimation. Used during the design process, the one-of-a-kind system provides quick feedback on a building's future energy consumption. The system also determines energy use impacts from internal factors such as lighting, temperature, humidity, ventilation, and building use. Softdesk Energy requires minimal input from the architect, which significantly reduces design time and costs and encourages the exploration of energy-efficient building designs. The system is designed and equipped to incorporate other energy design



Computer software aids design of energy-efficient buildings.

tools such as code and standards compliance, lighting design tools, detailed energy analysis packages, and heating, ventilation, and air conditioning equipment selection tools. **Of 167,000 computer-aided building design users, 100,000 (60 percent) are Softdesk Energy users.**

Appliance Efficiency Standards

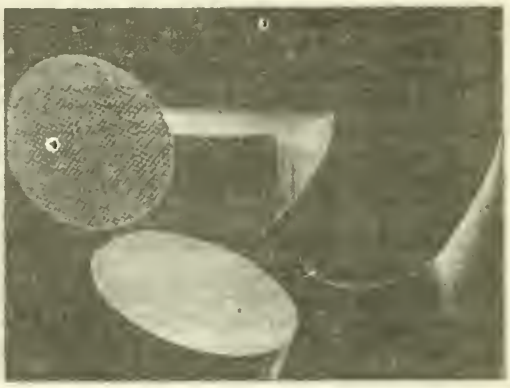
The Department of Energy is required by law to set energy-efficiency standards for a number of appliances, including refrigerators and freezers, stoves and ovens, dishwashers, water heaters, and heating and cooling equipment. The Department updates the standards to ensure that models coming onto the market incorporate the best available efficiency technologies. **These standards have already saved U.S. consumers nearly $2 billion on their energy bills.** Consumers save $2.50 on energy bills for every extra $1 paid to purchase appliances meeting the efficiency standards.

Transportation Technologies

The U.S. transportation sector is still almost totally dependent on oil, and it consumes more than 60 percent of the oil used in this country. Reducing the Nation's vulnerability to oil disruptions will require major changes in the transportation sector's energy demand patterns. Achieving improvements in air quality is also linked to breakthroughs in transportation propulsion technology, as well as changes in the mix of fuels used for transporting people and freight. To accelerate the introduction of more efficient, less polluting transportation technologies, the Department's activities focus on advanced propulsion systems, improved materials, and cost and performance improvements.

Ceramic Regenerator Matrix/Catalytic Exhaust Converters for Automobiles and Heavy-Duty Engines

The Department of Energy research and development in ceramic turbine and materials programs is spawning an entirely new industry with many spin-off components. As an example, the Department's ceramic regenerator development work provided the technological "roots" for a catalytic converter that is now commonly used to reduce automotive emissions. **Current sales of such ceramic components for automobiles are $600 million per year worldwide and are expanding.** Other component sales are projected at $1 billion and 10,000 jobs for the year 2000. Corning Incorporated holds the largest market share.



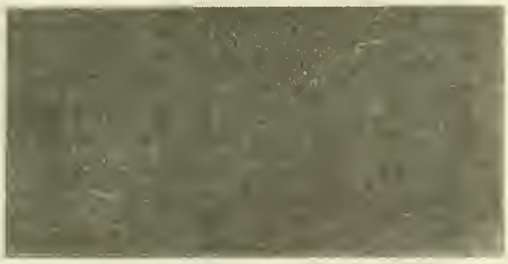
Ceramic substrates for automotive catalytic converters upon which platinum catalyst is deposited.

Silicon Carbide Whisker-Reinforced Ceramics

Silicon carbide whisker-reinforced ceramics developed by the Department of Energy have increased machining rates up to 800 percent and have dramatically decreased the frequency of cutting tool replacement. These advantages have allowed the United States to recapture a substantial international market share of the cutting tools industry. This composite material was developed in coordinated Department programs with a 7-year **investment of $3.8 million; worldwide sales now exceed $30 million.**

Sintered Silicon Carbide Used as a Seal Face in Automotive Water Pumps

The Department of Energy Transportation Materials Technology Program, with the Carborundum Company, has developed an improved sintered silicon carbide (ceramic) seal face for water pumps. These seals are used in 30 percent of new U.S. automobiles—up from 5 percent in 1993. Shipments will total 10 million seal faces this year for worldwide



Sintered silicon carbide steel faces for automotive water pumps.

markets. A Department of Energy investment in mechanical characterization of approximately $500,000 over a 5-year period has resulted in a potential **worldwide market for these seals in excess of 65 million units per year.**

AC Electric Drive Train

Under a cost-shared contract with the Department of Energy, the Ford Motor Company and General Electric have developed a new electric drive train. This drive train uses one design for a wide range of production vehicles. This new multivehicle design will reduce consumer costs and allow electric vehicles to enter the market sooner. Ford is testing this technology in 105 Ecostar electric vehicles operating around the country. The California laws mandating zero-emission vehicles will result in **approximately $70 million in electric vehicle sales in 1998 (the only current solution to the California mandates), growing to $350 million by the year 2003.** Should the New England states implement the California mandates, the market will grow to at least $1 billion by 2003.

Ceramic Material Heat Engine Components

High melting temperatures, hardness, light weight, and other properties of ceramic materials promise to enable energy efficiency, emissions reduction, and durability improvements in automobile and truck engines. The Department has worked with industry to develop processes that have improved the properties and reliability of ceramics. In 1983, ceramic heat engine parts repeatedly broke. Ten years and $109 million of DOE cost-shared research and development has resulted in U.S. industrial ceramic materials that **exceed the strength, durability, and reliability requirements for transportation applications.** The Department has developed a process, with a U.S. company, to reduce the cost of producing silicon nitride ceramic powder from $30 per pound to slightly more than $10 per pound. The ultimate goal is $6 per pound. Manufacturers are beginning to use this material for a variety of parts in production engines. Allied Signal, for example, is manufacturing ceramic oil pump spacers for use in commercial aircraft, including Boeing, Gulfstream, and Airbus. As another example, more than 15,000 ceramic cotter pins have been sold for aircraft applications.

Nickel Metal Hydride Cells, Modules, and Vehicle Batteries

Nickel metal hydride batteries are one of three midterm batteries being developed by the Department of Energy through the United States Advanced

A nickel metal hydride battery.

Battery Consortium. This battery technology is approaching all of the consortium's midterm goals, with the exception of cost. The consortium is now concentrating on developing lower cost materials and improved production processes. Given the performance of this technology, General Motors has formed a joint venture with the Ovonic Battery Company. Replacing the lead acid battery in the General Motors Impact car with this nickel metal hydride battery will increase the range of the vehicle from 70 miles to 140 miles between recharges. A conservative market estimate for this battery, as the result of the mandates for zero emission vehicles in California and the Northeastern States, is **approximately $350 million in 2003.**

Biomass Feedstock Technology

Hybrid poplar "supertrees," which are being commercially planted by six major pulp and paper companies in the Pacific Northwest, were developed through Department of Energy investment in research programs for producing biofuels feedstocks. This portion of the Department's Biofuels Feedstock Development Program, focused in the Northwest, has invested approximately $2 million over 17 years to produce genetically superior trees and improved agricultural production techniques. **Acreage planted is expected to double from the 25,000 acres planted now to well over 50,000 acres within the next 2 years.** Two mills are already using the fiber to produce paper as well as energy for their boilers, and two new nursery companies have emerged to supply high-quality cuttings to private industry and landowners. The Western Washington plantings established along rivers provide habitat to an endangered deer species and other wildlife. Each acre of hybrid poplars planted displaces the need to harvest 10 acres of Douglas Fir for fiber.

DYNA3D Finite Element Analysis Technology

The Department of Energy sponsored research that developed DYNA3D, a dynamic finite element analysis tailored to simulate high energy impacts, such as car crashes or aircraft collisions with birds. DYNA3D is available at near-zero cost to the public and has had a major impact on U.S. industry. It is used by more than 300 U.S. companies, including GE Aircraft Engines, General Motors, Chrysler, the Boeing Company, ALCOA, General Atomics, FMC Corporation, and Lockheed Missiles and Space Company. The technology is used by all U.S. car manufacturers and has sharply reduced the need for costly vehicle crash testing. An independent study placed the **savings to U.S. industry as a result of using the model at $350 million.**

Zymomonas Mobilis Organism

In 1994, research sponsored by the Department of Energy developed a new, genetically engineered organism, *Zymomonas mobilis*. This organism enhances the fermentation of cellulose, increasing the rate of conversion and yields of ethanol for use as fuel. It is estimated that this new technology, which was described in the prestigious journal, *Science*, and widely written about by the Associated Press, has **significantly reduced the cost of ethanol** from $3.60 per gallon to less than $1.00 per gallon, making ethanol a more competitive alternative fuel.

Lightweight Materials Technology Development

Reducing vehicle weight through the use of lightweight materials promises to enable major energy efficiency improvements in full-size automobiles without compromising passenger comfort and safety. At the program's inception in 1992, lightweight metals such as aluminum could not compete with steel as the material of choice for automotive manufacturing because of their cost and forming time. After three years and $3 million of Department of Energy cost-shared R&D, advanced forming of aluminum sheets for auto body components achieved weight reductions of 43 percent, parts count reductions of 89 percent, forming time reductions of 77 percent, and cost reductions of 15 percent. **Projected cost savings to auto companies are about $60 million per year by 1997.**

Industrial Technologies

The Department's industrial energy activities are motivated by energy, economic, and environmental policy objectives. Specific activities are shaped by the recognition that enhanced energy efficiency is a key to increasing industrial productivity and that improving efficiency of industrial energy use is closely linked to reducing waste and pollution. The goal of the industrial energy program is the creation of a more efficient, competitive, environmentally sound, and sustainable domestic industry, and to promote environmental stewardship, competitiveness, and job preservation and creation by demonstrating profitable alternative approaches to regulatory compliance.

The Department collaborates with industry to reduce energy use through new technologies in heat recovery, energy utilization, and industrial and municipal waste management. Other programs develop process improvements and innovations for specific energy-intensive industries such as pulp and paper, steel, and chemicals. In addition, applied research in combustion, biotechnology, advanced materials, and heat transfer will provide the foundation for future advances in technology. An active technology transfer program provides an effective link between the research and development programs and the community of potential users.

More than 50 technologies in the Department of Energy's Industrial Technologies Program are economically successful. An investment in developing these technologies of about $1.1 billion from fiscal year 1977 through 1994 has yielded approximately **$2.5 billion in energy savings and capital productivity.**

Catalytic Distillation

The advanced catalytic distillation process developed by the Department of Energy nearly 15 years ago has become a major commercial success. It is used to produce gasoline additives such as methyl-tertiary-butyl-ether and tertiary-amyl-methyl-ether, thus helping U.S. refiners produce the reformulated gasoline mandated by the Clean Air Act Amendments of 1990. As of fiscal year 1994, 80 units were on order at the manufacturer, Chemical Research and Licensing, Inc., 19 units were operating in the United States, and 40 units were operating worldwide—28 percent of the world market. **Advanced catalytic distillation saved 3.24 trillion British thermal units of energy in 1993 alone, at a rate of about $10 million per year.**

Ultralight Aerogels

Scientists sponsored by the Department of Energy at two national laboratories have developed a new material, called aerogel, that has the lowest density, highest porosity, lowest thermal conductivity, and lowest sound propagation of any solid ever made. A **1-inch-thick layer of aerogel replaces 12 inches of fiberglass insulation.** This feature is particularly valuable in appliances such as refrigerators and water heaters. While industry interest in better insulation is being explored, the unique properties of aerogel have opened other market opportunities for this emerging technology. Because of their high surface-to-volume ratio, these materials can be used as catalytic and adsorbent surfaces and as carbon ultracapacitors. Ultralight aerogels are being taken to the commercial market by Aerojet, a segment of GenCorp.

Aluminum Remelting Technology

A $400,000 grant from the Department of Energy, through the National Industrial Competitiveness Through Energy, Economics, and Environment program to AAP St. Mary's of Ohio has resulted in a more efficient technology for aluminum remelting. By avoiding the second aluminum chip melt during recycling, real energy savings are 6.36 billion British thermal units annually—6,249 gallons of diesel fuel, and 155,000 gallons of coolant. Additionally, the new technology eliminates 59 tons per year of emissions and 64 tons per year of dross. **Dollar savings equal $642,000 annually.**

Vacuum Pressure Swing Adsorption

By eliminating the nitrogen from air in glassmaking furnaces burning gas or oil, vacuum pressure swing adsorption technology has reduced furnace emissions of nitrogen oxides by 90 percent and particulates by 25 percent. Furnace energy requirements are reduced by 25 percent. Three companies, Praxair, Inc., (Tarrytown, N.Y.), Corning, Inc., (Corning, N.Y.), and Gallo Glass Company (Modesto, California) have commercialized this energy-efficient technology. **Approximately 15 percent of all glass made in the United States now employs this technology.**

Electrochemical Dezincing of Steel Scrap

Department of Energy scientists have developed an electrochemical method of removing the galvanized coatings from steel scrap that would allow 10 million tons of this valuable resource to be used in steelmaking furnaces. This process would increase production yields and quality as well as decrease environmental problems and cost. By the year 2000, electrochemical dezincing could **save 50 trillion British thermal units of energy,** reduce raw material costs by at least $160 million per year, and reduce the need to import at least 75,000 tons per year of zinc, saving at least $77 million annually.

A crane loads 3,000-pound bales of dezinced steel. This stamping plant scrap was dezinced using the electrochemical process developed by the Department of Energy.

High-Efficiency Weld Unit

Improving power supply efficiency is key to achieving significant energy savings in welding processes. Conventional arc-welding power supplies use a low-frequency transformer, which makes them power-inefficient and unwieldy in weight and size. The Department of Energy developed a more efficient power supply with the Cyclomatics Company. The new system uses solid-state electronics known as inverter technology to shut off power to essentially all of the power source components when a unit is idling. This reduces electrical energy consumption by up to 45 percent compared to conventional power supplies. Nationwide, these units have saved more than 13 trillion British thermal units of energy and can be credited with reducing emissions of carbon dioxide by 20,000 tons each year. **Annual savings are $15 million.**

Direct Steelmaking

The Department of Energy supported post-combustion research in a Basic Oxygen Steelmaking Furnace, which led to the application of the technology in the electric arc furnace. The result is a savings of 40 to 50 kilowatthour per ton and a 6- to 7-percent increase in productivity. This work was performed by Union Carbide, now Praxair, under a subcontract from the American Iron and Steel Institute. Praxair is now marketing the technology worldwide. This technology can be applied in approximately 50 million tons of steelmaking annually, with an annual savings of $30 million.

Superplastic Metal Formation Technology

The superplastic metal forming process developed through research sponsored by the Department of Energy allows the manufacture of metal components into shapes very near final dimension. This results in several advantages. It minimizes machining material waste, eliminates the use of environmentally damaging solvents, and saves energy, time, and labor costs. Further, it allows the use of new materials such as lightweight alloys, and enhances design freedom by creating the opportunity to produce unique complex shapes. **Manufacturers report a 20-percent savings in metal machining processes.**

Securing Future Energy Supplies

Today more than 85 percent of the useful energy and power produced in the United States comes from boilers, furnaces, and internal combustion engines that rely on fossil fuels. The Nation's increasing dependence on imported oil makes us vulnerable to supply disruptions and related price shocks. Although natural gas and coal are mostly domestic fuels, the heavy reliance on fossil fuels necessitates costly efforts to control pollution. Improving the Nation's ability to develop cleaner technologies and secure future energy supplies is vital to our economic, environmental, and social well-being.

