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ENERGY INNOVATION

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BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND INNOVATION

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

MARCH 20, 2007

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ENERGY INNOVATION

TUESDAY, MARCH 20, 2007

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND INNOVATION,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:38 p.m. in room SR–253, Russell Senate Office Building, Hon. John F. Kerry, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. JOHN F. KERRY, U.S. SENATOR FROM MASSACHUSETTS

Senator KERRY. This hearing will come to order. I apologize to all for being a moment late. We had a caucus meeting that went a little bit long, and I apologize.

Thank you all, witnesses, for being here. I'll introduce you in a few minutes.

This is an ongoing part of a series of hearings that both this Committee, as well as a number of other committees, are focusing on to try to really pinpoint what we can and can't do with respect to the increasingly pressing issue of global climate change.

I just had an opportunity to share some thoughts in our caucus, where had a brief discussion about it. But I've been involved in this for a long time now. When I was Lieutenant Governor, we dealt with the acid rain issue, with then Governor John Sununu, of New Hampshire, and Dick Celeste, of Ohio. And we actually put together the first cap-and-trade, that's where we developed it, and subsequently put it into the Clean Air Act in 1990. We found that were able to reduce emissions at a faster rate and less cost than anybody had predicted. The industry came in and said, "Oh, God, don't do this to us. It's going to cost $8 billion and take X number of years." And we said to the environmental community, "No, it won't. It's going to cost $4 billion, and we can do it in half that time." Well, guess what? It cost less than that, and we did it in less time. Why? Because no one ever factors in, or has an ability completely to factor in, what happens when you start down the technology road. And once we start down that road, one thing leads to the next, and cost goes down and a whole bunch of market forces set into play which aren't there originally, because you, in effect, create these markets.

This issue is long overdue for this Congress to respond to it. There are over 450 mayors in our Nation who are taking steps today, Mayor Rocky Anderson, Salt Lake City, the mayors out in

Portland and in other parts of our country. The evidence is overwhelming, the science.

I met with a number of scientists, a few nights ago, who were gathered in Washington as board members of the Heinz Center, and to listen to these people—Ed Miles, Bob Corell, others known publicly—talk about their increased sense of urgency—the evidence is overwhelming of what is happening, not just in the temperature increases themselves, but in the impacts: Alaska, Senator Stevens' state, where the permafrost is melting, where fishermen are having greater trouble going out and doing their fishing, where the white spruce are infected by beetles, 4 million acres worth of it, because they used to die in the cold and it's not that cold. And you can go anywhere and see these impacts. The glaciers in the mountains and the ocean edges disappearing, increased impact on rainfall, evaporation, the species movement, mitigation, and so forth. I'm not going to run through all of that right now, except to say that, when I hear Jim Hansen, a renowned climatologist, say, "You've got a 10-year window to respond," and when I hear a group of these scientists say that the evidence is more rapidly showing things they predicted at a greater rate, and at a greater quantity, you'd better stop and listen. And that's what this Congress needs to do.

Now, one of the interesting things that's happening is, a lot of companies are responding themselves. You have USCAP, you have a bunch of the top corporations who have come together, saying, "We need a carbonwide cap in our economy." You have major corporations, like IBM and GE and Alcoa and others, who have reduced their emissions, some as much as 65 percent, and saved hundreds of millions of dollars, $621 million in one case, almost a billion dollars in another case. So, there's money to be made here.

There are three very significant—and only three—major ways to deal with global climate change. One is through energy efficiencies. And that's what you're here to help us understand today. Two is through alternative and renewable fuels. And, again, we're going to discuss that today. The third is through clean coal technology. I talked, just the other day, with the president of AEP, who tells me the next two plants they're building, one in Ohio and one in West Virginia, will be built with IGCC technology, integrated gasification combined cycle technology, which General Electric, incidentally, has just recently said they will stand behind, in terms of the liability on the technology itself. So, having backed up the technology, they've freed a company to feel comfortable to move forward to implement it. This means this is within grasp. We don't have to sit here and panic about loss of jobs; in fact, we will create more jobs.

And, in the end, I believe—you know, we've all heard of a twofer, where you do one thing, and you get something for it—this is a fivefer, because if you do it, you not only live up to your global climate-change responsibilities, you get better health for your citizens, cleaner air, cleaner water, you restore fisheries, you revitalize our economy with a whole group of new jobs and new technologies, which grow our economy. And, guess what? You provide America with greater energy security and greater security overall. Those are big wins.

And so, my hope is that this committee can contribute significantly to this dialogue, and that we can make some significant progress in this field.

Senator Ensign?

STATEMENT OF HON. JOHN ENSIGN, U.S. SENATOR FROM NEVADA

Senator ENSIGN. Thank you, Mr. Chairman. Thank you for holding this hearing.

I was proud to chair this Subcommittee's first hearing on alternative energy technologies. At that hearing we heard some great testimony about some of the new, exciting technologies that have the potential to help the United States satisfy its energy demand while facilitating reduced greenhouse gas emissions.

Dr. Sridhar, I want to welcome you back to our subcommittee. I have visited your company and have seen some of the exciting things that you are doing out in California. I would also like to welcome the other entrepreneurs at the witness table. I think that there are some incredibly exciting developments out there in the private sector, including some that are in the early stages of development.

I agree with the Chairman that this is an important part of our developing economy. We often hear about the high-tech world and this is certainly a big part of the high-tech world. The high-tech world is demanding more energy these days, and more reliable energy. At the same time, we are so dependent these days on foreign oil and fossil fuels. I believe there exists a great opportunity at this moment in history. People are concerned about climate change, increasing greenhouse gas emissions and clean air. At the same time, these concerns are combining with the concern about the United States' strategic position in the world and our dependence on some of the world's "bad actors" to fulfill our need for energy.

When we use some of the foreign sources of oil in the world, we make people who are not exactly our friends wealthier. Innovative energy solutions are what we need to make us less dependent on foreign sources of energy and, at the same time, address environmental concerns.

My own State is in a unique position. Between geothermal, solar, and wind, we have some great opportunities for renewable energy that I think could be developed. I'm very much a free-market thinker. I do not believe that the government should be in the business of picking winners and losers, but I also believe that we have subsidized many of our oil concerns with our military. I think that the government can play a role in encouraging some of these fledgling technologies, and then stepping back to allow the market to determine their viability. By doing so, I believe that the outcome can be very valuable to our country in the long term.

Next month, Nevada Solar One, the world's third-largest solar plant, is scheduled to start generating power. This plant will develop enough energy to power approximately 48,000 homes in Nevada. It's not enough to supply Las Vegas or Reno, but it is certainly very encouraging to see that solar power is becoming an important part of Nevada's energy portfolio. We also have huge amounts of geothermal energy in Nevada, I believe we are second in the country, as a State, for geothermal energy for power production. Nevada also has great potential for wind energy, specifically in eastern Nevada. However, the transmission lines needed to use that power do not exist. There are many issues that need to be addressed in order to achieve energy innovation and independence. The bottom line, however, is that I'm glad that this subcommittee has been taking the lead on addressing this issue, and I'm glad that the witnesses present today are helping to move the country forward. I agree with you, Mr. Chairman, that this is, overall, going to have a very positive effect on the economy and the types of jobs and the types of technology that will move this country forward.

I appreciate you holding this hearing today, and I'm really looking forward to hearing from the witnesses.

Senator KERRY. Thank you, Senator.

Senator Stevens?

STATEMENT OF HON. TED STEVENS, U.S. SENATOR FROM ALASKA

Senator STEVENS. Well, Mr. Chairman, I'd like to ask you to put my statement in the record.

I would like to point out, though, that we have some very interesting things going on in our state. And I'd like for you to come up sometime and see the development at Chena Hot Springs. I think one of the witnesses will be talking about that today. That's a very interesting way to harness geothermal resources.

We also have a plant that's being run now on fish oil, the waste from—really, from a processing operation. There are many things we can do to meet some of these challenges, and I look forward to working with you on it.

[The prepared statement of Senator Stevens follows:]

PREPARED STATEMENT OF HON. TED STEVENS, U.S. SENATOR FROM ALASKA

Mr. Chairman, thank you for holding this hearing on energy innovation. This country's growing demand for energy is an issue that is important for us all.

Our country needs a new energy paradigm. The 21st Century will be the proving ground for our commitment to achieve both energy independence and new, clean fuels. Our current energy challenges will be solved by a combination of energy initiatives, increased domestic production of petroleum, and the development of alternative sources of energy. These are all part of the broader solution and we must find the appropriate balance between them.

The future holds a staggering list of possibilities for new energy technologies. In my state alone, we are looking at harnessing ocean and tidal energy and utilizing wood waste to produce ethanol. Some of our fishermen are currently using fish oil to power their operations and Chena Hot Springs, outside Fairbanks, has harnessed energy from geothermal resources to power their resort.

However, renewable and alternative sources of energy are expensive and it will take time for them to become realistic and affordable options.

I look forward to hearing from the witnesses today as they discuss a wide spectrum of emerging ideas and technologies.

Senator KERRY. Thank you very much, Senator. Well, we really look forward to your input, which will be very critical to moving the Senate. So, we're delighted to have you involved in it.

Senator Klobuchar?

STATEMENT OF HON. AMY KLOBUCHAR, U.S. SENATOR FROM MINNESOTA

Senator KLOBUCHAR. Thank you, Senator Kerry. And thank you for doing this hearing.

I was listening to Senator Stevens talking about fish oil. I decided that sounded more glamorous than our work we're doing with poultry litter. But there is clearly——

[Laughter.]

Senator KLOBUCHAR.—a lot of exciting things going on.

Senator STEVENS. That's a new name for it, I'm sure.

[Laughter.]

Senator KLOBUCHAR. Very nice.

There are a lot of exciting things going on across the country. I'm proud to be on the Agriculture Committee, the environmental committee, and this committee. So, on all three of those Committees, we're focused on climate change. And I will say that, in addition this being such an important issue for jobs, I think that if we don't move ahead with this technology, we're going to lose out on this economic opportunity to other countries that are going to move more quickly than we do, if we don't move ahead.

Earlier this year, our State passed a new law that's considered the Nation's most aggressive standard for promoting renewable energy in electricity production with a portfolio standard. It's a "25 x '25" standard, by the year 2025, the State's energy companies are required to generate 25 percent of their electricity from renewable sources. For Xcel Energy, which is our largest provider, they must reach 30 percent by 2030, and they were part of this agreement, as well, as well as our Republican Governor and the Democratic-controlled two bodies of the State legislature. It was a complete bipartisan effort. And I hope we will see similar bipartisan work going on in the U.S. Senate.

The reason that it's so important in our State is, as Senator Ensign talked about, we're seeing just great economic opportunity here in our State. We're seeing it with wind. We have so many wind turbines right now in southeastern Minnesota that they've opened up a bed and breakfast. So, if you're looking for a romantic weekend, Mr. Eckhart, you can come down—the whole deal—the package deal is, you spend the night in the bed and breakfast, and you wake up in the morning and look at a wind turbine. That's it.

[Laughter.]

Senator KLOBUCHAR. So, anyway, we're doing a lot with wind. We're obviously doing a lot——

Senator KERRY. And then you go out and clean up the kitty litter.

[Laughter.]

Senator KLOBUCHAR. We're doing a lot in the area of agriculture, and I want to move ahead to the next frontier, which is cellulosic ethanol, and we're trying to develop something as part of our agriculture bill, which focuses funds on the development of the next stage of ethanol, which will be better with carbon, obviously, and be—contribute to—help with the climate-change issue.

We've always considered environmental stewardship a way of life in our State, and we want to do something to make a difference and take action. So, I thank you for being here. As I mentioned, to you when I came up ahead of time, I am going to preside over the Senate, which we do often as freshman Senators, but I will submit my questions in writing. They deal, as we discussed, a lot with the wind, the transmission issues, and perhaps you'll touch on that in your testimony and I can hear about it later.

So, thank you so much, all of you, for being here.

Senator KERRY. Senator, thank you. Thanks very much for your interest in these issues, and we're delighted to have Minnesota represented in this effort. And we know you've been a leader. I remember seeing some of the wind operations out there, and you've been great leaders on this.

Well, we look forward to your testimony. If we could try to hold the testimonies to a summary of about 5 minutes, it'll give us more time to interact. Your full statements will be put in the record as if read in full.

Mr. Bill Prindle, the Acting Executive Director, American Council for an Energy-Efficient Economy—thank you, Bill, for being here. Michael Eckhart, President of the American Council on Renewable Energy; Dr. Francis Preli, Jr., Vice President of Engineering, UTC Power, from Connecticut; K. R. Sridhar, Chief Executive Officer of Bloom Energy, Sunnyvale; and Dr. James Katzer, MIT Laboratory for Energy and the Environment, who's doing some really terrific breakthrough stuff on this, from Cambridge. We're delighted to have you all here. Thank you.

You want to lead off, Bill? We'll just run right down the——

STATEMENT OF WILLIAM PRINDLE, ACTING EXECUTIVE DIRECTOR, AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY (ACEEE)

Mr. PRINDLE. Yes, thank you, Mr. Chairman, Members of the Committee. It's a pleasure to be here today.

ACEEE is a nonprofit research and advocacy organization formed in 1980 by leading researchers who decided that there was really no way for people to understand what energy efficiency is, in toto, because it's composed of so many small scattered devices throughout the economy. So, our job for the last 25 years has been to try to articulate, What is this thing we call energy efficiency, and how does it contribute to our economy, and what kind of policies do we need to move it forward?

And as we've come to term "efficiency" lately, we call it the "first fuel" in the race for clean and secure energy, because, when you think about it, we have to slow down energy-demand growth; otherwise, none of the clean sources that we want to develop, be they clean coal or renewables, will be able to keep up with rising energy demand.

We also have begun to demonstrate how much of a force energy efficiency is in the economy today. Over the last 30 years, we've cut our energy use per dollar of gross domestic product in half, and what that means is that most of the growth in energy services—the lighting and the heating and the other things we want to do with energy—has actually been served by energy efficiency, not by electricity or gas or oil. And so, that's been a key point.

But a lot of people still misunderstand efficiency. A lot of people think of energy efficiency as turning off the lights or not driving to the drugstore or just doing with less, when, in fact, the record in the last 30 years shows that efficiency is about investing in advanced and accelerated technology, and doing the same or more than you used to do, with less energy input.

And what we've also begun to find out is that the energy-using infrastructure in our economy is actually larger, when you add it up, than the energy supply infrastructure. So, if we look at the economy in a recent year, we'll find maybe $100 billion worth of investment in powerplants, pipelines, LNG terminals, you name it. It's about $100 billion. When we look at the Energy Star products program that the Federal Government sponsors, products sold under that logo total over $100 billion in sales in a single year. And that's only about a third of those markets—so, those energy equipment markets are actually over $300 billion. And so, our economy actually spends more money on the use of energy than it does on energy supply; and yet, we don't see that because energy efficiency is hidden under the hood of the car or in the back of the refrigerator or up above the ceiling, where the light fixture is, and we just don't see that. And yet, it's contributing this huge value to the economy.

The potential remains very large. We've just done a number of major studies ourselves. States like Florida and Texas, where the potential for major growth and efficiency in renewables could meet just about all of the new energy service needs over the next 15 years. But to do that, we have to accelerate the pace of innovation, we have to accelerate the rate of efficiency and of progress on the renewable side. And so, that means both technology, and it means policy support.

And so, I want to highlight just three areas where we see innovation happening today, to give you a flavor for what's going on.

Last Wednesday, we attended a National Press Club press conference with Philips Lighting Company to announce a 10-year initiative to shift the lighting market in the United States so that residential light bulbs will use 90 percent less energy in 10 years. And, given Dr. Hansen's admonitions that we need to make some shifts in the next 10 years, I thought that was a meaningful commitment on the part of companies like Philips. And so, we expect the other lighting companies to join in this and for the lighting market to start to shift much more rapidly.

One of our closest allies is Dow Chemical Company, which, over the last 10 years, has cut its energy use per pound of product by 20 percent through technology innovation. They have just announced a new commitment to cut their energy use per pound by another 25 percent by 2015 by accelerating their innovation. It's not just their internal operations. They make building insulation, they make advanced materials for lighter weight and stronger vehicles, so they're actually contributing to the efficiency solution on the demand side, as well.

And—you know, and yet we still need policy action, because the markets—while the markets are working, they're not accelerating innovation fast enough across all the broad areas we need to attack.

So, one of the things that the Commerce Committee could do is to get some of the infrastructure restored, and that includes things like restoring some of the Census surveys. The M-series, for example, that collects information on how much equipment is sold, was discontinued as of 2003. That's an infrastructure loss that we can't afford. On the R&D side, we need to start restoring funding. We need new policies to save oil. We support the "Ten-in-Ten" fuel economy bill that several of the Committee members have been behind. We need to set energy efficiency targets for utilities, the way Governor Pawlenty did. And, in fact, in Nevada, the State has a combined renewable and energy efficiency target for utilities. So, more and more States are going that way.