The Department of Energy seeks to achieve this goal by research and applied technology development aimed at diversifying energy sources—especially promoting increased use of indigenous resources, including oil, gas, coal, nuclear, and renewable energy. We also support efforts to increase the efficiency of electric energy distribution and storage. To better ensure early commercial application of successful technologies, this research and development will be based on cost-shared joint government-industry-university collaborations wherever possible.

Some success stories on the supply side of the energy ledger are highlighted in the following paragraphs.

Renewable Energy

The Department supports a balanced development and deployment effort on promising renewable energy technologies aimed at increasing the production and use of domestic energy resources, and is working with industry to strengthen the technology base leading to new products and processes for the commercial market. The number of private-sector partners willing to cost-share key research projects is evidence that the private sector has a legitimate interest in these technologies. Research and development on photovoltaics, solar thermal, wind, biomass, and geothermal energy will help strengthen the Nation's energy security, promote sustainable energy approaches, and increase U.S. industrial competitiveness. The goal in this program area is to triple the U.S. nonhydropower renewable energy capacity by the year 2000.

Continued cost reductions fostered by our strategic research, development, and deployment activities can ensure the United States a place in an emerging multibillion-dollar clean energy market. The establishment of footholds by U.S.-based firms in international sales activity is clearly vital. Currently, U.S. photovoltaic and geothermal companies are worldwide leaders as a **result of Department of Energy investments** in advanced technology development. More than **70 percent of U.S. photovoltaic manufacturing output is exported,** resulting in more than **$90 million in annual revenues.** U.S. companies have installed more than 1,000 megawatts of geothermal facilities in other countries and have orders for an additional 2,000 megawatts, creating an annual income stream of **$250 million.**

Photovoltaics

Research and development supported by the Department of Energy has been instrumental in the discovery, synthesis, and development of state-of-the-art semiconducting and photonic materials and devices. Photovoltaic technology converts photons (light) into electricity. Today photovoltaic cells power a wide variety of devices, including spacecraft, watches, calculators, highway signs, navigational aids, emergency telephones, and relay stations; in developing countries, photovoltaic cells power entire remote villages. Photovoltaic systems are an ideal, environmentally sensitive technology for bringing people in remote sites such basic services and amenities as light, water, communications, power for businesses, and power for other productive uses.

Photovoltaic electricity costs dropped from 90 cents per kilowatthour in 1980 to 20 cents per kilowatthour today. Since 1988, photovoltaic output has doubled; photovoltaic output increased another 24 percent just from 1993 to 1994. Maintaining and expanding this phenomenal growth depends on continuous improvements in the performance and cost-competitiveness of photovoltaic products, supported through cost-shared R&D between industry and the Department of Energy. At present, **every $100 million in direct module photovoltaic sales helps support or create 3,800 U.S. jobs.**

Wind Turbine Technology

Collaborative Department of Energy and industry research and development has created today's modern wind turbines, which are already providing sufficient electricity for 1 million Americans. Costs have been reduced from almost $.25 per kilowatthour in 1980 to the current range of $.05 to $.07 per kilowatthour in locations with good wind resources. New wind turbine blades, advanced materials development, and developments in airfoil technology are expected to further reduce the cost of wind-generated electricity to $.04 per kilowatthour by 2000. In California alone, there are more than 1,700 megawatts of generating capacity. California's wind powerplants **currently provide up to 8 percent of Pacific Gas and Electric's load and save the energy equivalent of 4.4 million barrels** of oil each year while producing no air pollution. (In fact, wind power prevents the creation of 2.5 million tons of carbon dioxide and 15,000 tons of other pollutants per year.)

Wind Energy Analysis Systems

A team of scientists at a Department of Energy laboratory produced and documented the most comprehensive analyses available of wind energy resources and wind electric potential in the United States. These analyses are used by utilities, energy planners, and industry. Team members also combined their skills to develop a measurement and analysis system for characterizing turbulence in the wind inflow to a turbine rotor. Efforts are now being extended across the globe to assist developing countries in establishing local wind energy projects. Data derived from the research also convinced the World Bank to include wind power as a viable option for a **$600 million rural electrification project in Indonesia. This investment directly serves the Department of Energy missions of pollution prevention and increased energy efficiency.**

Geothermal Technologies

The commercially operated geothermal site at The Geysers in northern California reached peak electric power output of 2,000 megawatts in 1988. Inexplicably, a steady decline in output began in 1989. In 1990, a concerned geothermal industry asked the Department of Energy for assistance in determining the cause. Failure of power production at The Geysers would have a depressing effect on all potential markets for geothermal power. During fiscal years 1990 through 1994, the Department of Energy shared costs with a coalition of geothermal operators and made available both experts and expertise to help diagnose the problem. The cause proved to be reservoir fluid depletion, the result of inadequate reinjection practices and insufficient knowledge of reservoir management requirements. The lessons learned in this effort will continue to benefit geothermal reservoir development for years to come. With a $12 million Department of Energy investment—matched by $42 million from industry—a potential crisis for hydrothermal energy systems was overcome, reservoir practices leading **to decades of stable operation were developed, and more than 300 jobs were directly preserved.**

Gas and Oil Exploration and Production Technologies

Oil remains one of our Nation's vital commodities, supplying 40 percent of the United States' primary energy needs and nearly all of its transportation fuel. Domestic production, however, continues to decline, with two-thirds of all the oil ever found in the United States remaining unrecoverable by conventional production methods. Moreover, the United States has technically recoverable reserves of 113 billion barrels, almost 6 times today's proved reserves. In addition, as much as 1,300 trillion cubic feet of natural gas is technically recoverable in the lower 48 States—about 8 times more than current proved reserves.

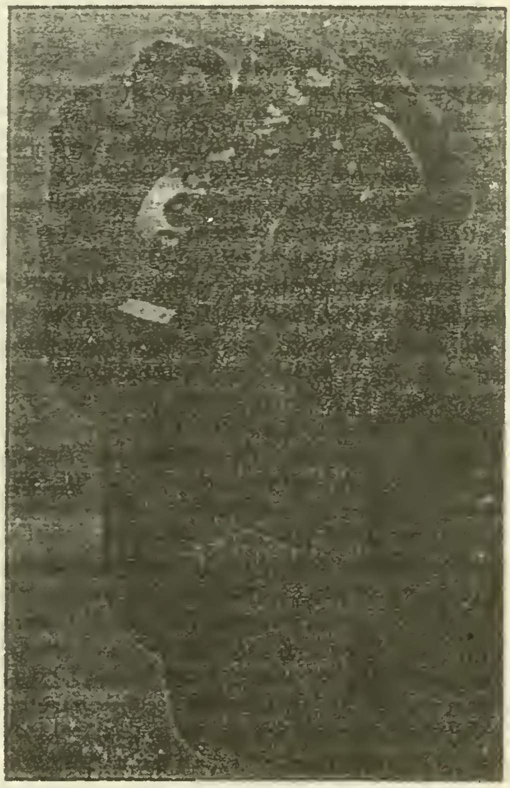
To realize the potential of these oil and gas resources requires continued development of advanced exploration and extraction technologies. The Department is working with industry to develop advanced computing technologies to improve drilling success rates, rock drilling systems for natural gas, and advanced oil recovery technologies, as well as carrying out related research and analytical activities. By enhancing the efficiency and competitiveness of U.S. industry, these research and development efforts will increase domestic energy production, reduce dependence on imports, and create jobs.

Polycrystalline Diamond Drill Bits

Research and development sponsored by the Department of Energy produced one of the most important advances in drilling technology, a new drill bit design that uses polycrystalline diamond cutters. Previous diamond cutting bits failed when the cutting assembly would break away from the bit after prolonged drilling. This technology, which was spawned by Defense Programs basic research at Sandia National Laboratories, permanently bonds the cutters to the bit. In time-critical drilling situations, this drill bit can save as much as $1 million per well. Worldwide, 13 companies now fabricate this synthetic diamond drill bit. U.S. companies produce approximately 4,000 bits per year.

Mudpulse Telemetry for Measurement While Drilling

One of the most important timesaving innovations used today in the drilling industry is the "measurement-while-drilling" instrument. Before its invention, operators needing to determine drill bit direction had to cease drilling, remove hundreds or thousands of feet of drill pipe, and lower an instrument into the well. Readings would then be taken, the instrument retrieved, and drilling would recommence. In the 1970s, the Department of Energy helped Teleco, Inc., pioneer a wireless system that could transmit the location of a drill bit by sending pressure pulses through the drilling mud that circulated from the bit face to the surface. Today, mudpulse telemetry has gained wide acceptance in



Polycrystaline diamond drill bit is one of the most important advances in drilling technology. Thirteen companies currently manufacture the bit.

the drilling industry and is estimated to have saved **the natural gas and oil industry at least $1 billion over the past 20 years.**

Carbon Dioxide Sand Fracture Production Technology

The Department of Energy's Morgantown Energy Technology Center developed, tested, and helped commercialize this technology for stimulating production from natural gas wells. A nondamaging treatment process, it won the natural gas industry's **1994 Best Technology in the Northeast Award.** Of special importance to small, independent producers, the technology has been shown to increase production by 200 to 500 percent. At $2.00 per thousand cubic feet, a 3 to 9 million cubic foot well using carbon dioxide sand fracturing **will generate $20 million more revenue over its productive life.**

Hot Oiling Paraffin Treatment

Buildup of paraffin in the wellbore and near-wellbore formation can cause severe reductions in production of waxy crudes and result in lifting equipment failures. Traditional batch treatments are expensive and can result in formation damage if sound hot oiling practices are not followed, that is, if melted paraffin solidifies before it reaches the bottom of the well and plugs the formation. The Department of Energy developed a computer model that optimizes hot oiling paraffin treatments and aids in determining good practices. The use of this software, to estimate downhole temperatures and effectiveness of hot oiling, helps both producers (especially independents) and service companies by reducing operating and maintenance costs. For example, application of the software by an independent producer in a West Texas field increased the efficiency of production equipment, reduced equipment failures, and resulted in about $1.00 per barrel-equivalent reduction in average lifting cost. Industrywide use of the software and good hot oiling practices could result in **more than $150 million per year in reduced operating cost,** and also reduce well abandonments.

Insulating Doughnut for Steam Flood of Deeper Oil Wells

Steam injected into deeper heavy-oil wells can lose significant amounts of heat during the trip from the surface to the reservoir. In fact, a phenomenon known as wellbore refluxing can result in up to six times the heat loss in an uninsulated tubing string than would be normally expected. Sandia National Laboratories, working under a Department of Energy program, devised a 2-inch-long "doughnut" of plastic insulation that, when inserted in the standard tubing coupling, prevents steam from contacting the thin outer coupling walls. Heat loss through refluxing is reduced substantially. This simple device is now standard in the industry, and the savings to the industry will amount to **hundreds of millions of dollars over the next decade.**

Improved Oil Recovery Technology for the Green River Formation

An oil recovery field demonstration program cosponsored by the Department of Energy has shown that by properly applying improved water-flooding technology in the Uinta Basin in Utah's Green River Formation, additional oil can be produced from fields that might otherwise have been abandoned. The Department's test has turned around conventional thinking in the region, giving Utah producers a technology that was previously thought to be unusable in the region's complex geology. The initial field test has already added **2.4 million barrels of producible oil to the region's reserves.** More importantly, neighboring operators have begun using the technology and will **return more than $160 million in Federal taxes and royalties, well above the $112 million Federal investment** to date. Ultimately, recoverable oil reserves in Utah could be expanded by 3.5 billion barrels because of the Department of Energy cost-shared project.

Carbon Dioxide Miscible Flooding Technology for Oil Recovery

Three percent of all domestic crude oil (about **180,000 barrels per day**) is produced by injecting carbon dioxide into aging reservoirs to force out oil that conventional production techniques cannot recover. The gas mixes with some of the remaining oil in the reservoir, and creates a miscible bank of fluid that pushes additional oil to production wells. In large part, industry gained confidence in carbon dioxide flooding technology through a series of eight field tests conducted in the 1970s and co-financed by oil companies and the Department of Energy and its predecessors. Because of the success of carbon dioxide-enhanced oil recovery, carbon dioxide pipelines have been built throughout west Texas and eastern New Mexico, the principal regions of successful carbon dioxide miscible flooding. With the completion of the LaBarge pipeline, carbon dioxide-enhanced recovery has also been extended to oil fields in Wyoming and could reach others in North Dakota. Today, roughly **68,000 Americans are employed** directly and indirectly because of this oil recovery technology. Moreover, data developed through the Department's laboratory research has saved the domestic oil producers **at least $10 million** by allowing them to accelerate development of other recovery processes.

Computerized Oil Field Simulators

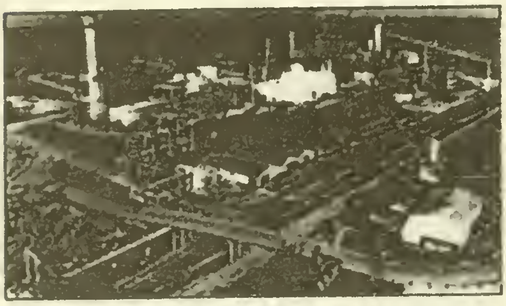
Closely related to predictive models is a family of oil field simulation software developed by the Department of Energy. BOAST (Black Oil Applied Simulation Tool) was introduced in 1982 as a way to simulate the movement of oil, gas, and water through an oil reservoir. BOAST has been upgraded to operate on personal computers and expanded to assess larger areas, larger numbers of wells, and more solution options. More than 2,400 copies of BOAST PC software have been distributed by the Department. Several oil industry consulting firms have modified the program to their own specifications. **More than 20 million barrels of oil** have been produced as a result of using these simulators, and **the return to the taxpayer is more than $1,000 for each $1 of Department of Energy investment.** Universities are also using BOAST as a textbook for reservoir simulation instruction. A second simulator, UTCHEM, has been developed specifically for chemical flooding. The simulator is being used by approximately 20 oil companies to project the behavior of tracers, polymers, polymer gels, surfactants, and alkaline agents injected into oil reservoirs. Better management of reservoirs has **saved these companies more than $23 million, $8 million of which will flow back to the U.S. Treasury.** The Department developed a third simulator, MASTER, to assist the natural gas industry in evaluating miscible and nonmiscible gas-enhanced oil recovery processes. By 1994, more than 250 copies of the software package had been distributed. Studies indicate that use of these processes will generate a 3-billion barrel increase in potential reserves.

Foam Fracturing of Gas Reservoirs

Another technique for creating fractures in a gas reservoir is to inject foam under high pressure into the wellbore. Foam has an advantage over high pressure water injection because it does not create as much damage to the formation, and well cleanup operations are less costly. Before the mid-1970s, use of foam fracturing was limited almost exclusively to Canada and the Rocky Mountain region. The Department's research in the late 1970s extended the technology to the Eastern region of the country, where effective fracturing is required to produce commercial quantities of gas from shale formations. More than 50 stimulation tests were conducted to apprise oil and gas operators in 8 Eastern States of the technique's merit. Once it was shown that the process **accelerates the rate of natural gas production from these wells by nearly 200 percent,** the foam fracture process became the dominant stimulation technique for marginal gas wells in the United States.