And, of course, appliance efficiency standards are quietly saving more and more energy. We have three products in consensus agreements now that could go into legislation today. And on the lighting side, we may have another one in 3 weeks, tax incentives and so on.

I'll stop now, because I know my time is quickly running out, but I just wanted to hit a few of the high points and I'll stop and turn the mike over to the next witness.

Thank you.

[The prepared statement of Mr. Prindle follows:]

PREPARED STATEMENT OF WILLIAM PRINDLE, ACTING EXECUTIVE DIRECTOR, AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY (ACEEE)

Introduction

ACEEE is a nonprofit organization dedicated to increasing energy efficiency as a means of promoting both economic prosperity and environmental protection. We were founded in 1980 and have contributed in key ways to energy legislation adopted during the past 25 years, including the Energy Policy Acts of 2005 and 1992 and the National Appliance Energy Conservation Act of 1987. I have testified before the Senate several times and appreciate the opportunity to do so before the Subcommittee.

Energy Efficiency as the Engine of Economic Prosperity

Energy efficiency improvements have contributed a great deal to our Nation's economic growth and increased standard of living over the past 30 years. Energy efficiency improvements since 1973 accounted for approximately 50 quadrillion BTUs in 2003, which is *more than half of U.S. energy use and nearly as much energy as we now get annually from domestic coal, natural gas, and oil sources combined.* [1] Thus, energy efficiency can rightfully be called our country's largest energy source. If the United States had not dramatically reduced its energy intensity over the past 30 years, consumers and businesses would have spent about $650 billion more on energy purchases in 2006.

Energy efficiency is measured not just in abstract terms like declining energy intensity, but also in concrete terms like product sales, job creation, and capital investment. ACEEE estimates that in 2006, total investment in energy supply systems, from pipelines to powerplants, totaled about $100 billion. But Americans also invest in energy-using technologies: energy-efficient products bearing the Federal Energy Star label accounted for some $101 billion in sales last year, in a range of home and business products like home appliance, home electronics, heating and cooling systems, office equipment, lighting, and windows. These are large markets: our data show that, for example, that Americans buy some 11 million refrigerators, 64 million residential windows, 150 million pieces of office equipment, and about 1.5 billion light bulbs. We estimate that Energy Star products account for only about ⅓ of these markets in the aggregate, totaling some 330 million products, so one could project that total sales in these markets may be in the range of $300 billion annually. This suggests that, in rough terms, the U.S. economy spends perhaps three times as much per year on energy end-use technology as it does on energy supply technologies.

Moreover, the Energy Star data does not include investments in the 160,000 Energy Star new homes sold in 2005, or the high-efficiency commercial and industrial technologies, vehicles, combined heat and power systems, and others that would increase the size of the "efficiency economy" still further. While our analysis in this area continues, and we have not come to detailed conclusions on this topic, the data we have developed so far indicates that the demand side of the economy is very large in comparison with the supply side, and that efficiency investments in the aggregate account conservatively for over $100 billion.

These data help to erase a persistent misconception, which often occurs as an unstated assumption in many analyses, that energy efficiency is an economic "brake", that it involved reducing economic output or slowing economic growth. This misconception tends to stem from confusing energy efficiency with energy conservation. Conservation means reducing our consumption of energy services, whereas efficiency means consuming the same level of energy services with reduced consumption of energy commodities. This distinction between energy services and energy commodities is important. It is energy services we want—cold beverages, hot showers, well-lit rooms, comfortable living spaces, information services—and we are typically indifferent as to how much of which kinds of energy commodities supply those services.

Energy conservation, cutting back on the level of energy service, can in theory have an economic "brake" effect, if there is no shift of technology or spending of energy savings on other goods. But conservation usually occurs during times of rising energy prices, so the total economic output of the energy sector may continue to rise, and consumers may spend energy savings on other goods. Efficiency, on the other hand, involves technology investment to replace less-efficient products and systems. These investments create an economic stimulus with ripple effects through the economy, and our macroeconomic analyses show that efficiency investments tend to produce greater net economic benefits, in the form of increased output, income, and employment, than do investments in supply-side technologies.

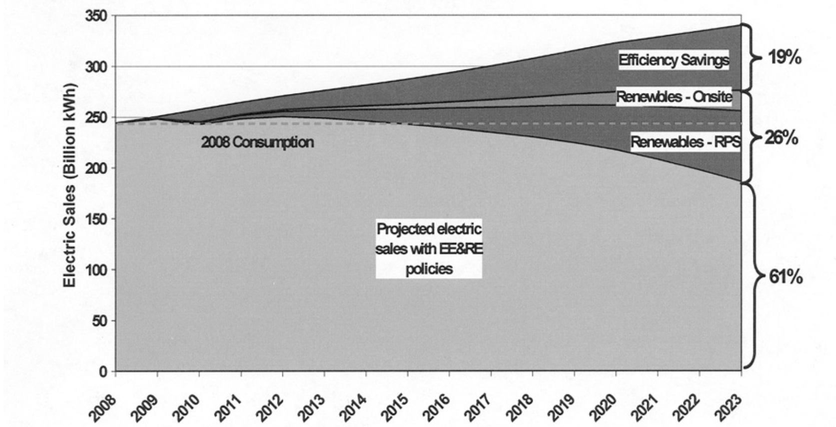
We estimate that energy efficiency has provided some 75 percent of the growth in energy services from the 1970s to the present. While efficiency is often invisible—today's refrigerators look and perform the same or better than 30 years, ago, but use ⅓ the energy—it is nonetheless measurable. And even though it is distributed in millions of individual buildings, vehicles, and devices, it has been and continues to be an effective engine of economic growth for the United States.

How Big is the Efficiency Resource?

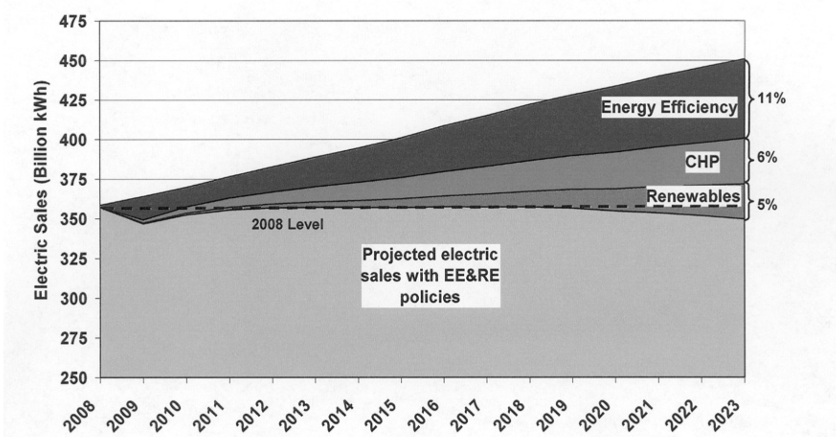
Even though we spend large amounts on efficient technology today, and the United States is thus much more energy-efficient than it was 30 years ago, there is still enormous potential for additional cost-effective energy savings. Some newer energy efficiency technologies have barely begun to be adopted. Other efficiency measures could be developed and commercialized rapidly in coming years, with policy and program support. For example, in a study from 2000, the Department of Energy's national laboratories estimate that increasing energy efficiency throughout the economy could cut national energy use by 10 percent or more in 2010 and about 20 percent in 2020, with net economic benefits for consumers and businesses.[2] Studies for many regions of the country have found similar if not even greater opportunities for cost-effective energy savings.[3]

ACEEE recently completed major studies of the energy efficiency and renewable energy resource potential in the states of Texas and Florida. These studies showed and efficiency and renewables can meet all of the growth in energy service needs, even in such fast-growing states, over the next 15 years or more. The figures below summarize these results. While public and private investment are needed to develop them, these resources provide better returns to the economy than conventional energy supply investments.

Share of Florida's Future Electricity Needs that Can Be Met with Energy Efficiency and Renewable Energy



Share of Texas' Future Electricity Needs That Can Be Met with Efficiency and Renewables Resources



It should be noted that the efficiency potential analyses discussed here are inherently quite conservative. They are based on technologies that are established in the market today, and on today's energy prices and technology costs. They are thus very conservative in the sense that new technologies, higher energy prices, and lower technology costs may well justify much greater estimates of efficiency potential. In the 1970s, for example, electricity growth rates were in the range of 3.5 percent per year. In that era, there was little of the high-efficiency technology we have today: examples include refrigerators that use ⅓ the energy of similar 1970s models; air conditioners that are twice as efficient; light bulbs that save ¾ the energy used by incandescent bulbs; LCD computer monitors that use ¼ the energy of CRT monitors; and the list goes on. Because of such technology advances, the Energy Information's 2007 Annual Energy Outlook projects that electricity demand will grow by only 1.5 percent annually through 2030, less than half of 1970s projections.

McKinsey Global Institute recently completed an analysis of global energy demand, and the potential for energy efficiency and related energy productivity gains to reduce current reference forecasts for energy demand growth. The study found that energy demand growth can be reduced by more than half by economically-viable technologies driven by public policies. It also found that in the U.S., energy consumption need not grow at all through 2030 if the cost-effective productivity improvements were realized in all sectors.[4]

The Case for Accelerated Policy Action on Efficiency

Policies are Needed to Overcome Market Barriers

Regardless of the size of energy efficiency's aggregate potential, or of the cost-effectiveness of such investments, a variety of market barriers keep these technologies from being implemented. These barriers fall in two main categories: (1) principal-agent or "split incentive" barriers, in which, for example, home builders must invest added capital in efficient homes, but receive none of the energy savings benefits; and (2) transaction costs, which stem from inability of average consumers or businesses to make "economically optimum" decisions in time-and-information-limited real world conditions. A study ACEEE conducted for the International Energy Agency covering five countries found that half or more of the energy used in major home and business energy end-use markets are affected by the principal-agent barrier alone.[5]

In addition, basic forces in the economy work against the tendency of higher energy prices to moderate energy demand. This principle of "price elasticity of demand", while economically correct, is countered by "income elasticity of demand", under which rising incomes cause consumers to be less affected by rising prices. A large segment of our population continues to buy low-mileage, high prices vehicles, with little concern for fuel costs. For less-affluent consumers, "cross-elasticities" come into play, which cause them to keep using energy as an essential service, but to cut back on other goods to balance their budgets. Economists have documented the slowing of retail sales in response to rising energy prices. Both the income elasticity and cross-elasticity effects suggest that energy prices alone won't balance our energy markets, and we need stronger energy policies if we want to stabilize energy markets without damaging our economy.

Reasons to Accelerate the Energy Efficiency Engine

Recent developments in our energy markets indicate that the U.S. needs to *accelerate* efforts to implement energy efficiency improvements:

- Oil, gasoline, natural gas and coal prices have risen substantially in recent years. For example, residential natural gas prices have more than doubled since 2000, and retail gasoline prices are up by similar proportions. Even America's cheapest fuel, coal, has seen price inflation: Powder River Basin coal has more than doubled in price since 2003. Energy efficiency can reduce demand for these fuels, reducing upward price pressure and also reducing fuel-price volatility, making it easier for businesses to plan their investments.
- A recent ACEEE analysis found that natural gas markets are so tight that if we could reduce gas demand by as little as 4 percent over the next 5 years, we could reduce wholesale natural gas prices by more than 20 percent.[6] This analysis was conducted by Energy and Environmental Analysis, Inc. using their North American Gas Market Model, the same analysis firm and computer model that was employed by DOE and the National Petroleum Council for their 2003 study on U.S. natural gas markets.[7] These savings would put over $100 billion back into the U.S. economy. Moreover, this investment would help bring back U.S. manufacturing jobs that have been lost to high gas prices and also help relieve the crushing burden of natural gas costs experienced by many households, including low-income households. Importantly, much of the gas savings in this analysis comes from electricity efficiency measures, because much of the marginal electric load is met by natural-gas fired power plants.
- The U.S. is growing increasingly dependent on imported oil, with imports accounting for more than 60 percent of U.S. oil consumption in 2006, of which more than 40 percent came from OPEC countries.[8] The U.S. Energy Information Administration estimates that imports will account for 68 percent of U.S. oil use in 2020.[9] While moderate amounts of new oil are available in hard-to-reach areas of the U.S., much greater amounts of oil are available by increasing the efficiency with which we use oil. A January 2006 report by ACEEE found that the U.S. can reduce oil use by as much as 5.3 million barrels per day in 2020 through improved efficiency, including more than 2 million barrels per day in industry, buildings, heavy duty vehicles and airplanes.[10] *In other words, there are substantial energy savings outside of the highly contentious area of light-duty vehicle fuel economy.* These 5.3 million barrels per day of oil savings are nearly as much as we presently import from OPEC (OPEC imports were 5.5 million barrels per day in 2005).[11] Energy efficiency can slow the growth in oil use, allowing a larger portion of our needs to be met from sources in the U.S. and friendly countries.

- Economists have increasingly raised concerns that the U.S. economy is slowing and that robust growth rates we have had in recent years will not be sustained. Energy efficiency investments can spur economic growth; they often have financial returns of 30 percent or more, helping to reduce operating costs and improve profitability. In addition, by reducing operating costs, efficiency investments free up funds to spend on other goods and services, creating what economists call the "multiplier effect", and helping the economy broadly. This stimulates new economic activity and job growth in the U.S., whereas most of every dollar we spend on oil flows overseas. A 1997 study found that due to this effect, an aggressive set of efficiency policies could add about 770,000 jobs to the U.S. economy by 2010.[12]
- Overall, the U.S. has ample supplies of electricity at present, but demand is growing and several regions are projecting a need for new capacity in the next few years in order to keep reserve margins adequate.[13] Energy efficiency resource policies can slow growth rates, postponing the date additional capacity will be needed.
- Greenhouse gas emissions continue to increase. Early signs of the impact of these changes are becoming apparent in Alaska and other Arctic regions.[14] And several recent papers have identified a link between warmer ocean temperatures and increased hurricane intensity.[15,16] The Intergovernmental Panel on Climate Change's 2007 report[17] documents more conclusively than ever that human activity is affecting the global climate, and that the environmental and economic consequences of inaction may be severe. Energy efficiency is the most cost-effective way to reduce these emissions, as efficiency investments generally pay for themselves with energy savings, providing negative-cost emissions reductions. The term "negative-cost" means that, because such efficiency investments produce net economic benefits, they achieve emission reductions at a net savings for the economy. This important point has been missed in much of the climate policy analysis modeling performed to date. Too many economic models are incapable of characterizing the real economic effects of efficiency investments, and so forecast inaccurate economic costs from climate policies. Fortunately, this kind of flawed policy analysis is beginning to be corrected. For example, a May 2006 study just released by ACEEE found that the Regional Greenhouse Gas Initiative (RGGI—the planned cap and trade system for greenhouse gases in the northeastern U.S.) can have a small but positive impact on the regional economy provided increased energy-efficiency programs are a key part of implementation efforts.[18]

Energy efficiency also draws broad popular support. For example, in a March 2005 Gallup Poll, 61 percent of respondents said the U.S. should emphasize "more conservation" versus only 28 percent who said we should emphasize production (an additional 6.5 percent volunteered "both").[19] In an earlier May 2001 Gallup poll, when read a list of 11 actions to deal with the energy situation, the top four actions (supported by 85–91 percent of respondents) were "invest in new sources of energy," "mandate more energy-efficient appliances," "mandate more energy-efficient new buildings," and "mandate more energy-efficient cars." Options for increasing energy supply and delivery generally received significantly less support.[20]

The Role of Innovation in Advancing Energy Efficiency

Technological innovation in energy efficiency, as is true of many facets of the U.S. economy, relies on a stream of innovations. ACEEE reviews emerging technologies in the buildings, industry, and transportation sectors, and periodically publishes reports on leading technologies. A summary of, and hyperlinks to, ACEEE reports on these technologies in the buildings sector can be found at the following World Wide Web address: *http://www.aceee.org/emertech/buildings.htm#reports.*

Our most recent buildings-sector technology assessment examines 72 emerging technologies in detail. While this testimony is too short for a full discussion of all of these innovations, I would like to use one technology—the residential incandescent light bulb—as an emblematic example. In our 2004 emerging technologies report, we examined several lighting technologies, including compact fluorescent fixtures, halogen lighting, and light-emitting diode (LED) lighting. All of these show promise as alternatives to the incandescent light bulb that has been the most common form of residential electric lighting for more than a century. It still accounts for more than 90 percent of total residential lighting sales in the U.S.