Enhanced Oil Recovery Predictive Models

The Department of Energy, in partnership with the National Petroleum Council and Software/Intercomp, has developed easy-to-use, predictive computer models for numerous enhanced oil recovery techniques. More than 1,000 copies of the PC-based predictive models have been distributed to oil field operators, drilling and service companies, consultants, researchers, and several major oil companies. The use of these models has **saved the industry $400 million** by screening out uneconomical projects.



The Wabash River Coal Gasification Repowering Project, about 70-percent complete by the end of 1994. Destec Energy's two-stage, oxygen-blown gasifier tower is on the right and the integrated gasification combined cycle heat exchanger, and stack is on the left.

Coal-Use Technologies

Coal is the Nation's most abundant fossil fuel and is currently used to generate 57 percent of U.S. electric power. With coal projected to remain a dominant fuel for the power industry for many years, cleaner and more efficient coal-based technologies are becoming increasingly important for the Nation's energy and economic future. Working in close collaboration with industry, the Department's research and development efforts focus on improving the environmental acceptability of coal. These include developing technologies to burn coal more cleanly and efficiently, as well as technologies that can reduce the costs of producing liquid transportation fuels from coal.

Integrated Gasification Combined Cycle

Capitalizing on a successful gasification program, the Department of Energy has provided the foundation for an advanced power generation system that will be the powerplant of the 21st century. Advanced integrated gasification combined cycle (IGCC) technology will have system efficiencies ranging from 41 to 52 percent. Emissions of sulfur dioxide and nitrous oxide are limited to less than one-tenth of that allowed by New Source Performance Standards, carbon dioxide emissions are reduced by 35 to 45 percent, and solid waste is reduced by 40 to 50 percent. The IGCC powerplant is cost-competitive to build, in fact it is projected to be significantly less costly than conventional powerplants, while the cost of production would be reduced by 10 to 20 percent. At present, the Department's Clean Coal Technology program will provide the IGCC system entry into the global market as a top-ranking clean coal power generation technology with a **potential global market of more than $400 billion in capital investment by 2030, and about $150 billion in the domestic market.**

Super 9 Chrome Alloy

During the 1980s, Department of Energy research and development was instrumental in the development of a superstrong alloy called Super 9 Chrome, which is now used worldwide as an industry standard for improving the safety and reliability of equipment in coal-fired powerplants. This 9 percent chromium and 1 percent molybdenum alloy improves the life and performance of equipment under the severe operating temperature, pressure, and corrosion conditions typical of fossil fuel plants. Department of Energy scientists received the prestigious R&D 100 Award for this technology, which has since been incorporated into American Society of Mechanical Engineers Boiler and Pressure codes and transferred directly to industry for commercial applications. **Sales of this product exceed $100 million to date.** Use of this alloy has enabled an increase in coal-fired powerplant efficiency of more than 3 percent, which results in a **savings of more than $1.7 million per year in fuel costs in a typical 500 MW powerplant.** The higher efficiency also results in reduced emissions of sulfur dioxide, nitrogen oxides, and particulates, as well as reduced production of carbon dioxide by 280,000 tons per year.

Atmospheric Fluidized Bed Coal Combustor

The most significant advance in coal-fired boiler technology in more than half a century, the Fluidized Bed Coal Combustor has been the commercial success story of the last decade in the power generation business. This state-of-the-art, low-polluting combustion system technology has progressed into even larger scale utility applications. To date, **more**

than $6 billion in domestic sales and $2 billion in foreign sales have been achieved through this Department of Energy investment. Domestic sales alone translate into nearly 250,000 jobs. Every major U.S. boiler manufacturer now offers a fluidized bed combustor in its product line.

Low Nitrogen Oxide Burner

With nitrogen oxides targeted for reduction by the 1990 Clean Air Act Amendments, Low Nitrogen Oxide Burner technology developed by the Department of Energy and Altex Technologies Company has rapidly found its way into the power market. **Domestic sales to date total more than $250 million, supporting 1,800 U.S. jobs.** For wall-fired boilers, nitrogen oxide reduction levels of 35 to 40 percent are achieved at a capital cost of about $20 per kilowatthour and a levelized cost of about $280 per ton of nitrogen oxide removed. For tangentially fired boilers, the same degree of nitrogen oxide reduction is achieved at a capital cost of $15 to $20 per kilowatthour and a levelized cost of $220 to $350 per ton of nitrogen oxide removed. These costs are significantly lower than other options.

Pure Air Scrubber

The first utility in the United States to meet new Clean Air Act standards for sulfur dioxide control did so using an advanced technology supported by the Department of Energy, the Pure Air Scrubber. The capital cost per unit was half of previous air scrubbers, and it produces a commercially marketable gypsum material, rather than the waste sludge commonly produced by older scrubbers (which causes landfill problems). In one year, the Pure Air Scrubber is eliminating 50,000 tons of sulfur dioxide emissions, turning an air pollutant into enough wallboard to construct nearly 19,000 homes. **The project earned Power Magazine's 1993 "Power Plant of the Year" award.**

Powerplant equipped with a pure air scrubber system.

Micro-Mag Sulfur Removal Process

Application of the Micro-Mag sulfur removal process removes 80 percent or more mineral-bound sulfur in coal. Scientists supported by the Department of Energy received a Federal Laboratory Consortium annual award for excellence for developing and transferring this technology to the private sector. This technology is central to a **$900 million coal preparation and slurry pipeline energy project in China.** The China project alone, developed by Custom Coals Corporation, will support **6,300 U.S. jobs.**

Advanced Instrumentation Development

The Department of Energy's advanced instrumentation development efforts have generated and contributed to several commercial businesses, while fulfilling its role of supporting advanced and conventional power systems. The instrumentation developed in this program includes novel elemental analyzers, combustion turbine flame monitors, a steam quality monitor for advanced heat exchanger applications, and an on-line, real-time particle counter. The instrumentation applications range from optimizing environmental performance to process monitors for reduction of off-specification operations. The commercial value of the instrumentation installed in current operating plants exceeds $40 million.

Ceramic Composite Filters for Hot Gas Cleanup

The Department of Energy developed a process that produces continuous fiber ceramic composite filters that will reduce tons of pollutants and save millions of dollars in cleanup costs at hundreds of fossil fuel powerplants across the U.S and elsewhere. Subsequently, Department of Energy scientists developed a chemical vapor infiltration and deposition process to produce filters many more times more resistant to thermal and mechanical shock than conventional filters. 3M is now beginning to market the filter technology worldwide. **The annual market share for the filters is estimated to be $200 million per year.**

Slagging Advisor Software Model

The Slagging Advisor Software Model, the result of an industry, university, and Department of Energy team in laboratory coal science, is being marketed worldwide by PSI Powerserve. By optimizing control of boiler fouling, the software improves efficiency and cost in both conventional and advanced systems. Potential industrywide savings are hundreds of millions per year. For example, the software has **saved more than $1 million annually for one utility alone.**

Nuclear Fission Technologies

Nuclear energy currently provides approximately 20 percent of the electricity supply of the United States. Maintaining nuclear energy as an option to meet the Nation's growing demand for energy is one objective of the Department of Energy. Nuclear energy can provide a secure and clean domestic source of energy generation without emissions of greenhouse gases or acid rain precursors. Conducted in cooperation with the electric utility and nuclear industries, the Department's civilian nuclear energy program is focused on advanced light-water reactors that are expected to be safer, more reliable, and less expensive than current-generation nuclear energy plants. By working toward making standardized, certified, advanced light-water-reactor designs available before the end of the 1990s, the Department will help ensure that nuclear energy remains an option for the Nation's energy supply in the 21st century.

Light-Water Reactors

Although the bulk of the Department of Energy's work on light-water reactors was conducted over many decades, including the 1950s and 1960s, the Department continued to research important refinements in the 1970s and 1980s to improve safety and reduce costs. Based upon Department of Energy research and development in nuclear physics, reactor engineering, and related materials development, there are currently 109 nuclear powerplants (about 100 gigawatts-electric) with full power operating licenses. These powerplants produce approximately 22 percent of the Nation's electricity. The electrical power produced by these plants, if replaced by conventional powerplants, is equivalent to $20 billion per year. **Over the past 20 years, these plants have replaced the equivalent of $400 billion in fossil power,** displacing significant amounts of air pollution. Additional Department of Energy research in partnership with the nuclear industry is leading to procedures to extend the life of existing plants. Estimated savings in energy costs for 20-year life-extension versus replacement is $800 million per plant.

Extended Burnup of Light Water Reactor Fuel

By 1985, a 10-year research and development partnership between the Department of Energy and the nuclear fuel industry had provided the technology for an approximate 50-percent increase in the burnup (or energy extraction) achieved by each unit of nuclear fuel. This technology is being implemented in operating water-cooled reactors worldwide, yielding **fuel cost savings of several million dollars per year for each operating reactor,** reducing the amount of spent fuel to be disposed of by approximately one-third, and serving U.S. nonproliferation policy interests by making the reprocessing of such spent fuel even more uneconomical.

Greenhouse Gas Emissions Reduction

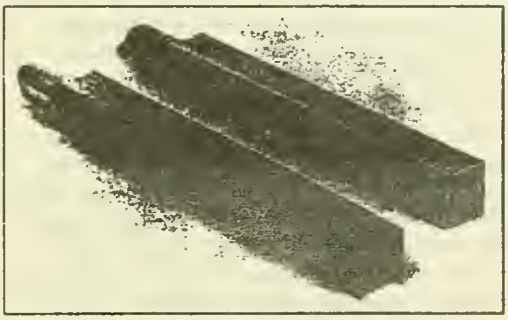
Department of Energy nuclear research has resulted in 92 percent of all carbon dioxide emission reductions realized in the electric utility sector since 1973, avoiding 1,615 million metric tons of carbon emissions. Also, nuclear energy has mitigated 27 million tons of nitrogen oxide and 65 million tons of sulfur dioxide emissions in the United States alone. Internationally, emissions avoided from 1973 through 1991 through the use of U.S. nuclear energy technology is 4,300 million metric tons of carbon dioxide, 70 million tons of nitrogen oxide, and 160 million tons of sulfur dioxide.

Advanced Light-Water Reactors

The Department of Energy supports research and development to make the next generation of nuclear powerplants, certified advanced light-water reactors, available at the earliest possible date to the marketplace, to ensure the light water reactor is an option in contributing to the new electrical energy capacity required by 2010. In 1994, Final Design Approval, a major milestone toward certification, was achieved for two 1,350-megawatt evolutionary advanced light-water reactor designs. The Senate noted this success in its report on the Energy and Water Appropriation Bill of 1995. Building on research and development sponsored by the Department, the **General Electric Company recently sold two advanced boiling water reactor plants to Tokyo Electric Power Company**, kicking off sales of the next generation in advanced light-water reactors.

Reduced-Enrichment Fuels for Research and Test Reactors

During the 1980s, the Department of Energy's Reduced Enrichment Research and Test Reactor Program at Argonne National Laboratory developed and qualified a high-density dispersion fuel that serves U.S. nonproliferation policy interests by significantly decreasing the amount of weapons-grade uranium being used for civil programs throughout the world. The U_3Si_2 dispersion fuel has received the Innovation Research 100 award (1985), has been accepted by all major research reactor regulatory authorities, and is currently being manufactured commercially in the United States, France, and Denmark. Additionally, fuel fabricators in Canada, Indonesia, and the United Kingdom are in the process of adopting the U_3Si_2 fuel. Through 1994, seven foreign and seven U.S. reactors have converted or begun to convert to this low-enriched fuel. Ten other reactors were converted to low enrichment uranium using lower density fuels also developed by the program.



Mock-up standard and control fuel elements fabricated during conversion of the Ford Nuclear Reactor at the University of Michigan to low-enriched uranium fuel.

Isotopes

As a direct result of energy research, Department of Energy national laboratories have been producing and distributing isotopes and isotope services and meeting national isotope needs in nuclear medicine, industrial, and research applications for nearly 50 years. Continued domestic isotope production and its ongoing transfer to private industry fulfills a vital national need. In the United States, isotopes are used in 36,000 diagnostic procedures and 50,000 therapeutic applications daily, **with more than 30 million medical uses valued at $7 billion to $10 billion each year.** One promising new medical therapy uses Yttrium-90, currently supplied to several major U.S. cancer treatment institutions. **The precommercial research and development success of Yttrium-90 cancer therapy has interested a number of commercial pharmaceutical companies.** Savings to U.S. patients could approach hundreds of millions of dollars in improved cancer treatment. The Yttrium-90 is obtained from Strontium-90, a nuclear waste product.

RadioIsotope Thermoelectric Generators

The Department of Energy has developed and provided radioisotope thermoelectric generators (RTGs) to power spacecraft used in the exploration of outer space (24 missions) for more than 30 years. **These deep space missions would not have been possible without the RTGs.** RTGs convert heat from the radioactive decay of plutonium-238 directly into electricity. They are powering experiments left on the moon by Apollo astronauts, as well as experiments on Mars. The RTGs provide the enabling power for the Pioneer and Voyager spacecraft that have studied Jupiter, Saturn and Neptune and continue to send back data from beyond our solar system. RTGs power the Galileo spacecraft that is on its way to orbit Jupiter and that provided pictures of the recent Levy-Shoemaker comet impact. RTGs also power the Ulysses spacecraft that is the first such craft to study the polar regions of the Sun. By powering NASA spacecraft, RTGs have made a major contribution to our knowledge of the universe.

Advanced Electricity Generation and Storage Technologies

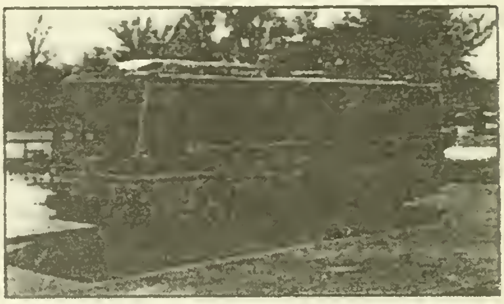
The convenience and flexibility of electric power have made this energy form a basic component of our economy and way of life. As previously discussed, the Department of Energy supports R&D activities that focus on improving the economics, environmental acceptability, and efficiency of conventional and emerging technologies. But in addition, the Department has been actively working on a variety of advanced electric technologies, some of which do not fit neatly into specific program areas.

For example, the Department's Office of Fossil Energy and Office of Energy Efficiency and Renewable Energy have been working with industry on an accelerated program to develop advanced gas-fired turbine systems and fuel cell systems. The new generation of electric power generating systems are expected to have environmental performances and fuel-to-electricity efficiencies that are much improved over today's conventional technologies. Other crosscutting technological areas include large- and small-scale electricity-storage technologies.

Phosphoric Acid Fuel Cells

A Federal investment in the 1980s and early 1990s yielded a radically new approach for commercial power generation, the fuel cell, and positioned the United States as the world leader in fuel cell technology. Relying on electrochemistry rather than combustion, the fuel cell is attractive for both heavily polluted urban areas and remote applications.

The phosphoric acid fuel cell was the first technology to emerge from one joint public-private, cost-shared program sponsored by the Department of Energy. Seventy-five 200-kilowatt commercial onsite cogeneration systems have been sold throughout the world, including 31 in the United States, by



An urban bus powered by phosphoric acid fuel cells developed by the Department of Energy. This bus demonstrates twice the fuel economy and a 99-percent reduction in emissions when compared with equivalent diesel buses.

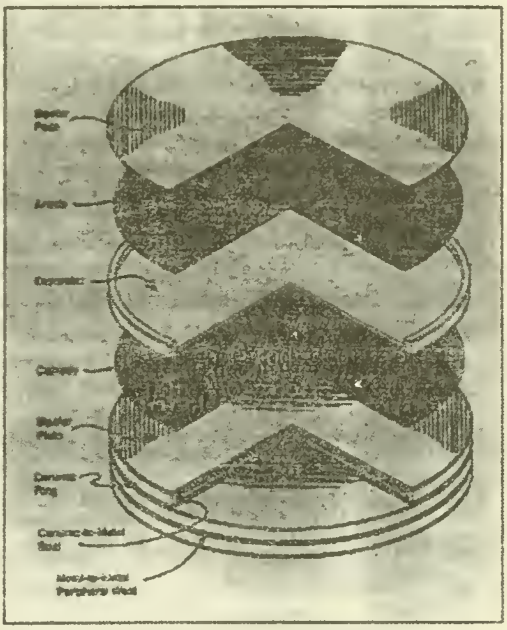
International Fuel Cells Corporation of South Windsor, Connecticut. One of these fuel cells, operated by Southern California Gas, set a record last year for uninterrupted operation at more than 80 percent efficiency. Phosphoric acid fuel cells have also been successfully developed by the Department for transportation applications. A fuel-cell-powered bus, now undergoing field testing, demonstrates significant energy benefits (twice the fuel economy of comparable diesel buses) and environmental benefits (emissions reduced by more than 99 percent compared to diesel buses). The projected annual sales of fuel cell technologies could total more than $1 billion by 2020, a market that could create as many as 100,000 U.S. jobs.

Advanced Gas Turbine Components

The Department of Energy is cost-sharing an 8-year development program to produce a leapfrog advanced gas turbine technology that will ensure continued U.S. leadership in the global market. While the entire turbine system will not be completed until the year 2000, key components have already emerged from the development effort and are being used in commercial turbines. In late 1994, Westinghouse Corporation announced a new type of industrial gas turbine, the 501G, the most fuel-efficient machine in its class. Advanced technology from the Department's R&D program is incorporated into the turbine. Closed-loop steam cooling of blades and rotors, techniques developed in the joint government-industry program, have effectively eliminated efficiency losses caused by earlier methods of air cooling. Although the United States dominates the global turbine market, foreign vendors are closing the gap. The leapfrog turbine emerging from the Department's program is expected to **maintain U.S. dominance in a multibillion dollar world market.**

High-Energy Batteries for Consumer Products

Investigations supported by the Department of Energy of nonaqueous electrolytes such as propylene carbonate provided the fundamental information needed to develop batteries based on electrolytes. High-energy primary (nonrechargeable) lithium batteries, which were not available prior to this research, are now in widespread commercial use. New generations of these electrolytes are also employed in secondary (rechargeable) lithium batteries now under development and in early stages of commercialization. The commercial use of such high-energy batteries has accompanied and enabled **the explosive growth of the multibillion-dollar portable electronics industry**, which includes laptop computers and portable tools. The technology can also be used in home and auto security systems, electronic tools, robotics, and medical instruments.



Rechargeable bipolar lithium iron disulfide battery stack.

APPENDIX D

R&D Cost and Benefits Analysis: A Case Study of DOE's Industrial Technologies R&D Programs

The effectiveness of many Department of Energy research and development programs can be analyzed in terms of the aggregated national benefits and costs of individual projects within an historically evolving portfolio. Such data-based, comprehensive analyses can provide evidence, pro and con, of a program's net economic benefits or value to the nation. Such analyses should be a key part of the analytical agenda of every technology-oriented R&D program supported with public funds. With appropriate refinement, this analytical approach could be adopted for systematic evaluation of DOE's entire energy R&D. One example of this type of analysis is that performed over a period of years since 1976 by the Office of Industrial Technologies (OIT), within the Office of Energy Efficiency and Renewable Energy.

Case Study

OIT co-sponsors research and development of innovative industrial production technologies designed to improve energy efficiency, minimize industrial waste products and pollutants, and improve the competitiveness of U.S. industry with it foreign counterparts. The common denominator among these goals is that whenever any new industrial production technology successfully enters a commercial market, production cost savings result. That is to say, industry will not purchase a production technology unless it offers an attractive economic return on the investment. The economic return may be in the form of energy cost savings, labor savings, material cost savings, reduced costs for pollution control, and so on, but any net economic return can be expressed in the form of production cost savings.

OIT tracks the numbers of commercially operating units of each of approximately 47 industrial technologies developed with its support. An additional 20 or more technologies have recently been commercialized and will be added to the tracking program in future years. Together with unit technology information on costs and benefits, the tracking data allow an annually updated estimate of the total production cost savings attributable to each technology. By tracing a cumulative total of the annual production cost savings, since the program's inception, and subtracting the cumulative Federal appropriations for the entire

OIT program, since its inception, one can compute a time-dependent, historical measure of the net economic benefits of the program to the nation.

Cumulative Federal appropriations for the entire OIT program from 1976 through fiscal year 1994 were $1,098,454,000. Cumulative energy savings for the OIT technologies currently tracked are approximately 614 trillion Btu, representing a net production cost savings of about $1.6 billion. These savings represent the net economic benefit—that is, the total value of all energy saved by technologies developed with OIT support; minus the cost to industry of using the technologies, including capital costs and O&M costs; plus any non-energy production cost savings. Subtracting the cumulative program appropriations yields the data point of about $480 million for fiscal year 1994, as shown in the curve of Exhibit 1. Because the energy savings attributable to the program are growing rapidly as competing technologies penetrate the market and additional technologies are commercialized by private industry, the net "cash flow" to the nation, defined by comparing the program's benefits and costs, is increasing. It should be noted that the magnitude of these net benefits, already significant and on the order of several hundred million dollars, would increase rapidly if energy prices were to escalate in the future.

Exhibits 2 and 3 present details of the individually-tracked technologies included in this analysis. Exhibit 2 lists technology units currently tracked by the program. Exhibit 3 lists mature technology units no longer being tracked because they have been in commercial use for more than ten years. Both sets of data are used to derive the cumulative production cost savings curve of Exhibit 1.

While *production cost savings* may be ideally suited to measure the financial history of public investment in the OIT program, other DOE R&D programs might be better analyzed by other measures. The most important features of this example are that (1) a systematic, bottom-up, data-based analysis is performed annually to trace the history of the program's R&D accomplishments, and (2) the measure used (net economic benefits to the U.S. economy, less the Federal R&D program costs) illustrates a basic methodological approach to evaluate R&D programs.

Exhibit 1. OIT Program Benefit/Cost History

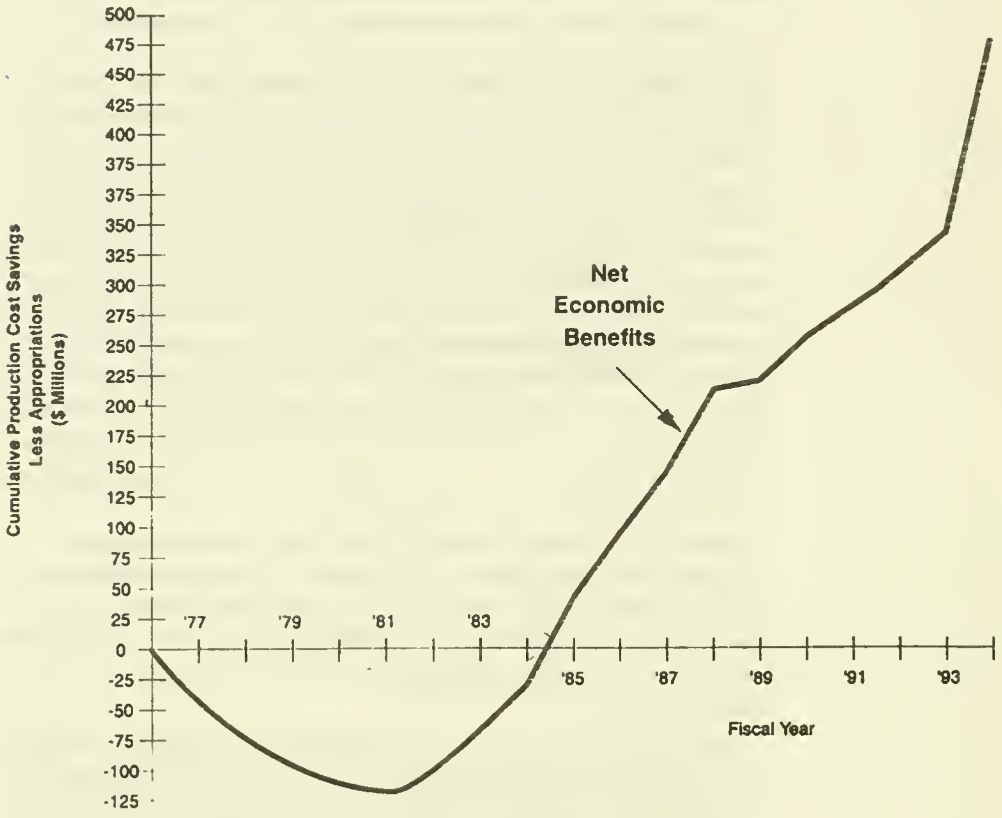


Exhibit 2. Estimated Energy Savings from Commercially Successful OIT Technologies—1994

Technology and Approximate First Year of Installation	*Total Number of Units Installed*	*Total Number of Units Counted in Energy Savings*	*Estimated Energy Savings (10E12 Btu)*	*Cumulative Savings (10E12 Btu)*	*Type of Fuel Saved*
Biomass Grain Dryer (1980)	32	7	0.03	0.92	E,P
Biphase Rotory Separator Turbine (1994)	1	1	0.00	0.00	F,NG
Catalytic Reactor (1982)	40	39	3.24	8.30	RG
Cement Particle Size Classifier (1984)	220	217	2.16	10.72	E
Chemical Separation oy Fluid Extraction (1991)	2	2	0.00	0.02	F
Cogeneration-Coal-Fired Steam Turbine (1982)	19	17	11.54	80.78	C
Computer Controlled Oven (1982)	15	6	1.40	23.71	NG
EADCs (1976)	4,879	3,496	7.75	82.02	E,F,NG
Energy Efficient Canning (1980)	133	76	0.16	2.48	G
High Efficiency Weld Unit (1983)	44,345	42,845	2.75	13.51	E
Humidity Sensor (1994)	15	15	*	*	*
Hyperfiltration-Food (1990)	14	11	0.76	3.39	E
Hyperfiltration-Textiles (1983)	10	7	0.19	0.90	C
Improved Diesel Engines (1992)	662,000	662,000	70.08	167.13	F
Irrigation Systems (1981)	15,000	5,000	1.43	46.02	E,F,NG
Membrane System for Purified Gas Production	55	55	N/A	N/A	N/A
Methanol Recovery Process (1993)	1	1	0.04	0.10	NG
Motor Master Software (1990)	8,961	8,961	N/A	N/A	N/A
Nitrogen-Methanol Carburization (1978)	2,251	808	0.38	10.17	NG
No-Clean Soldering Process (1990)	1	1	0.00	0.02	E
Oxygen Enriched Co-Combustion - Glass Industry	65	65	0.55	1.29	NG
Plating Waste Concentrator (1982)	78	62	0.55	2.02	F,NG
Reclaim and Re-Use Wastewater (1994)	1	1	N/A	N/A	N/A
Recuperators (GTE) (1981)	1,137	549	0.84	21.42	F,NG
Reverse Brayton Cycle Solvent Recovery (1989)	9	8	0.32	1.09	Ch,NG
Slot Forge Furnace/Recuperator (1978)	38	32	0.94	10.76	F,NG
Solvent Recovery from Effluent Streams (1990)	31	31	0.21	0.48	Ch
Waste Energy Recovery, Honolulu (1990)	1	1	0.27	4.39	F
Waste Energy Recovery, Tacoma (1991)	1	1	0.69	2.36	F
Total	739,355	724,315	106.29	494.01	

C = Coal, Ch = Feedstock Chemicals, E = Electricity, F = Fuel Oil, G = Gasoline, NG = Natural Gas, O = Other,
P = Propane, RG = Refinery Gas
* = Data is not yet available

Exhibit 3. Estimated Energy Savings from Mature OIT Technologies—1994

Technology and Approximate First Year of Installation	*Number of Mature Units**	*Cumulative Savings for Units No Longer Tracked (10E12 Btu)**	*Type of Fuel Saved (a)*
Biomass Grain Dryer (1980)	25	0.08	E,P
Catalytic Reactor (1982)	1	0.05	RG
Cement Particle Size Classifier (1984)	3	0.00	E
Cogeneration-Coal-Fired Steam Turbine (1982)	2	1.36	C
Cogeneration-Slow Speed Diesel (1983)	3	1.47	E,F
Coil Coating (1977)	25	35.20	NG
Combination Grain Drying (1980)	2,500	7.30	P
Computer Controlled Oven (1982)	7	1.23	NG
Cupola Stack Air Injection (1981)	2	0.08	NG
Dye Bath Reuse (1979)	69	2.00	NG
EADCs (1976)	1,383	2.36	E,F,NG, O
Energy Efficient Canning (1980)	57	0.13	NG
FBWHRS (Aerojet) (1984)	1	0.03	F,NG
Foam Processing (1980)	(c)	11.40	NG
Heat Exchanger-Dryer	3	0.79	NG
High Efficiency Weld Unit (1983)	500	0.03	E
HTBDR (AiResearch) (1979)	1	(b)	NG
HTBDR (Babcock and Wilcox) (1981)	1	0.02	NG
Humidity Sensor (Optical) (1988)	2	0.02	NG
Hyperfiltration-Textiles (1983)	1	0.02	C
Irrigation Systems (1981)	10,000	2.87	E,F,NG
Membrane Separation of Sweeteners	1	(b)	E,NG

Exhibit 3: Estimated Energy Savings from Mature OIT Technologies—1994
(Continued)

Technology and Approximate First Year of Installation	*Number of Mature Units**	*Cumulative Savings for Units No Longer Tracked (10E12 Btu)**	*Type of Fuel Saved (a)*
Nitrogen-Methanol Carburization (1978)	1,442	0.55	NG
ORC Bottoming Unit (1981)	7	0.50	E
PET Bottle Separator (1988)	1	1.21	Ch
Pipe Cross Reactor (1976)	31	2.60	NG
Plating Waste Concentrator (1982)	3	0.02	F,NG
Recuperators (GTE) (1981)	588	0.87	F,NG
Recuperators (AiResearch) (1981)	106	4.50	NG
Slot Forge Furnace/Recuperator (1978)	4	0.12	F,NG
Waste Atactic Polypropylene to Fuel (1980)	1	0.50	F,NG
Workshops (Boiler) (1977)	10 (d)	42.20	F,NG
Total		119.51	

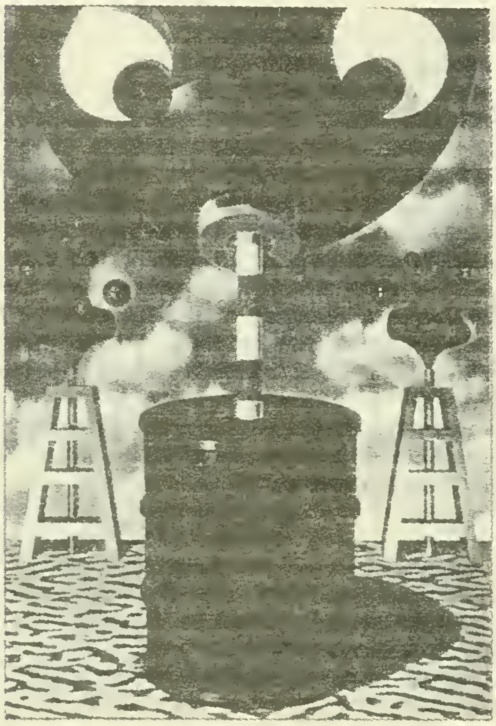
(a) C = Coal, Ch = Feedstock Chemicals, E = Electricity, F = Fuel Oil, G = Gasoline,
NG = Natural Gas, O = Other, P = Propane, RG = Refinery Gas
(b) Less than 0.01 (trillion Btu)
(c) Estimates were listed in linear yards processed annually.
(d) Number does not include indirect savings from workshops held by other firms.
* Units and savings shown here are for units not appearing in Exhibit 2. Savings are for units that are either older than ten years of age or are not operating.