On March 14, 2007, ACEEE and other organizations announced a new coalition effort, initiated by Philips Lighting Company, that will fundamentally change the U.S. home lighting market in 10 years. By setting new high-performance targets for typical lighting applications, we expect to reduce residential lighting consumption by as much as 90 percent. While such standards are technology-neutral, based on our emerging technologies analysis we expect that compact fluorescents, halogens, and LEDs will all play a role in this transformation.

The residential light bulb was the first universal electricity end-use application when the electricity industry first developed in the 19th Century. Its main role in those early years was to create a universal, electric lighting energy service technology. Until the advent of the electric light bulb, lighting energy services were met by kerosene, whale oil, and of course paraffin (which we use as candles). Electric lights were the first in a long line of electricity-powered end use technologies that enabled the development of our modern power grid, and that drove much of our economic growth in the 20th Century.

In the 21st Century, however, we have a different imperative. Our electricity grid is built; to sustain economic growth while protecting our environment, we must cut waste from the energy-services side of the grid while cutting pollution from the generation side. Last week's lighting coalition announcement is one significant shift among many that must be achieved on the energy services side. Our technology studies and potential analyses show that such shifts toward energy-efficient technology can occur in many other end-uses.

Philips' new lighting initiative is representative of the kinds of innovation we are seeing in the buildings sector. In the industrial sector, companies like Dow Chemical are achieving dramatic gains in energy efficiency and carbon emission reductions. From 1995 to 2005, Dow reduced the energy consumed per pound of product by 20 percent. In 2006, the company announced a new commitment to reduce its energy used per pound of product by another 25 percent by 2015. This requires continuous innovation, in end-use technology, in the application of combined heat and power systems, in process improvement, and in operation and maintenance practices.

Program and Policy Initiatives Needed to Realize Efficiency Potential

The Energy Policy Act of 2005 (EPAct 2005) made some useful progress on energy efficiency. Particularly notable were sections that established new consensus Federal efficiency standards on 16 products and that created energy efficiency tax incentives. ACEEE estimates that the energy efficiency sections of EPAct 2005 will reduce U.S. energy use by about 1.8 quadrillion BTU ("quads") in 2020, reducing projected U.S. energy use in 2020 by 1.5 percent. Of these savings, more than 75 percent will come from equipment efficiency standards and energy-efficiency tax incentives.[21]

EPAct 2005, however, did not address several key energy efficiency issues. And since 2005, America's energy challenges have increased. We therefore recommend that Congress take further action to stimulate energy efficiency innovation.

Energy Market and Technology Data Collection

One of the core functions and responsibilities of the Federal Government is to collect information on market activity, so that businesses, researchers, and policymakers have the fundamental information they need to understand markets and plan for future initiatives. The Commerce Department through its Census and other activities, and the Department of Energy through its Energy Information Administration surveys, are two of the key sources of information needed to keep up with developments in energy markets. We have seen disturbing trends in both agencies, with key surveys being cut back in comprehensive and in frequency, and in some cases dropped altogether.

We urge the Committee to investigate this issue and seek to restore this key information infrastructure. Cutting back on energy market surveys is like cutting back on the U.S. Geological Survey, on whose information the energy supply industries depend for energy resource information; we need to continue and expand, not curtail, government efforts in this area.

For specific examples, we are concerned about the loss of the M-series surveys in the Census Bureau. These surveys collect essential information on product shipments, without which it is not possible to track the trends that indicate which technologies are penetrating the market. In addition, last year's discontinuation of the Vehicle Inventory and Use Survey was a tremendous disservice to the cause of heavy-duty truck efficiency, and indeed to the understanding of and planning for the trucking industry generally. The VIUS, conducted every 5 years, is the only source of national data on the number, size, fuel economy and driving patterns of the U.S. truck stock. It should be reinstated as soon as possible, before the Commerce Department's institutional capability disappears. The next VIUS was to have occurred in 2007.

Research, Development, Demonstration, and Deployment (RDD&D)

Many of the energy efficiency technologies we see emerging today were created with Federal RDD&D support—these include Energy Star windows, compact fluorescent and LED light bulbs, and high-efficiency refrigerator technology. EPAct authorized significant increases in efficiency RDD&D; however, budget requests for efficiency RDD&D have declined by about one-third since FY 2002. These cuts are beginning to cripple our research infrastructure, by laying off senior personnel with irreplaceable technology expertise and research experience, and in some cases discontinuing entire research programs. If the U.S. wants to continue its record of innovation in the energy area, and wants to be an effective competitor in global markets.

We were encouraged to see the Senate Budget Committee allocate $1.6 billion for energy efficiency and renewable energy programs at the Department of Energy. This represents more than a $300 million, 25 percent increase over the administration's FY 2008 budget request. In our House Energy and Water Development Appropriations Subcommittee testimony, we recommended increases in 16 priority efficiency programs for a total increase of $217 million above the request. We hope the Senate appropriations process will follow these recommendations, and thus begin to rebuild the RDD&D infrastructure the U.S. needs to get ahead of the curve on the next generation of energy efficiency innovations.

Policies to Save Oil

Most notably missing from EPAct were significant provisions to reduce oil use or to accelerate energy efficiency investment in the electricity and natural gas industries. We recommend that Congress make these high priorities in its upcoming deliberations on energy policy. Fuel economy in the vehicle fleet must be improved, either through Federal fuel economy standards, tax incentives, or RD&D policies. Our analysis projects that more than 5 million barrels of oil per day, some 25 percent of current U.S. consumption, could be saved cost-effectively by 2025.

ACEEE supports the "Ten-in-Ten" fuel economy bill sponsored by several Commerce Committee members that would raise the average fuel economy of light-duty vehicles to 35 mpg by 2018. This target is achievable and necessary to allow the transportation sector to meet its responsibility to address climate and energy security goals.

There are companion policies that should be explored as well. On the consumer side, a feebate policy would ensure, in the face of volatile fuel prices, consistent consumer interest in the fuel economy of the vehicles that they buy and help to align consumer demands with requirements of manufacturers as fuel economy increases are phased in over the next decade.

Energy Efficiency Resource Standards for Utilities

We also recommend that Congress enact Energy Efficiency Resource Standards (EERS) for electric and gas utilities. EERS is a simple policy approach that sets overall performance targets for utility efficiency efforts and provides flexibility in compliance. Several states have implemented EERS, beginning with Texas in its 1999 electricity restructuring legislation.[22] It is somewhat analogous to the Renewable Portfolio Standards (RPS) the Senate has passed twice in this decade. In fact, EERS and RPS are quite complementary. Our preliminary analysis shows that the most recent Senate RPS bill, combined with the EERS in a current discussion draft, could begin to reduce carbon emissions in the U.S. electric power sector by 2020.

EERS laws and regulations are now in operation in several states and countries. Texas's law requires electric utilities to offset 10 percent of their demand growth through end-use energy efficiency. Utilities in Texas have already exceeded their targets, and there is legislation to raise them. Hawaii and Nevada recently expanded their renewable portfolio standards to include energy efficiency. Connecticut and California have both established energy savings targets for utility energy efficiency programs (Connecticut by law and California by regulation) while Vermont has specific savings goals for the nonprofit organization that runs statewide programs. Pennsylvania's new Advanced Energy Portfolio Standard includes end-use efficiency among other clean energy resources. Colorado's largest utility has energy savings goals as part of a settlement agreement approved by the Public Service Commission. And Illinois and New Jersey are planning to begin programs soon. EERS-like programs have been working well in Italy, the United Kingdom, France, and the Flemish region of Belgium.

Appliance and Equipment Efficiency Standards

Appliance and equipment efficiency standards are another proven policy for accelerating innovation in energy efficiency. Standards already in place will save Americans over $200 billion in net economic benefits through 2030. There are several consensus agreements for new standards that could be included in legislation in this session of Congress. We will work with the energy committees on these issues.

ACEEE, affected industries, and other stakeholders have a long history of negotiating consensus agreements on new efficiency standards. Many of these agreements were incorporated into the Energy Policy Acts of 1992 and 2005. ACEEE is now talking with stakeholders about standards on additional products and has agreements on several new standards. We are working with energy committee staff to include these new consensus standards in legislation this year.

Products which may lend themselves to consensus standards include the following:

- Reflector lamps
- Pool heaters
- Metal halide luminaires
- Bottle-type drinking water dispensers
- Portable electric spas (hot tubs)
- Single-voltage external AC to DC and AC to AC power supplies
- Commercial hot-food holding cabinets
- Walk-in refrigerators and freezers

Energy Efficiency Tax Incentives

We also recommend that the EPAct tax incentives for energy efficiency technologies be extended beyond their current expiration dates, which were truncated by the EPAct conferees at the last minute. The EXTEND Act (S. 822) was recently introduced in the Senate to achieve this end, while also refining some specific provisions. We support the EXTEND Act as part of a consensus among a wide range of stakeholders

While they are not included in the EXTEND Act, Hybrid tax credits in EPAct 2005 should be extended and expanded to ensure the continued growth of the hybrid market. Incentives for heavy-duty hybrids should be revisited and extended as well. Interest in heavy-duty hybrids is high among users, and as is the potential for fuel savings.