The cumulative savings have been limited to savings during the unit's operating period, but not to exceed 10 years of saving, on the assumption that the units would likely have been invented and installed by the 10th year, without the Department of Energy's R&D accelerating their introduction.

Mideast Oil Forever?

by JOSEPH J. ROMM AND CHARLES B. CURTIS

Congressional budget-cutters threaten to end America's leadership in new energy technologies that could generate hundreds of thousands of high-wage jobs, reduce damage to the environment, and limit our costly, dangerous dependency on oil from the unstable Persian Gulf region



IMAGINE a world in which the Persian Gulf controlled two thirds of the world's oil for export, with $200 billion a year in oil revenues streaming into that unstable and politically troubled region, and America was importing nearly 60 percent of its oil, resulting in a $100-billion-a-year outflow that undermined efforts to reduce our trade deficit. That's a scenario out of the 1970s which can never happen again, right? No, that's the "reference case" projection for ten years from now from the federal Energy Information Administration.

Imagine another world in which fossil-fuel use had begun a slow, steady decline: more than a third of the market for new electricity generation was supplied from renewable sources; the renewables industry had annual sales of $150 billion; and the fastest-growing new source of power was solar energy. An environmentalist's fantasy, right? No, that's one of two planning scenarios for three to four decades from now, developed by Royal Dutch/Shell Group, the world's most profitable oil company, which is widely viewed as a bench mark for strategic planning.

A decade's worth of little-heralded technological advances funded by the Department of Energy have helped to bring such a renewables revolution within our grasp. Yet budget cuts already proposed by Congress would ensure that when renewable energy becomes a source of hundreds of thousands—if not millions—of new high-wage jobs in the next century, America will have lost its leadership in the relevant technologies and will once again be importing products originally developed by U.S. scientists. Moreover, Congress's present and planned cuts in advanced transportation and fossil-fuel research and development impede efforts to maximize the nation's conventional-energy resource base.

Although little can be done to change the first scenario, Congress's actions all but guarantee that if an oil crisis comes,

Illustrations by Dave Jonason

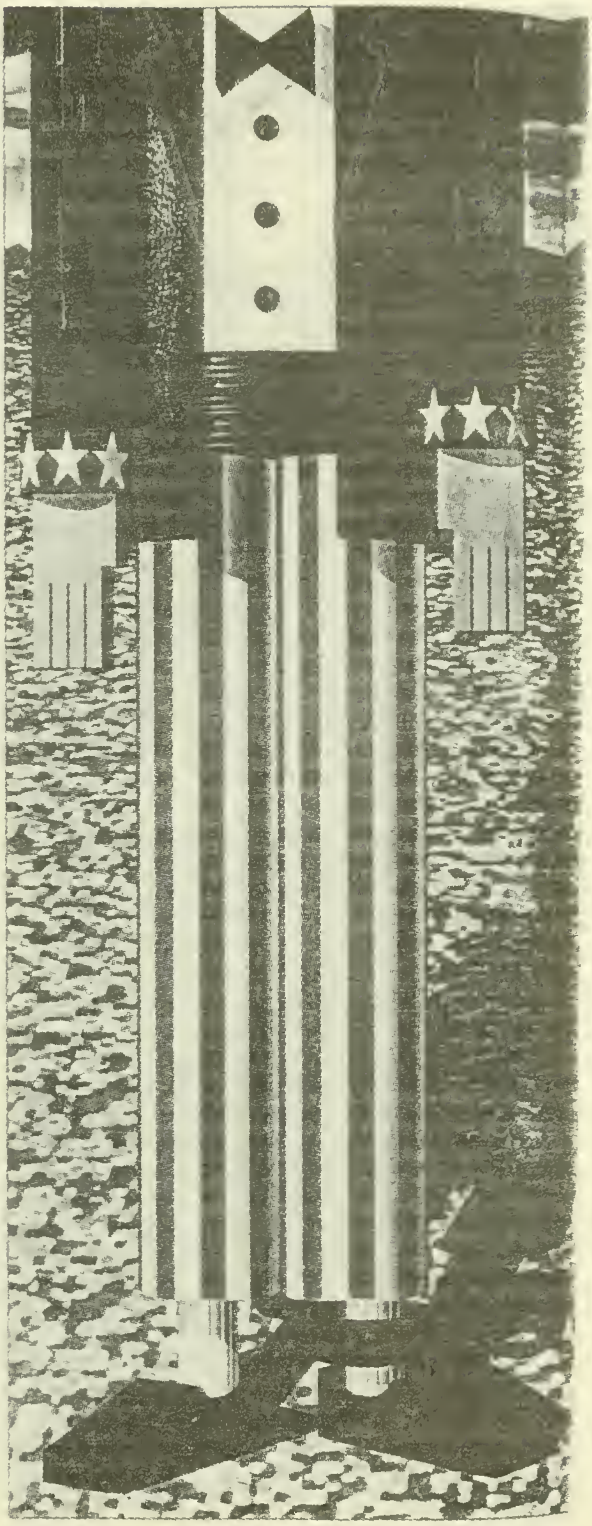
our national response will be reactive, uninformed, and unduly burdensome. Having abandoned the technological means to minimize the crisis, the nation will be left in the next century with little more than its usual responses to energy crises: price controls or other rigid regulations, or unplanned, ineffective attempts to deal with the effects of sharp price or supply fluctuations.

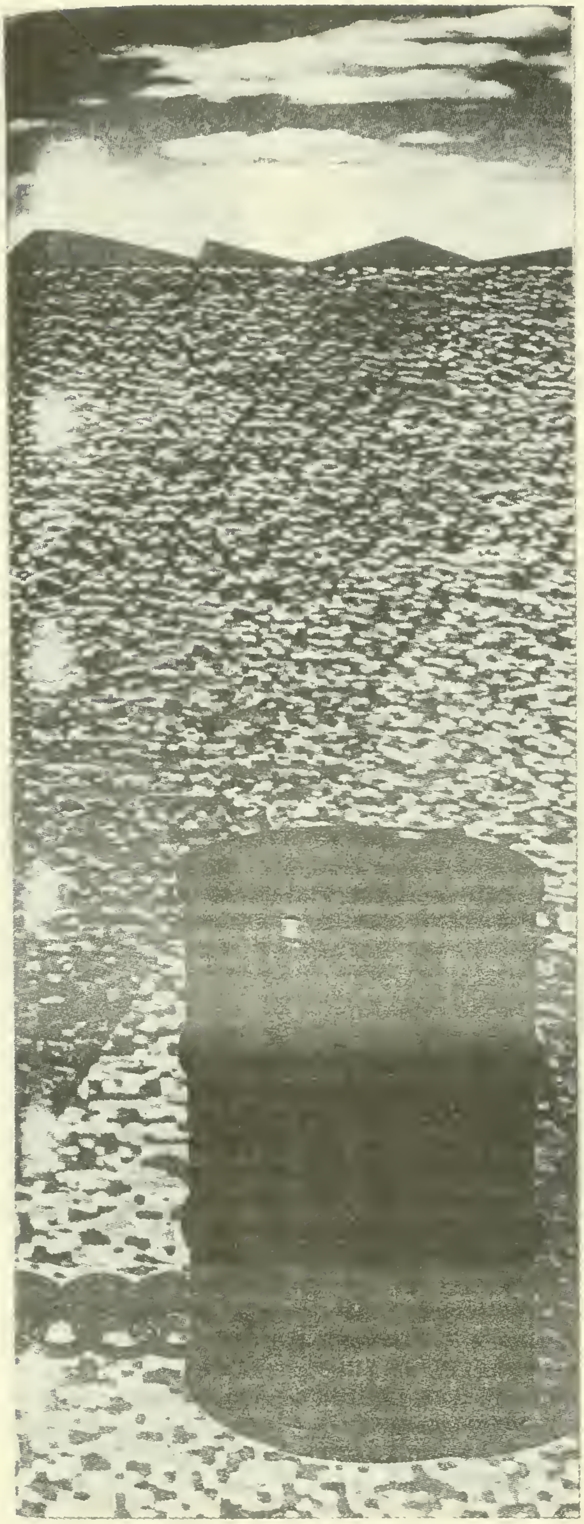
What's more, cuts in research on clean-energy technologies represent a statement by Congress—conscious on the part of some members, unintentional on the part of others—that global climate change is of little or no concern, and that domestic environmental problems, such as urban air quality and industrial waste, require nothing more than existing strategies. Yet the nation's "tools" for dealing with pollution are similar to those for dealing with an oil crisis, and new technology usually provides the most cost-effective solution. One example: A relatively small amount of money spent today to develop, test, and deploy highly reflective roofing and road material and plant shade trees could help cool the Los Angeles area by five degrees, reducing annual air-conditioning bills by more than $150 million. Since smog formation is very temperature-sensitive, such cooling would reduce smog concentrations by 10 percent, which would be comparable to removing three quarters of the cars on the road. The health-related benefits of that smog reduction would be worth $300 million a year. Applied nationally, the energy savings alone could exceed $10 billion a year by 2015.

Although news coverage of the environment has focused on congressional efforts to roll back environmental regulations, cuts in environmental-technology programs will have as significant an impact on our quality of life in the long run. And by turning a blind eye to the technological solutions to environmental problems, we limit ourselves to far-more-onerous alternatives. The environmental regulations that Congress is rolling back today may become all the more necessary in the not too distant future.

The programs being cut are not those failures of the past that are often mentioned by critics of federal energy research —for example, the synfuels program of a decade and a half ago. They are instead programs that have been delivering results for years. A report released last June by a blue-ribbon panel of independent energy analysts, led by the energy expert Daniel Yergin, the Pulitzer-winning author of *The Prize*, cited dozens of federally funded technological advances that "are generating billions of dollars worth of annual consumer energy savings and new business opportunities, and playing an important role in job creation." This is what will be lost.

Government and the people it represents cannot expect that the best-case scenario will play out. Rather, government should in behalf of the people try to prevent plausible worst-case scenarios or take advantage of likely trends and opportunities through long-term investments that the private sector will not make (either because they are too risky or because





the reward is too far off). Both of us work for the Department of Energy, and in this article we examine some likely scenarios concerning petroleum, power generation, and pollution to help focus attention on a quiet revolution in energy markets and energy technologies which will have a profound impact on U.S. economic strength, environmental health, and national security in the next century. The impact will probably equal that of the much-ballyhooed information revolution, which receives far more attention from policymakers and the media. Yet if we don't focus on energy today, our quality of life tomorrow will be permanently diminished.

The Coming Oil Crisis

GIVEN that the most recent war America fought was in the Persian Gulf, let's start by examining the likelihood that an oil crisis will occur in the coming decade. Forecasting is always risky, especially where oil is concerned, but consider what a variety of experienced energy hands from every point on the political spectrum have said in the past year alone. Donald Hodel, who was a Secretary of Energy under Ronald Reagan, has said that we are "sleepwalking into a disaster," and predicts a major oil crisis within a few years. Irwin Stelzer, of the American Enterprise Institute, says that the next oil shock "will make those of the 1970s seem trivial by comparison." Daniel Yergin says, "People seem to have forgotten that oil prices, like those of all commodities, are cyclical and will go up again." James Schlesinger, who was the Secretary of Energy under Jimmy Carter, has said, "By the end of this decade we are likely to see substantial price increases." In March of last year Robert Dole, the Senate majority leader, said in a speech at the Nixon Center for Peace and Freedom, "The second inescapable reality of the post-twentieth-century world is that the security of the world's oil and gas supplies will remain a vital national interest of the United States and of the other industrial powers. The Persian Gulf . . . is still a region of many uncertainties. . . . In this 'new energy order' many of the most important geopolitical decisions—ones on which a nation's sovereignty can depend—will deal with the location and routes for oil and gas pipelines. In response, our strategy, our diplomacy, and our forward military presence need readjusting." The chairman of the Federal Reserve, Alan Greenspan, not known for being an alarmist, in testimony before Congress last July raised concerns that a rising trade deficit in oil "tends to create questions about the security of our oil resources."

Concerns about a coming oil crisis have surfaced in the financial markets as well. Last October, in an article titled "Your Last Big Play in Oil," *Fortune* magazine listed several billionaires and "big mutual fund managers" who were betting heavily that oil prices would rise significantly. The magazine went on to suggest an investment portfolio of "companies that are best positioned to profit from the coming boom."

Fundamental trends in oil demand and supply underlie this emerging consensus. First, the world will probably need another 20 million barrels of oil a day by the year 2010, according to the Energy Information Administration (EIA). The International Energy Agency projects an even greater growth in demand, following the inexorable tide of population growth, urbanization, and industrialization.

Second, the world's population is expected to increase by 50 percent by 2020, with more than half those additional people born in Asia and Latin America. And as farm workers move to the city, much more energy and oil will be needed. The fundamentals of urbanization—commuting, transporting raw materials, constructing infrastructure, powering commercial buildings—all consume large amounts of oil and electricity. At the same time, fewer farms will have to feed more people, and so the use of mechanization, transportation, and fertilizer will increase, entailing the consumption of still more energy and oil. An analysis by one of the Department of Energy's national laboratories found that a doubling of the proportion of China's and India's populations that lives in cities could increase per capita energy consumption by 45 percent—even if industrialization and income per capita remained unchanged.

Finally, industrialization has an even greater impact on energy use. As countries develop industries, they use more energy per unit of gross national product and per worker. Crucial industries for development are also the most energy-intensive: primary metals; stone, clay, and glass; pulp and paper; petroleum refining; and chemicals. In the United States these industries account for more than 80 percent of manufacturing energy consumption (and more than 80 percent of industrial waste).

As *Fortune* has noted, if the per capita energy consumption of China and India rises to that of South Korea, and the Chinese and Indian populations increase at currently projected rates, "these two countries alone will need a total of 119 million barrels of oil a day. That's almost double the world's entire demand today."

Barring a major and long-lasting worldwide economic depression, global energy demand will be rising inexorably for the foreseeable future. The Persian Gulf, with two thirds of the world's oil reserves, is expected to supply the vast majority of that increased demand—as much as 80 percent, according to the EIA. Within ten to fifteen years the Persian Gulf's share of the world export market may surpass its highest level to date, 67 percent, which was attained in 1974. The EIA predicts that in the face of increased demand, oil prices will rise slowly to $24 a barrel (1994 dollars) in 2010. If, instead, they remain low, the Gulf's share of the world export market may rise as high as 75 percent in 2010.

Although non-OPEC nations did increase production by almost 15 percent from 1980 to 1990, they increased proven reserves of oil by only 10 percent. The net result is that the remaining years of production for non-OPEC reserves has actually fallen from eighteen years to seventeen years. On the other hand, while OPEC increased production by 20 percent in the 1980s, it increased its proven reserves by 75 percent. As a result, OPEC's reserves-to-production ratio doubled to ninety years.

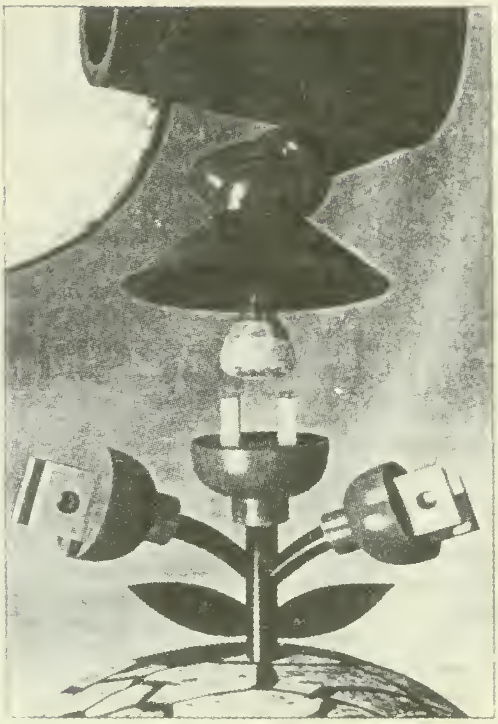
The growing dependence on imported oil in general and Persian Gulf oil in particular has several potentially serious implications for the nation's economic and national security. First, the United States is expected to be importing nearly 60 percent of its oil by ten years from now, with roughly a third of that oil coming from the Persian Gulf. Our trade deficit in oil is expected to double, to $100 billion a year, by that time—a large and continual drag on our economic health. To the extent that the Gulf's recapture of the dominant share of the global oil market will make price increases more likely, the U.S. economy is at risk. Although oil imports as a percent of gross domestic product have decreased significantly in the past decade, our economic vulnerability to rapid increases in the price of oil persists. Since 1970 sharp increases in the price of oil have always been followed by economic recessions in the United States.

Second, the Persian Gulf nations' oil revenues are likely to almost triple, from $90 billion a year today to $250 billion a year in 2010—a huge geopolitical power shift of great concern, especially since some analysts predict increasing internal and regional pressure on Saudi Arabia to alter its pro-Western stance. This represents a $1.5 trillion increase in wealth for Persian Gulf producers over the next decade and a half. That money could buy a tremendous amount of weaponry, influence, and mischief in a chronically unstable region. And the breakup of the Soviet Union, coupled with Russia's difficulty in earning hard currency, means that for the next decade and beyond, pressure will build to make Russia's most advanced military hardware and technical expertise available to well-heeled buyers.

The final piece in the geopolitical puzzle is that during the oil crisis of the 1970s the countries competing with us for oil were our NATO allies, but during the next oil crisis a new, important complication will arise: the competition for oil will increasingly come from the rapidly growing countries of Asia. Indeed, in the early 1970s East Asia consumed well under half as much oil as the United States, but by the time of the next crisis East Asian nations will probably be consuming more oil than we do.

Abandoning the Solution

WHAT is the appropriate national response to the re-emerging energy-security threat? Abroad the Department of Energy has been working hard to expand sources of oil outside the Persian Gulf region—in the former Soviet Union, for example—and to encourage the



privatization of the oil companies in Mexico and other Latin American countries.

At home the DOE is encouraging greater production by providing royalty relief in the deep waters of the Gulf of Mexico and similar incentives, so that the industry can drill wells that otherwise would not be cost-effective. The DOE is working to reduce the cost for the industry to comply with federal regulations. Finally, the department is spending tens of millions of dollars a year to develop new technologies that will lower the cost of finding and extracting oil—for example, using advanced computing to model oil fields. Still, few expect to reverse the decade-long decline in U.S. oil production. Some would open the Arctic National Wildlife Refuge to drilling, a plan the Clinton Administration has opposed on environmental grounds, but not even that would change our forecasted oil dependency much. This is true even using earlier, more optimistic estimates that the refuge could provide 300,000 barrels of oil a day for thirty years. The EIA projects that within ten to fifteen years the United States will probably be importing *thirty times as much*—some 10 million barrels of crude oil a day, even if the decline in other domestic production levels off in the next few years.

Increasing domestic supply, although it may help to slow the rising tide of imports, cannot itself reverse the major trend. And reversing the nation's ever-increasing demand for oil would be difficult. The country is in no mood to enact higher energy taxes in order to bring our energy markets into better balance. To most people, an increase in gasoline taxes of even a few cents a gallon—let alone the amount needed to have a noticeable impact on consumption—is anathema. Similarly, Congress is in no mood for a regulatory approach, such as mandating increased fuel efficiency for cars.

That leaves one solution for reducing consumption: the technological approach, which draws on America's traditional leadership in research and development. Here tremendous progress has been made. Given the uncertain nature of long-term, high-risk R&D in leapfrog technologies, the prudent approach is to explore a number of possibilities. The DOE has invested in the development of cars and trucks that are highly fuel-efficient, along with cars that run on electricity, on liquid biofuels from crops, crop waste, and municipal solid waste, or on natural gas.

The programs being cut are not those failures of the past that are often mentioned by critics of federal energy research. They are instead programs that have been delivering results for years.

Consider biofuels. In 1994 research sponsored by the DOE created a genetically engineered organism that enhances the fermentation of cellulose, increasing the rate of conversion and the yield of ethanol. This achievement, described in the journal *Science*, was named one of the hundred most significant technological advances of the year by *R&D* magazine. This and other federally supported research has brought the cost of making ethanol from \$3.60 a gallon fifteen years ago to about \$1.00 a gallon today. If biofuels R&D were funded at current levels for five to ten years, ethanol from fast-growing dedicated crops, crop waste, and wastepaper could be produced for as little as sixty to seventy cents a gallon by 2005. In a country with excess cropland, such as the United States, the potential for biofuels is enormous. Rather than paying some farmers not to grow anything, we might in the future pay the same farmers to grow dedicated bioenergy crops. In a country where cropland is scarce, such as China, bioenergy could come from municipal and agricultural wastes.

Technologies are also being developed to make possible a superefficient hybrid vehicle that has both an internal-combustion engine and some kind of energy-storage device, such as a battery or a flywheel. A very advanced hybrid has been described by Amory

B. Lovins and L. Hunter Lovins (see "Reinventing the Wheels," January, 1995, *Atlantic*). Supporting technologies include lightweight, superstrong materials and advanced engines, among other things. This research has been undertaken by the Partnership for a New Generation of Vehicles, a collaboration among several federal agencies, the DOE's national laboratories, and the auto industry. The goal of the partnership is to design and construct by 2004 a prototype clean car that has three times the fuel efficiency of existing cars and very low emissions, and also comparable or improved performance, safety, and cost. Such a car would allow domestically produced advanced technologies to replace oil imports.

Another direction that research is taking is toward advanced batteries for use in electric cars—among them the nickel metal-hydride battery—which promise to double the range achievable with existing lead-acid batteries. In conjunction with advances in clean power generation, described below, these batteries hold the prospect of replacing imported oil with domestically produced electricity.

The technology that most experts would agree has the best chance over the long term of replacing petroleum use in the transportation sector is fuel cells. These are compact modular devices that generate electricity and heat with high efficiency and virtually no pollution. They run on hydrogen converted from natural gas and other fuels. The National Aeronautics and Space Administration developed early versions of fuel cells for use on space missions. Over the past two decades the DOE has spent tens of millions of dollars on several types of fuel cells that will soon be used to power cars, trucks, utilities, commercial buildings, and industries. The Japanese government has been increasing its fuel-cell budget by an average of 20 percent a year for the past five years, and Japanese companies are less than five years behind U.S. companies in this technology. The Europeans are considering significantly increasing their fuel-cell funding. Sustained federal support might well give America the lion's share of a multibillion-dollar global market.

Fuel cells are one of many advances that may increase the use of natural gas as a transportation fuel over the long term. Since 1992 the DOE has significantly increased its budget for research and development related to enhancing the supply and the efficient use of natural gas. It is seeking to encourage a wider use of natural-gas vehicles, to establish a nationwide infrastructure for fueling those vehicles, and to develop gas-turbine engines for light-duty vehicles.

Current DOE programs—unlike those of the late 1970s, which required oil to cost $80 a barrel if they were to be competitive—are aimed at making alternatives competitive even if oil prices decline. The likely outcome of all the programs mentioned above should not be overstated: we will not achieve energy independence in the next fifteen years. What this investment portfolio does offer is a chance in the years thereafter to blunt any foreign threat to raise oil prices dramatically and to limit the economic and geopolitical impact of Persian Gulf oil in particular. At the same time, domestic jobs will be created if money that might have gone overseas to buy foreign oil goes instead to manufacturing superefficient cars and trucks or domestic biofuels.

What's more, the rapid population growth and urbanization of developing nations, coupled with the harsh pollution that characterizes most major urban centers in those nations, ensure a tremendous market for low-emission, superefficient automotive technology. Our industrialized competitors have one inherent advantage in the race to develop the supercar: gas prices of $3.00 or $4.00 a gallon. Fuel efficiency matters more in their economies, and vehicles that use alternative fuels will be cost-competitive in their markets sooner. The primary counterbalance to that advantage is U.S. technological leadership in most relevant areas, stemming in part from historically higher levels of R&D spending.

That counterbalance is about to disappear. Congress has cut the proposed fiscal year 1996 allocations for the DOE's advanced-transportation-technology budget by 30 percent. Moreover, the multi-year balanced-budget plan approved by the House and Senate would cut the budget for such technology by 60–80 percent in real terms.

The fact that the DOE has been collaborating with the auto industry in the Partnership for a New Generation of Vehicles gives some in Congress a thin excuse to label the partnership's programs "corporate welfare." Yet Detroit's car makers agreed to match federal spending while coordinating their corporate research with the DOE's national laboratories in order to address the pressing national problems of oil imports and urban air quality. The last time America ignored the warning signs of growing dependence on imported oil, the Japanese were able to seize a significant share of the U.S. auto market with fuel-efficient cars.

Congress's own Office of Technology Assessment released a report last September acknowledging that the DOE's "strategy of pursuing several different [vehicle] technology options is advantageous for a variety of reasons." Congress is ignoring the advice of the office it set up, staffed, and funded to provide independent advice on technological issues of national importance. Indeed, it apparently no longer wants to hear any advice on such issues. Late last year Congress closed the Office of Technology Assessment for good.

That the nation's and the world's dependence on Persian Gulf oil will grow over the next decade seems inevitable. This is particularly true since most projections assume continuing significant technological progress in bringing down the cost of domestic production, in developing alternatives, and in using energy and oil more efficiently. But those projections have not factored in the federal government's plans to withdraw from its role in fostering the development and deployment of those technologies.

The Renewables Revolution

PREDICTING our energy future beyond 2010 is chancy, but here we have an opportunity to rely on perhaps the most successful predictor in the energy business: Royal Dutch/Shell Group. According to *The Economist*, "The only oil company to anticipate both 1973's oil-price boom and 1986's bust was Royal Dutch/Shell." Anticipating the oil shocks of the 1970s helped Shell to move from being the weakest of the seven largest oil companies in 1970 to being one of the two strongest only ten years later. Anticipating the oil bust was apparently even more lucrative. According to *Fortune*'s ranking of the 500 largest corporations, Royal Dutch/Shell is now not only the most profitable oil company in the world but the most profitable corporation of any kind.

When such a company envisions a fundamental transition in power generation from fossil fuels to renewable energy beginning in two decades, a transition that will have a significant impact on every aspect of our lives, the prediction is worth examining in some detail. Chris Fay, the chairman and CEO of Shell UK Ltd., said in a speech in Scotland last year, "There is clearly a limit to fossil fuel. . . . Shell analysis suggests that resources and supplies are likely to peak around 2030 before declining slowly. . . . But what about the growing gap between demand and fossil fuel supplies? Some will obviously be filled by hydro-electric and nuclear power. Far more important will be the contribution of alternative renewable energy supplies."

Fay presented a detailed analysis of future trends in energy supply and demand. noting that the fossil-fuel peak in 2030 would occur at a usage level half again as high as today's. Shell's analysis does not rely exclusively on supply limits—after all, for decades people have been worried about such limits, and the supply has continued to expand—but also incorporates a recognition of the tremendous advances that have been made in renewable-energy technologies over the past two decades and that are expected to be made over the next two decades.

Although these advances in renewables have received very little media attention. they have persuaded Shell planners that renewables may make up a third of the supply of new electricity within three decades *even if electricity from fossil fuels continues to decline in cost.* An "Energy in Transition" scenario that they have prepared does not assume price increases in fossil fuels—also, as we have seen, a plausible hypothesis. Nor does Shell assume any attempt by governments to incorporate environmental costs into the price of energy, even though every single independent analysis has found that fossil-fuel generation has much higher environmental costs than non-fossil-fuel generation has. According to Shell's strategic-planning group, "The Energy in Transition future can claim to be a genuine 'Business as Usual' scenario, since its energy demand is a continuation of a long historical trend, and the energy is supplied in a way which continues the pattern."

Indeed, in the past fifteen years the Department of Energy, working with the private sector, has reduced the costs of electricity from biomass (such as crops and crop waste) and wind, bringing them into the current range of wholesale costs for coal and other traditional sources of electricity: three to five cents per kilowatt-hour.

A quiet revolution has already brought the United States almost eight gigawatts of biomass electrical capacity. Gasifying biomass and using advanced turbines could bring biomass power to 4.5 cents per kilowatt-hour within a decade, according to the DOE's National Renewable Energy Laboratory. Shell projects that by 2010 commercial energy from biomass could provide five percent of the world's power; using Shell's projections, we estimate that the value of that power generation could exceed $20 billion.

Over the past fifteen years electricity from wind power has declined in cost by 10 percent a year. The problems of the windmills that were rushed to market in the 1970s, such as noise and TV interference, have largely been solved. With the DOE's help the old wind-turbine blades, borrowed almost directly from aircraft-propeller design, have been replaced with sophisticated blades designed to capture wind energy efficiently over a broad range of wind speeds and direction. Utilities are already receiving long-term bids for electricity from wind at 4.5 cents per kilowatt-hour in the best wind sites in the country. With a continued public-private partnership in technology advancement, wind could hit three cents per kilowatt-hour by 2020, and soon after that wind-power plants' annual sales could reach $50 billion.