Conclusion

Energy efficiency is the "first fuel" for America's energy policy. Energy efficiency has saved consumers and businesses trillions of dollars in the past two decades, but these efforts should be accelerated in order to:

- Wean America from its addiction to oil and so enhance our national security;
- Help American consumers and businesses cope with high energy bills;
- Bring balance to America's energy markets by softening energy prices;
- Strengthen our economy by generating American jobs and capital investment; and
- Start to meet the global warming challenge by moderating carbon dioxide emissions.

This concludes my testimony. Thank you for the opportunity to present these views.

ENDNOTES

[1] Specifically, national energy intensity (energy use per unit of GDP) fell 46 percent between 1973 and 2003. About 60 percent of this decline is attributable to real energy efficiency improvements and about 40 percent is due to structural changes in the economy and fuel switching.

[2] Interlaboratory Working Group, 2000, *Scenarios for a Clean Energy Future.* Washington, D.C.: Interlaboratory Working Group on Energy-Efficient and Clean-Energy Technologies, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

[3] For a summary of many of these studies, see Nadel, Shipley and Elliott, 2004, *The Technical, Economic and Achievable Potential for Energy-Efficiency in the U.S.—A Meta-Analysis of Recent Studies.* Washington, D.C.: American Council for an Energy-Efficient Economy.

[4] *http://www.mckinsey.com/mgi/publications/Global_Energy_Demand/index.asp*. We note that this is a proprietary, copyrighted analysis. The limited review in this testimony comes from information shared with the National Petroleum Council.

[5] Prindle et al. 2007. *Quantifying the Effects of Market Failures in the End-Use of Energy.* American Council for an Energy-Efficient Economy (forthcoming International Energy Agency publication)

[6] Elliott and Shipley, 2005, *Impacts of Energy Efficiency and Renewable Energy on Natural Gas Markets: Updated and Expanded Analysis. http://www.aceee.org/pubs/e052full.pdf.* Washington, D.C.: American Council for an Energy-Efficient Economy.

[7] National Petroleum Commission. 2003, *Balancing Natural Gas Policy—Fueling the Demands of a Growing Economy: Volume I Summary of Findings and Recommendations.* Washington, D.C.: U.S. Department of Energy.

[8] Energy Information Administration, 2006, *Monthly Energy Review May 2006.* Washington, DC: U.S. Dept. of Energy.

[9] Energy Information Administration, 2006, *Annual Energy Outlook.* Washington, D.C.: U.S. Department of Energy.

[10] Elliott, Langer and Nadel, 2006, *Reducing Oil Use Through Energy Efficiency: Opportunities Beyond Cars and Light Trucks.* Washington, DC:. American Council for an Energy-Efficient Economy.

[11] See note #9.

[12] Alliance to Save Energy et al., 1997, *Energy Innovations: A Prosperous Path to a Clean Environment.* Washington, DC: American Council for an Energy-Efficient Economy.

[13] North American Electric Reliability Council, 2006, *2006 Long-Term Reliability Assessment: The Reliability of Bulk Electric Systems in North America.* Princeton, N.J.: North American Electric Reliability Council.

[14] Hassol, 2004, *Impacts of a Warming Arctic: Arctic Climate Impact Assessment. http://www.acia.uaf.edu.* Cambridge University Press.

[15] Webster, Holland, Curry and Chang, 2005, "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment." *Science,* 309, 16 September, 1844–1846.

[16] Emanuel, 2005, "Increasing Destructiveness of Tropical Cyclones over the Past 30 Years." *Nature,* 436, 4 August, 686–688.

[17] Intergovernmental Panel on Climate Change. *Climate Change 2007: The Fourth Assessment Report (AR4).* United Nations Environment Program, 2007.

[18] Prindle, Shipley and Elliott, 2006, *Energy Efficiency's Role in a Carbon Cap-and-Trade System: Modeling Results from the Regional Greenhouse Gas Initiative.* Washington, DC: American Council for an Energy-Efficient Economy.

[19] Gallop, 2005, "Gallop Poll Social Series—The Environment." Princeton, N.J.: The Gallop Organization.

[20] Moore, David, 2001, "Energy Crisis: Americans Lean toward Conservation over Production." Princeton, N.J.: The Gallup Organization.

[21] Nadel, Prindle and Brooks, 2006, "The Energy Policy Act of 2005: Energy Efficiency Provisions and Implications for Future Policy Efforts" in *Proceedings of the 2006 ACEEE Summer Study on Energy-Efficiency in Buildings.* Washington, DC: American Council for an Energy-Efficient Economy.

[22] Nadel, Steven. 2006. *Energy Efficiency and Resource Standards: Experience and Recommendations.* American Council for an Energy-Efficient Economy, Report No. E063.

Senator KERRY. Thank you very much.

Dr. Preli?

STATEMENT OF DR. FRANK PRELI, VICE PRESIDENT OF ENGINEERING, UTC POWER

Dr. PRELI. Thank you very much. I'm Frank Preli, Vice President of Engineering for UTC Power.

UTC Power is a business unit of United Technologies Corporation. It's a world leader in commercial stationary fuel-cell development and deployment, but we also develop other innovative products. And, at the Committee's request today, I will focus my remarks on our PureCycle® geothermal system.

This is an innovative, low-temperature geothermal energy system being used for the first time for power production in the State of Alaska. It operates at 165° F, which is the lowest-temperature geothermal resource ever used for commercial power production.

Our Nation's faced with air-quality and global climate-change challenges, ever increasing fuel costs, and a desire to be less dependent on unstable and foreign energy sources. Geothermal energy offers a renewable, continuously available, largely untapped domestic resource. Although the U.S. leads the world with 2800 megawatts of geothermal energy production, this represents only .5 percent of the current U.S. demand for electricity. It's estimated that, with effective Federal and State support, as much as 20 percent of the U.S. power needs could be met by geothermal energy by 2030.

The PureCycle® system is based on a closed-loop process that uses geothermal water to generate 225 kilowatts of electrical power. Think of an air conditioner that uses electricity to generate cooling. The PureCycle® geothermal system reverses this process and uses heat to produce electricity. The system is simply driven by an evaporation process. It's entirely enclosed, so there are no emissions produced. The only byproduct is the electricity. And the fuel, hot water, is a renewable resource.

Thanks to a partnership between UTC Power, Chena Hot Springs Resort, the U.S. Department of Energy, and various Alaska authorities, Alaska was added, last year, to the list of States generating electricity from geothermal energy. The power system uses geothermal water at 165° F. And this is actually a very exciting breakthrough, because previously it was assumed that the geothermal fluids needed to be at least 225° F for economic power production, and this has a big impact on how much of the United States is now available, or will be available, for geothermal power production.

The Chena Hot Springs Resort is owned by Bernie and Connie Karl, a visionary couple who are committed to a sustainable community that is entirely self-sufficient for energy, for food, and for fuel. The resort operates independent of the grid and pays 30 cents per kilowatt hour for electricity, and, with the new geothermal system, they're saving $1,000 per day and eliminating the need for diesel fuel for their power source. This eliminates harmful emissions and also eliminates the need for the logistical transport of fuels over the rough terrain. They have two PureCycle® systems operating today, and they've logged 5,400 hours, and the availability is over 92 percent.

This project won two awards last year, a U.S. Environmental Protection Agency and a Department of Energy 2006 National Green Power Award for Onsite Generation, and also *Power Engineering* magazine named it "The Renewable Sustainable Energy Project of the Year."

So, simply put, the PureCycle® technology could result in significant new domestic and continuously available renewable energy resources, not in just Alaska, but across the country. For example, there are more than 500,000 oil and gas wells in the U.S., many of which are unprofitable. Geothermal hot water is abundant at many oil and gas well sites, and could be used to produce a renewable source of electrical power and extend the life of many of these assets.

But it's unfortunate that the Federal Government is proposing to eliminate all R&D funding for geothermal at a time when there are exciting innovative developments emerging. The rationale given is that the technology is mature and represents a resource with limited value, since it's confined only to the Western States. But, as our Chena project demonstrates, low-temperature geothermal energy production is a developing technology that enables a much broader geographic reach. This can eventually satisfy a significant portion of our growing energy needs, but appropriate government policies must be adopted and implemented.