Photovoltaic (PV) cells, which convert sunlight into electricity, now cost one tenth what they did in 1975. The DOE has invested heavily in new thin-film PV panels, which take advantage of U.S. expertise in semiconductor fabrication. Shell expects that PVs. along with fuel cells and small gas-fired power plants, will permit the growth of distributed-power systems. In developing nations distributed sources can obviate the need for huge power lines and other costly elements of an enormous electric-power grid (much as personal computers replace large mainframe computers). PV modules sold worldwide totaled less than four megawatts in 1980 and now exceed 80 megawatts a year; sales continue to grow. The Energy in Transition scenario predicts that photovoltaics and other direct conversions of sunlight will be the most rapidly growing form of commercial energy after 2030. Sales could quickly exceed $100 billion. Shell itself has bought two photovoltaics companies.

This scenario. a highly credible one given Shell's reputation, is tantalizing. because it holds out the possibility that the world could within a few decades begin to realize the dream of nearly pollution-free energy. Consider also that the United States, which is now the leader in most areas of renewables technology, could simultaneously reduce its dependence on foreign energy supplies, reverse the trend toward an ever-increasing energy trade deficit, and capture a large share of what promises to be perhaps the largest new job-creating sector of the international economy.

This is only a scenario; our actions today can have an impact either positive or negative. According to Chris Fay, of Shell, "New technologies cannot leap from laboratory to mass market overnight. They must first be tested in niche markets, where some succeed but many fail. Costs fall as they progress down the 'learning curve' with increasing application." The long-term nature of research, and the real potential for failure, are why many options must be pursued at once and why many private-sector companies have been reluctant to invest. Fay observes, "Renewables will have to progress very quickly if they are to supply a major proportion of the world's energy in the first half of the next century. . . . They can only emerge through the process of widespread commercial experimentation and competitive optimization."

Federal investments clearly make a difference in technology development and global market share. Consider the case of photovoltaics. In 1955 Bell Laboratories invented the first practical PV cell. Through the 1960s and 1970s investments and purchases by NASA, the Pentagon, and the National Science Foundation helped to sustain the PV industry and gave America leadership in world sales. In 1982 federal support for renewable energy was cut deeply, and within three years Japan became the world leader in PV sales. The Bush Administration began to increase funding for solar energy and, in 1990, collaborated with the American PV industry in efforts to improve manufacturing technology; three years later the United States regained the lead in sales in this rapidly growing industry. The Clinton Administration has accelerated funding for PVs.

ON PICKINESS

When the first mechanical picker had stripped the field,
It left such a copious white dross of disorderly wispiness
That my mother could not resign herself to the waste
And insisted on having it picked over with human hands,

Though anyone could see there was not enough for ten sheets
And the hands had long since gone into the factories.
No matter how often my father pointed this out,
She worried it the way I've worried the extra words

In poems that I conceived with the approximate
Notion that each stanza should have the same number
Of lines and each line the same number of syllables—
And disregard it, telling myself a ripple

Or botch on the surface, like the stutter of a speaker,
Is all I have to affirm the deep fluency below.
The Hebrews distrusted Greek poetry (which embodied
Harmony and symmetry, and, therefore, revision)

Not for aesthetic reasons but because they believed
That to change the first words, which rose unsmelted
From the trance, amounted to sacrilege against God.
In countries where, because of the gross abundance

Of labor, it's unlawful to import harvesting machines,
I see the women in the fields and think of how,
When my mother used to pick, you could tell
Her row by the bare stalks and the scant poundage

That tumbled from her sack so pristinely white
And devoid of burrs, it seemed to have already
Passed through the spiked mandibles of the gin.
Dr. Williams said of Eliot that his poems seemed so

Cautiously wrought that they seemed to come
To us already digested in all four bellies of the cow.
What my father loved about my mother was not
Just the beauty of her body and face but the practice

Of her ideas and the intelligence of her hands
As they made the house that abides in us still
As worry and bother, but also as perfect freedom beyond—
As cleanliness is next to godliness but is not God.

—RODNEY JONES

Sadly, however, the cuts of the 1980s have taken their toll: in the past decade German and Japanese companies snapped up several major American PV companies, which accounted for 63 percent of the PVs manufactured in the United States. Such purchases represent huge savings for our foreign competitors. They don't have to spend hundreds of millions of dollars to determine which technologies succeed. They need only let the United States do the basic research, and then spend a few tens of millions of dollars plucking the winners when the federal government abandons funding for applied research.

Although many members of Congress argue that the cuts in federal R&D will be made up for by the private sector, historically this hasn't happened. When the government pulls out of an area of technology, it sends a signal to the industrial and financial communities that the area has no long-term promise and that the federal government is not a reliable partner. The situation is especially bad today, because recent studies make clear that private-sector R&D has been fairly flat since 1991, and because U.S. companies have been shifting away from basic and applied research toward incremental product and process improvement—a shift that has been exacerbated by increased international competition and the downsizing of corporate laboratories.

In addition, whereas the federal government only recently, and temporarily, increased funding for renewable energy, reversing the deep cuts of the 1980s, our foreign competitors have been steadily increasing such funding for a decade and a half. Whereas we once spent several times as much as the rest of the world combined, the rest of the world now significantly outspends us. Moreover, countries such as Germany, Japan, Denmark, and the Netherlands have far greater financial incentives for renewable energy. And their prices for electricity are typically much higher: in 1991 electricity cost Germany's industrial sector 8.8 cents per kilowatt-hour, whereas in the United States it cost 4.9 cents per kilowatt-hour. That means renewable energy will be cost-effective in foreign countries before it is in America.

The primary competitive advantage the United States has had in renewables is technological leadership driven by long-term federal spending prior to the early 1980s and then the spending in the early 1990s. Recently Congress cut renewable-energy funding by 30 percent, and its multi-year budget plan calls for overall cuts of 60 percent or more by the year 2002. The cuts will have two effects.

First, the transition to renewables that Shell envisions will probably be slowed somewhat, since America remains the leader in many relevant renewables technologies and U.S. government funding remains a sizable fraction of R&D funding worldwide. The transition, however, even if slowed, seems inevitable at some point in the middle of the next century.

Second, when the transition occurs, the United States will miss what may well be the single largest new source of jobs in the next century. Mature areas like automobile manufacturing and aerospace haven't been significant net job producers for the country in two decades. The most highly promoted new area—the information revolution—is unlikely to provide as many jobs as manufacturing can, because making duplicate pieces of information generates many fewer new jobs than manufacturing duplicate pieces of hardware. Yet according to Shell's numbers, annual sales in renewable-energy technologies may hit $50 billion in 2020 and almost $400 billion in 2040. In the later year such an industry would support several million jobs.

Moreover, as said above, the United States will be importing $100 billion worth of oil annually ten years from now. With prudent federal investment today, that might be the peak, and we might then see a gradual decline as U.S. technology and domestic fuels, including homegrown biomass, replace imported oil. With Congress's cuts, however, we may be only augmenting our debilitating trade deficit in oil with an equally debilitating trade deficit in oil-replacing technologies.

Preventing Pollution

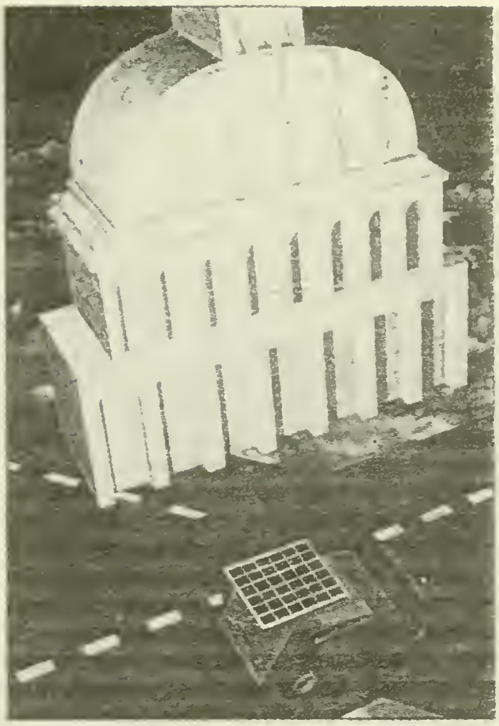
THE renewables revolution, inevitable or not, won't spell the end of the nation's or the world's environmental problems. In Shell's scenario overall fossil-fuel use will increase steadily for decades, peaking in 2030 at a level half again as high as today's, and will not dip below current levels until 2100. If we are to achieve genuine prosperity—higher living standards accompanied by improved environmental quality—we will need to do better.

Consider one of the nagging environmental problems around the world: urban air quality. Most cities have dark surfaces and less vegetation than their surroundings, creating a "heat island" that affects climate, increases energy use, and decreases habitability. Buildings' dark roofs and inadequate shade in summertime raise the demand for air-conditioning, so more power and pollution are generated. Heat islands raise the temperature of many cities by as much as five degrees, increasing the production of smog, which is typically created in hot weather. Finally, urban heat islands exacerbate all heat waves, contributing to summer fatalities.

We know the basics of how to cool a city: Buildings need shade trees, and buildings, roads, and parking lots require light-colored surfaces. Cooler roads might cost slightly more initially, but they would probably last 20–50 percent longer because they reduce thermal wear and reduce ultraviolet damage. Over a twenty-year period trees could be planted cheaply, and roads, roofs, and parking lots could be resurfaced during the course of normal maintenance, saving the country billions of dollars a year.

Clearly, the mitigation of urban heat islands is an important effort. The federal government has a crucial role to play in research and testing to help identify and develop the best roofing and paving materials, in funding computer models for determining the optimal approach to cooling a city, and in disseminating information in the nation and the world.

This energy-saving, pollution-avoiding approach would be part of a much broader shift in the nation's environmental policy, which is vital if we are to be a prosperous country in the next century. The environmental paradigm that has predominated since the 1960s has been based on the notion that pollution is an inevitable by-product of business and that public- and private-sector efforts should be aimed at cleaning up that pollution after the fact or safely disposing of it in land, water, or the atmosphere. This so-called end-of-pipe approach is increasingly being challenged not only on environmental grounds but also on economic ones. Michael Porter, a professor at the Harvard Business School, wrote in the September-October, 1995, issue of the *Harvard Business Review*,



> When scrap, harmful substances, or energy forms are discharged into the environment as pollution, it is a sign that resources have been used incompletely, inefficiently, or ineffectively. Moreover, companies then have to perform additional activities that add cost but create no value for customers: for example, handling, storage, and disposal of discharges.

The traditional end-of-pipe approach involves three kinds of economic waste: two identified by Porter (using resource inputs and pollution outputs inefficiently) and the societal costs associated with the myriad harmful side effects of resource overuse (for example, dependence on foreign oil) and of pollution (such as human illness and agricultural loss).

That dependence on Persian Gulf oil will grow seems inevitable. Congress has all but guaranteed that if an oil crisis comes, our response will be reactive, uninformed, and burdensome.

Because of the close connection between energy production and consumption on the one hand and pollution on the other, the Department of Energy provides a substantial majority—70 percent—of all federally funded pollution-prevention R&D. Pollution-prevention technologies take a variety of forms. Renewable energy prevents pollution in the production of electricity. Fuel cells offer the hope of preventing pollution in the transportation sector. Many other sectors of the economy have equally great prevention opportunities.

As Yergin's task force noted, in the past two decades a DOE investment totaling about $1.1 billion in energy-efficient industrial technologies has yielded "approximately $2.5 billion in documented energy savings and net productivity gains, and the accumulation of these savings continues to grow at increasing rates." By 2000 these investments will be generating savings of about $10 billion a year. Very few other federal investments produce as great a societal return on taxpayers' dollars.

One technology, a process for dezincing (removing the galvanized coating from) scrap steel, provided the breakthrough that industry needed in order to recycle up to 10 million tons of scrap metal annually. By 2005 electrochemical dezincing could reduce raw-materials costs by $150 million a year, saving 50 trillion BTUs in the process, and reduce the need to import at least 70,000 tons of zinc, for further savings of at least $70 million annually. Another government-funded technology, vacuum-pressure swing adsorption, which is now used in manufacturing 15 percent of the glass made in the United States, reduces glass-making emissions of nitrogen oxide by 90 percent and cuts furnace energy use by 25 percent.

Something that is not widely understood is that most industrial pollution in the United States comes from the country's seven most energy-intensive industries: steel, aluminum, petroleum refining, chemicals, pulp and paper products, glass, and metal casting. These industries account for about 80 percent of the energy consumed in U.S. manufacturing and for more than 90 percent of the hazardous waste. They represent the greatest opportunities for increasing energy and resource efficiency while reducing pollution. That's why the DOE has been forming partnerships with these industries to develop clean technologies.

Funding for pollution prevention is the best way for the nation to avoid the need for costly environmental regulations. The government has a role in encouraging pollution prevention for several reasons. First, pollution-prevention technologies often benefit each of many companies only a little bit, so no one company has an incentive to spend the necessary money by itself. Second, prevention has many societal benefits: it reduces energy and other resource consumption and improves the environment, among other advantages. Third, and most important, pollution prevention and resource efficiency help companies to shift money from consuming energy and resources to investing in technology and capital equipment, thus creating jobs and economic growth. Indeed, a shift from consumption to investment may be the single most important transformation the U.S. economy must undergo if we are to remain prosperous in the next century.

A 1993 analysis for the DOE attempted to quantify the macroeconomic benefits of pollution prevention. The study found that a 10–20 percent reduction in waste by American industry would generate a cumulative increase of $1.94 trillion in the gross domestic product from 1996 to 2010. By 2010 the improvements would be generating two million new jobs, or roughly 1.5 percent of employment in that year. According to the study, this is "a relatively large impact considering that the investments driving it were assumed to be made for purposes other than increasing employment."

Moreover, this analysis does not include the jobs to be gained from capturing the large and growing export market for clean technologies and processes. Resource inefficiency and environmental degradation are very real limitations on the attempts of developing nations to raise the living standards of their people, especially since most of those nations do not have the abundance of resources with which America is endowed. The World Bank estimates that by 2000 the countries of Asia alone will need to spend about $40 billion a year on clean technologies. By then the global market for environmental services and technologies is expected to exceed $400 billion. The resource, environmental, and capital constraints on the developing world guarantee a rich export market for the nation that leads the world in developing clean technologies.

As Michael Porter wrote in the *Harvard Business Review*,

> We are now in a transitional phase of industrial history in which companies are still inexperienced in handling environmental issues creatively. . . . The early movers—the companies that can see the opportunity first and embrace innovation-based solutions—will reap major competitive benefits, just as the German and Japanese car makers did [with fuel-efficient cars in the early 1970s].

That's why foreign governments are forming partnerships with their nations' companies to develop clean technologies: to overcome inexperience and ensure that they reap the benefits of early strength in the field.

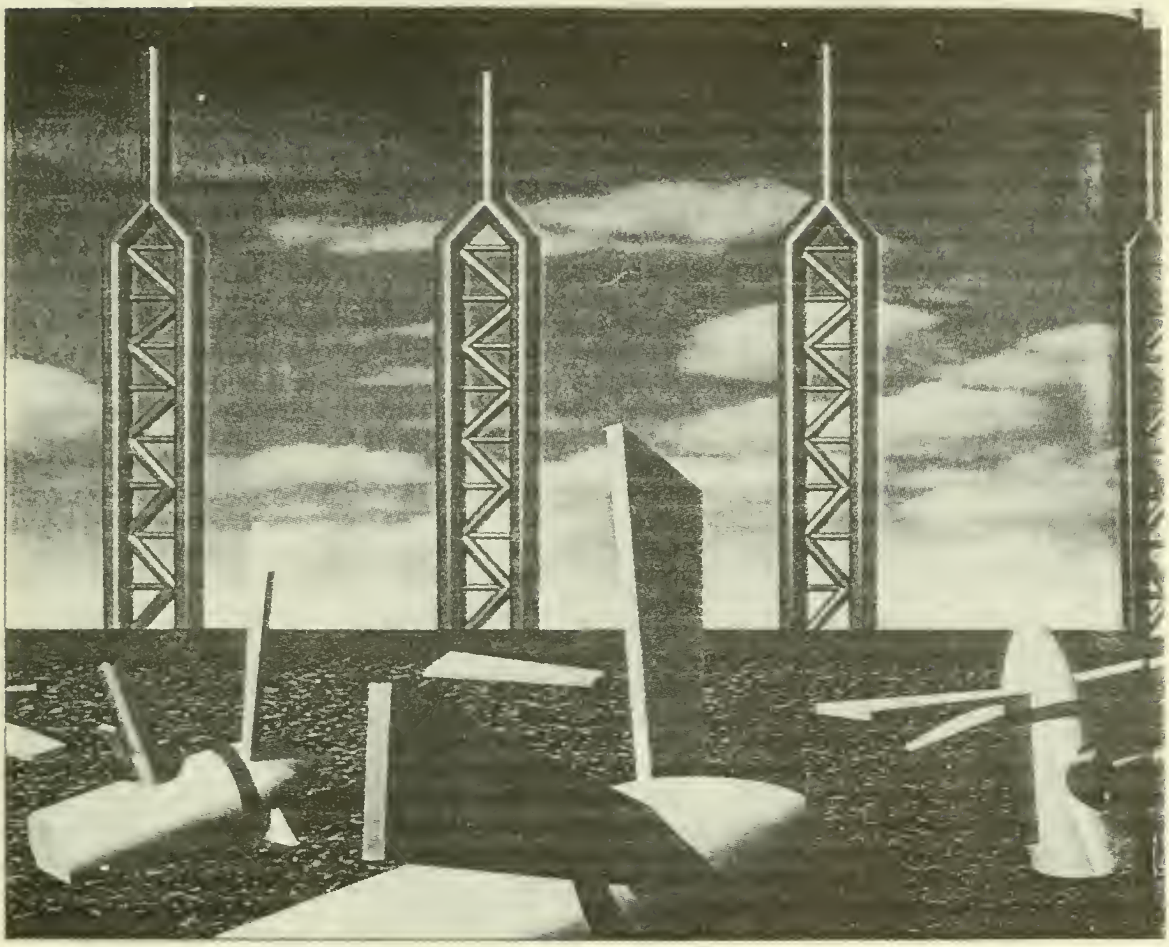
The Japanese government is betting heavily on clean technologies and renewable energy. It is vigorously pursuing the Asian environmental market through the Green Aid Plan, which is designed to help Asian countries prevent water and air pollution, recycle waste, conserve energy, and develop alternative energy sources. In 1993 Japan quadrupled funding for the Green Aid Plan, to $120 million.

Germany, too, is moving in this direction, with regulations that increasingly push industry toward prevention, recycling, and life-cycle analysis. Proposed or pending regulations throughout Western Europe have implications for U.S. companies, as noted in a 1993 report prepared for the Saturn Corporation by the University of Tennessee Center for Clean Products and Clean Technologies: "European auto manufacturers are the current world leaders in car recycling and the use of life-cycle assessment to design environmentally superior cars."

One of the countries most attentive to prevention is the Netherlands, which spends about $500 million a year on environmental technologies—equivalent on a per capita basis to $9 billion in the United States. More than a third of that money is spent on pollution prevention. The Netherlands also uses its tax code to promote clean technologies by allowing firms that practice innovative pollution prevention to depreciate their investment in one year instead of over ten years.

Congress, in contrast, has cut by a third the Department of Energy's proposed budget for the development and deployment of energy-efficient and pollution-prevention technologies—a step that threatens U.S. leadership in this crucial area. Congress has proposed still deeper cuts in its multiyear budget plans—cuts that would deny U.S. companies a great many opportunities to compete and the nation as a whole the opportunity to capture a big piece of a market whose potential is equal to that of renewable energy: several hundred billion dollars a year.

Even the vitally important urban-heat-island-mitigation program described above has gone unfunded. For the 1995 and 1996 budgets the DOE asked for $2 million—a tiny sum by federal-government standards—for a Cool Communities program, to take the idea beyond the realm of small-scale testing. Like many programs that save energy in a cost-effective way, the program would also reduce emissions of carbon dioxide, whose increasing prevalence in the atmosphere may be changing the earth's climate. The department



included the Cool Communities program in its Climate Change Action Plan, to meet the nation's international commitment to try to limit greenhouse gases.

In both years Congress zeroed out the Cool Communities program. Why? Whereas the pre-1994 Congress was skeptical of global climate change, the new one is downright hostile to the concept, with some labeling it "trendy" and "scientific nonsense."

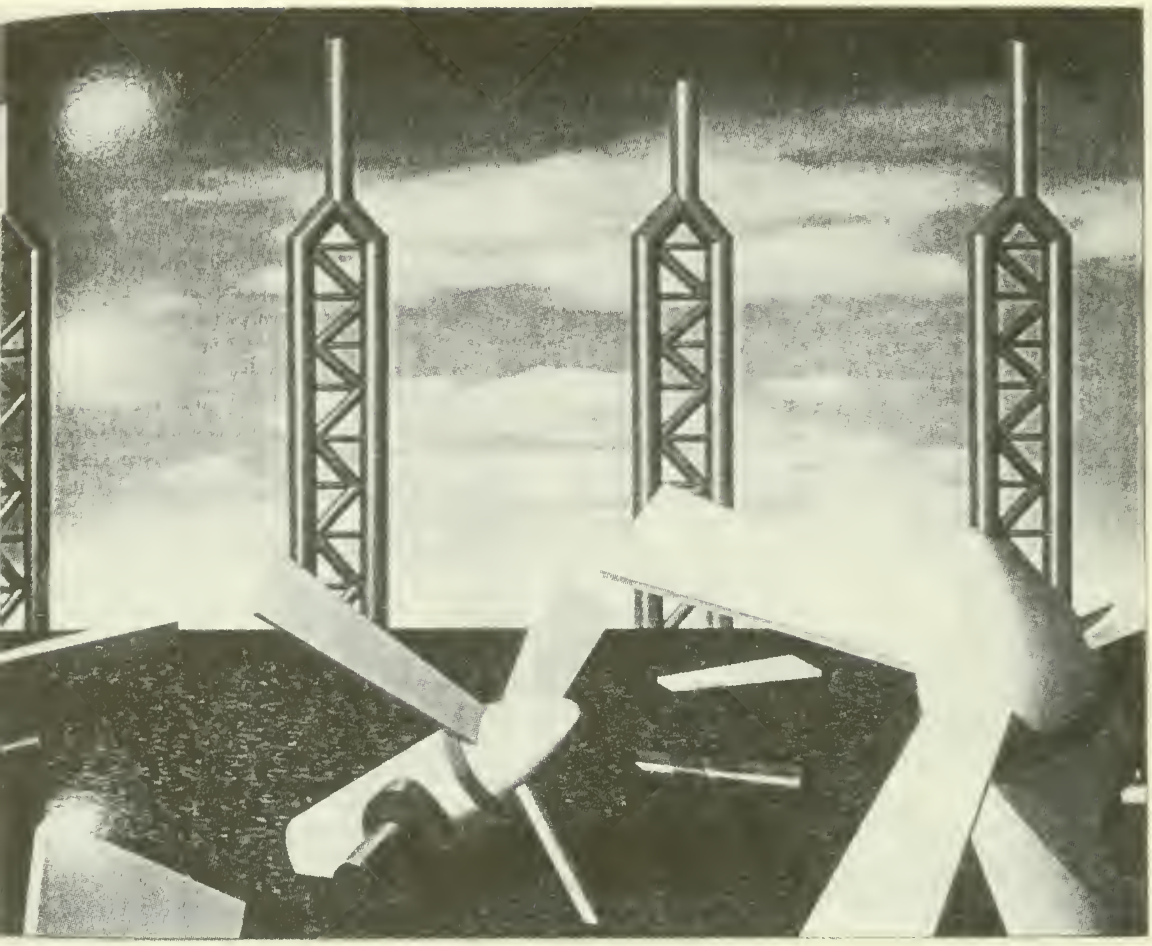
Yet at a meeting last December of the Intergovernmental Panel on Climate Change, representatives of 120 governments agreed that "the balance of evidence . . . suggests a discernible human influence on global climate." In a 1995 study scientists examined detailed records of weather over the past hundred years and concluded that weather extremes—heat, drought, excessive rain, or the kind of blizzard that the Northeast experienced in January—are becoming more common and that the extreme weather is almost certainly due to human-generated emissions of greenhouse gases.

The Economist concluded last October, "Climate change is a legitimate worry. Although still riddled with uncertainties, the science of climate change is becoming firmer: put too much carbon in the atmosphere and you might end up cooking the earth, with possibly catastrophic results."

Preparing for the Future

SOME argue that energy forecasts are notoriously inaccurate and that for the Department of Energy to base decisions on them is risky. We cannot, of course, say with certainty that an oil crisis will occur in the next decade, that a transition to renewable energy will occur as Shell envisions, or that industry worldwide will shift to pollution prevention. But each of these things seems very plausible, if not likely.

Another criticism often leveled at the DOE is that it has had big, expensive failures, such as the synthetic-fuels pro-



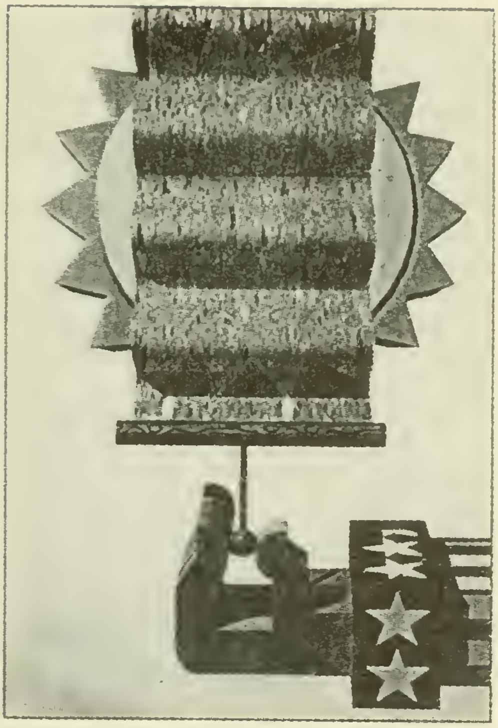
gram, but few successes. The department has learned from experience, however, and its R&D portfolio is diverse, emphasizing small-scale technologies that have in fact been remarkably successful in the past. The recently concluded independent review of the department's energy-research portfolio cited dozens of examples of such technologies, among them a $3 million investment in energy-efficient windows made in the late 1970s, which has already saved U.S. taxpayers more than $1 billion in lower energy bills; a polycrystalline diamond drill bit that has reduced the cost of drilling for oil by $1 million per well; and many of the advances described above, including photovoltaics.

Diversity is a key element of DOE policy today: diversify the world's oil supply, and diversify America's domestic supply and end-use options. Because no one can predict the future with certainty, or know the outcome of R&D in advance, the DOE must invest in many options. The sharp cuts that Congress is pursuing narrow the country's options and leave us far less flexibility to respond to future crises and opportunities.

Finally, some argue that government investments are "corporate welfare," a term implying a giveaway with no societal benefits. But the DOE has formed partnerships with the private sector to develop leapfrog technologies—such as the fuel cell, solar energy, and clean industrial, building, and transportation technologies—that will benefit many segments of our society.

Americans today have a duty to eliminate the deficit, rooted in their obligation to future generations, but the country also needs to acknowledge that public investment in R&D, far from being corporate welfare, is an investment in America's own future. As the Yergin task force wrote, Americans have an obligation to "assure for future generations that our Nation's capacity to shape the future through scientific research and technological innovation is continually being renewed."

The cuts planned for the energy-efficiency-and-renewable-energy program—30 percent this year and 60–80 per-



cent over the next several years—far exceed the cuts planned in overall domestic discretionary funding to balance the budget. The impact of such cuts will be enormous.

Perhaps the only way to begin to realize the loss to the future is to look at the past. Federal investment in research and development for national needs has been one of the great success stories in twentieth-century America. Why does the United States retain leadership and strong exports in vital industries like aerospace, computers, and biomedicine? American ingenuity and the private sector have certainly been instrumental in each of these industries. Yet these industries have also enjoyed government support for decades. Who can doubt that a sustained high level of federal funding—eight times as much money as America's leading competitor provides—is responsible for U.S. leadership in biomedical and biotechnological research?

As for computers and software, the Pentagon's Advanced Research Projects Agency "virtually single-handedly created the United States' position of world leadership in computer sciences," according to a Harvard Business School case study on ARPA. And of all R&D dollars spent in the aircraft industry from 1945 to 1984, some 85 percent came from the federal government. In an unexpected benefit of the kind that is common in federal R&D, much of the turbine technology that is today generating electricity and helping to keep down utility rates had its roots in government-funded work on jet engines.

Federal R&D for national needs has been one of the great success stories in twentieth-century America. Why else does America retain leadership in aerospace, computers, and biomedicine?

John Preston, formerly the director of technology development for the Massachusetts Institute of Technology, told Congress in 1993, "It seems clear that when the government teams up with academia and industry, and participates throughout the spectrum of technology, the United States becomes dominant in that industry." America's technological lead in most kinds of fuel cells and photovoltaics stems from almost two decades of NASA, National Science Foundation, and Pentagon support, followed by almost two decades of DOE support.

Some of the most pressing national needs in the coming decades are to reduce the country's huge and growing trade deficit in oil, to minimize any economic or political threat that might arise from the growing world dependence on Persian Gulf oil, to prevent pollution, to avoid irreversibly changing the global climate, and to capture a large share of the enormous potential market for energy and environmental technologies. Remarkably, a great many of the same R&D investments can simultaneously achieve all these ends while cost-effectively reducing the energy bills of businesses and consumers. Equally remarkably, Congress demonstrates an overwhelming desire to gut the funding for investments by the energy-efficiency-and-renewable-energy program, although it costs Americans only $4.00 per person a year.

Nothing is clearer to those who study the matter than that the world is on the verge of a revolution in energy and environmental technologies—a revolution made possible by more than two decades of U.S. government investment. This revolution can be expected to create a number of industries that collectively will provide one of the largest international markets and one of the largest sources of new high-wage jobs in the next century, with annual sales in excess of $800 billion.

Yet just as our foreign competitors are starting to catch on to the major trends in this American-led revolution, Congress wants to pull the federal government out of every relevant technology, leaving America on the sidelines, perhaps for good. Only a misbegotten ideology could conceive a blunder of such potentially historic proportions.

ISBN 0-16-053992-7
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