Attached to my testimony is a position paper that outlines key industry recommendations, including extension of the geothermal production incentive, robust funding for DOE's geothermal research program, incentives for geothermal exploration, and a comprehensive nationwide geothermal resource assessment. With your help, we can translate the potential of geothermal energy into a reality.

So, thank you for this opportunity to testify, and I'd be pleased to answer any questions.

Thank you.

[The prepared statement of Dr. Preli follows:]

PREPARED STATEMENT OF DR. FRANK PRELI, VICE PRESIDENT OF ENGINEERING, UTC POWER

Good afternoon. I am Frank Preli, Vice President of Engineering for UTC Power. I joined United Technologies Corporation in 1978 and have been with UTC Power since 1998. I am responsible for leading a group of approximately 250 engineers and scientists engaged in research and product development for UTC Power. Our work includes development of Proton Exchange Membrane (PEM), Phosphoric Acid (PAFC) and Solid Oxide (SOFC) fuel cell technology to serve commercial and transportation markets. We also develop integrated combined cooling, heating and power systems and organic Rankine cycle-based heat recovery systems for geothermal and waste heat applications.

Company Background

UTC Power, a business unit of United Technologies Corporation, is a world leader in commercial stationary fuel cell development and deployment. UTC Power also develops other innovative power systems for the distributed energy market. At the Committee's request, I will focus my remarks today on the latest addition to our portfolio of clean, efficient, reliable technology solutions—namely, the PureCycle® power system. This is an innovative low-temperature geothermal energy system that represents the first use of geothermal energy for power production in the state of Alaska and the lowest temperature geothermal resource ever used for commercial power production in the world. The technology currently is being demonstrated at the Chena Hot Springs resort 60 miles from Fairbanks, Alaska and 35 miles off the power grid.

Summary

Geothermal energy addresses many of our national concerns, but its potential is largely untapped. UTC Power's PureCycle® system represents an innovative advancement in geothermal energy production and is operating successfully today in Alaska as part of a demonstration effort. This geothermal energy breakthrough offers the possibility of tapping into significant U.S. geothermal reserves for a domestic, renewable, continuously available source of power to meet our growing energy demands. Congressional action is needed, however, if the U.S. is to translate this potential into reality.

Geothermal Energy Addresses Many National Concerns, But Huge Potential is Largely Untapped

Our Nation is faced with air quality and global climate change challenges, ever-increasing fuel costs and a desire to be less dependent on energy sources from politically unstable areas of the world. The United States is blessed with an abundance of geothermal energy resources that offer a renewable, continuously available, largely untapped domestic resource. The country generates 2,800 MWe of geothermal energy for power production in California, Nevada, Utah and Hawaii and another 2,400 MWe is under development. While estimates vary, the Geothermal Energy Association indicates that with effective Federal and state support, as much as 20 percent of U.S. power needs could be met by geothermal energy sources by 2030. The National Renewable Energy Laboratory's report "Geothermal: The Energy Under Our Feet" concludes: "Domestic resources are equivalent to a 30,000-year energy supply at our current rate for the United States." The study also notes: "New low-temperature electric generation technology may greatly expand the geothermal resources that can be developed economically today."

Chena Hot Springs Resort Puts Geothermal on the Map in Alaska

Thanks to a partnership between UTC Power, Chena Hot Springs Resort, the U.S. Department of Energy, Alaska Energy Authority, Alaska Industrial Development and Export Authority and the Denali Commission, Alaska was added last year to the list of states using geothermal resources for power production. The system operates on 165° F (74° C) geothermal water and by varying the refrigerant can use hydro thermal resources up to 300° F (149° C). This is an exciting breakthrough since previously experts had assumed that geothermal fluids needed to be at least 225° F (107° C) for economic power generation. It is also significant since a large portion of the estimated known U.S. geothermal resources are expected to be in the low to moderate temperature range, including a large number of deposits associated with oil and gas wells that are currently not economically viable and therefore non-productive.

Alaska has some of the highest energy costs in the country for electric grid connected power and even higher costs for those off the grid. The Chena Hot Springs Resort, which operates independent of the grid, pays 30 cents per kilowatt hour (kWh) for electricity. When fully optimized and fully implemented, we expect the UTC Power PureCycle® system can reduce this cost to 5–7 cents per kWh, thus saving the owners $1,000 per day in fuel costs and eliminating the need for diesel fuel-burning generators and their harmful emissions.

The system was commissioned in August 2006 and provides power for the resort's on-site electrical needs. Two PureCycle® 225 kW units are operational at Chena today and together have logged 5,400 hours of experience with 100 percent reliability after the initial 500-hour commissioning shakedown and greater than 99.2 percent reliability overall.

The visionary owners of the resort, Bernie and Connie Karl, are committed to a sustainable community that is entirely self-sufficient in terms of energy, food and fuel. Their dedication is evidenced by on-site renewable power sources that secure their energy independence while benefiting the environment.

We are working closely with Alaskan authorities regarding further development of and enhancements to this technology. There is significant potential to deploy PureCycle® systems at Alaska's more than 200 rural villages that currently depend on diesel generators with fuel being shipped by air or water. This results in high costs, logistics issues and dirty, loud power generation that is inconsistent with native cultural values.

Description of PureCycle technology

The PureCycle® system is the product of a UTC brainstorming session in 2000 focused on opportunities for organic growth. It is based on organic Rankine cycle (ORC) technology—a closed loop process that in this case uses geothermal water to generate 225 kW of electrical power. Think of an air conditioner that uses electricity to generate cooling. The PureCycle® system reverses this process and uses heat to produce electricity. The system is driven by a simple evaporation process and is entirely enclosed, which means it produces no emissions. The only byproduct is electricity, and the fuel—hot water—is a free renewable resource. In fact, after the heat is extracted for power, the water is returned to the earth for reheating, resulting in the ultimate recycling loop.

Innovative Features and Awards

The PureCycle® system reflects a number of key innovations and breakthroughs. As mentioned previously, the Chena project is the world's lowest temperature geothermal resource being used for commercial power production and represents the first time geothermal energy has been used to produce electricity in Alaska.

On the technical side, the PureCycle® system capitalizes on an advanced aero dynamic design that results in 85 percent efficiency from a radial inflow turbine derived from a Carrier Corp. compressor. Carrier Corp. is a sister UTC company and a world leader in air conditioning and refrigeration technology. The geothermal system is also unique in its ability to match the turbine design to working fluid properties, thus allowing the equipment to operate on a range of low to moderate temperature energy resources and enhancing its flexibility to meet customer requirements.

While the PureCycle® system and its application to the geothermal energy market are new, the product draws upon decades of UTC innovation, operating experience and real-world expertise. Key components of the system are derived from Carrier Corp. and 90 percent of the PureCycle system is based on UTC high-volume, off-the-shelf components that enhance the value proposition to our customers.

The Chena project has attracted world-wide attention and won two awards last year—a U.S. Environmental Protection Agency and Department of Energy 2006 National Green Power Award for on-site generation and Power Engineering magazine named it Renewable/Sustainable Energy Project of the Year.

What Is the Significance of Low Temperature Geothermal Energy?

Previously, geothermal energy for power production has been concentrated in only four Western U.S. states. The ability to use small power units at lower temperature geothermal resources will make distributed generation much more viable in many different regions of the country. Simply put, PureCycle® technology could result in significant new domestic, continuously available renewable energy resources—not just in Alaska, but across the country. The capability to operate with a low temperature resource allows the UTC PureCycle® System to utilize existing lower temperature wells and to bottom higher temperature geothermal flash plants and many existing ORC binary power plants.

In addition, there are more than 500,000 oil and gas wells in the US, many of which are unprofitable. The use of geothermal hot water, which is abundant at many oil and gas well sites, to produce a renewable source of electrical power could extend the life of many of these assets. This would result in significant environmental, energy efficiency, climate change, economic and other benefits associated with the development of geothermal oil and gas electrical power.

Recommended Actions

It is unfortunate that at this moment in time when there are exciting innovative developments in the world of geothermal technology, the Federal Government is cutting off research and development funding. The rationale given is that the technology is mature and represents a resource with limited value since it is confined to only a few Western states.

My message to you today is that we have only scratched the surface regarding our Nation's geothermal energy potential. We have not exhausted the R&D possibilities and this is not a resource that is limited to only a few Western states. As I've indicated in my testimony, there are advances in low-temperature geothermal energy alone that prove otherwise.

The National Research Council report "Renewable Power Pathways" recognized the importance of geothermal energy and stated: "In light of the significant advantages of geothermal energy as a resource for power generation, it may be undervalued in DOE's renewable energy portfolio."

My testimony has focused on only one element of the geothermal opportunity—low-temperature resources. There are a variety of other research needs, including cost-shared partnerships to enhance the performance of existing successful systems, increase the size of the units and demonstrate benefits for the oil and gas market. We also need continued Federal funding for public/private partnerships for exploration, resource identification and drilling. We need more up-to-date survey information. The most recent U.S. Geological Survey for geothermal energy was conducted in 1979. This survey used techniques that are outdated today and was based on technology available 30 years ago. It did not consider low to moderate temperature resources since there was no technology available at the time that could utilize these resources in a cost-effective manner.

As our Chena project demonstrates, far from being a mature technology with limited geographic reach, geothermal energy has the potential to satisfy a significant portion of our growing energy needs with a renewable, continuously available domestic resource. But appropriate government policies must be adopted and implemented to make this a reality. Congress can help to ensure we realize the full potential of geothermal energy. Attached to my testimony is a position paper by the Geothermal Energy Association* that outlines key industry recommendations and action items including:

- Extension of the geothermal production tax credit and revised "placed in service" rules.
- Robust funding for DOE's Geothermal Research Program.
- Incentives for geothermal exploration.
- Comprehensive nationwide geothermal resources assessment.

Thank you for the opportunity to testify and I would be pleased to answer your questions.

ATTACHMENT—ACHIEVING A 20 PERCENT NATIONAL GEOTHERMAL GOAL

The United States, as the world's largest producer of geothermal electricity, generates an average of 16 billion kilowatt hours of energy per year. While substantial, U.S. geothermal power is still only a fraction of the known potential. Today, roughly sixty new geothermal energy projects are under development in over a dozen states that will double current geothermal power production. With effective Federal and

* The information referred to has been retained in Committee files.

state support, recent reports indicate that as much as 20 percent of U.S. power needs could be met by geothermal energy sources by 2030.

To achieve this, the Administration and Congress should adopt the following *National Geothermal Goals* for Federal agencies: Characterize the entire hydrothermal resource base by 2010; sustain double digit annual growth in geothermal power, direct use and heat pump applications; demonstrate state-of-the-art energy production from the full range of geothermal resources; achieve new power or commercial heat production in at least 25 states; and, develop the tools and techniques to build an engineered geothermal system (EGS) power plant by 2015.

To support these goals and accelerate the production and development of energy from our geothermal resources, the following priority actions are needed:

Revise the Section 45 Production Tax Credit (PTC) to support sustained geothermal power development. The PTC timeframe is too short for most geothermal projects to be completed by the current placed in service deadline. To achieve sustained geothermal development, Congress should immediately amend the law to allow facilities under construction by the placed in service date of the law to qualify, and extend the placed in service deadline by at least 5 years, to January 1, 2014, before its expiration.

Fund a strong and effective DOE Geothermal Research Program that prioritizes the discovery and definition of geothermal resources; expands GRED funding; develops new exploration technologies; supports state-based programs to expand knowledge of the resource base and its potential applications; improves drilling technology; demonstrates geothermal applications in presently non-commercial settings; and develops and demonstrates of Enhanced Geothermal Systems techniques. DOE's geothermal program should be expanded to meet today's challenges and funded at $75 million annually.

Provide incentives for geothermal exploration through renewed DOE cost-shared funding and other measures. Ninety percent of geothermal resources are hidden, having no surface manifestations. Exploration is therefore essential to expand production, but exploration is expensive and risky. Cost-shared support for exploration drilling has been provided through DOE's Geothermal Resource Exploration and Definition (GRED) program. GRED should be continued and expanded, with at least one-half of DOE's effort supporting exploration, and an exploration tax credit should be established.

Expand and accelerate geothermal initiatives on the public lands. USGS should conduct a comprehensive nationwide geothermal resource assessment that examines the full range of geothermal resources and technologies; USGS should collect and make available to the public geologic and geophysical data to support exploration activities; BLM's Programmatic Environmental Impact Statement (PEIS) should be completed as a top priority; planning, leasing and permitting activities on BLM and National Forest lands should be adequately funded and conducted promptly. Appropriations (and dedicated funding) of $25 million annually should be provided for these agency efforts.

Senator KERRY. Thank you very much, Dr. Preli, very interesting.

Mr. Eckhart?

STATEMENT OF MICHAEL T. ECKHART, PRESIDENT, AMERICAN COUNCIL ON RENEWABLE ENERGY (ACORE)

Mr. ECKHART. Good afternoon, Chairman Kerry and Ranking Member Ensign. It's an honor to be here.

My name is Mike Eckhart, I'm President of the American Council on Renewable Energy, ACORE. We're a 501(c)(3) nonprofit based here in Washington, founded just 5 years ago to bring all the renewable energy industries together in one tent. We have 400 members now, gaining about one per day, growing rapidly, including companies, utilities, banks, law firms, financiers; even government agencies—DOE, EPA—are dues-paying members of our group.

Our mission is to bring all these organizations together on behalf of renewable energy, as a whole. Our focus is to bring renewable energy into the mainstream, which is the reverse of trying to bring the mainstream to renewable energy. As the founding philosophy, we're for renewable energy and against nothing. We're just for renewable energy.

We were honored, at our most recent national policy conference, held in the Cannon Caucus Room, to have 18 of the agencies, nonprofits, and trade associations all give their outlook on renewable energy. And I have that for you in this book, which was just published, and you can review each of the positions briefly in 2-page summaries.

I'll summarize the entire thing, including a consensus outlook we've gone on to do.

In wind power, the American Wind Energy Association concludes that it's feasible and affordable to run wind power up to 20 percent of our national electricity supply. But we need, and deserve to have, more stable—and I know you already know this—long-term commitment of public policy to build toward that potential and to create a successful wind power industry. And this is the point I wish to make today. The fact is that nine out of ten of the world's largest wind turbine manufacturers are non–U.S. companies. Non–U.S. companies. And all of them are building wind turbine manufacturing plants in China this year, not in the U.S. This is a direct result of the instability and uncertainty in the U.S. wind power market that is due to the 2-year sunset provision in the production tax credit, turning the market on and off. The PTC should have a 5-year rolling commitment, looking forward, so industry knows that—what the public policies are for its long-term investments.

In solar energy, it's somewhat similar. We see booming markets in Japan, Germany, Spain, and other countries. We need a booming market here. It can happen, and we can stabilize—if we can stabilize the investment tax credit to a longer-standing commitment. The solar energy industry's association believes there are over 100 gigawatts of solar power capacity that can be online by 2016, and as much as 150 gigawatts by 2025, with the stabilization of policy. And, here again, we have to look at jobs. Public policy must be stable to create an industry. We need to think about these jobs. In the ten of the ten largest solar cell manufacturers in the world, all ten are non–U.S. companies, and we need to recognize the state of the industry and bring it back to the U.S. We've lost our lead. We invented this technology, but we don't lead this as a manufacturing industry, and we need to bring it back here through stable, firm policies.

In geothermal—and I'm sure Mr. Preli will enjoy my comments here—it is my opinion that geothermal energy is the huge missed opportunity in renewable energy. I believe it is perhaps the greatest engineering challenge ever faced by mankind, greater than going to the Moon, to reach down into the center of the Earth and bring up that heat so that we can replace all the coal-fired powerplants that simply boil water, which we can do with geothermal heat. We can replace this, and we can run the world economy on geothermal energy plus solar energy.

In biofuels, we have the immediate opportunity, and we are acting well. We look at this and see the feasibility of getting to 30 percent of our motor fuel supply by biofuels. The combination of corn-based ethanol, cellulosic ethanol, and biodiesel offers us a path to reducing these oil imports and creating an industry here in rural America.

Looking ahead, we see that renewable energy can be 20 percent of our energy supply in 2020, 25 percent in 2025, and 30 percent in 2030. This can be—we can supply the incremental gain in energy requirements of the U.S. through renewable energy and begin to address climate change in a meaningful way.

What we offer is a recommendation on the kinds of public policy we need to make this happen.

We need resolve. We should act with decisiveness in favor of renewable energy, and not try to just produce more of any form of energy. We must make a choice.

We must be comprehensive, in that the national strategy must accommodate the differences, not the similarities—the regional differences in renewable energy resources, economics, and culture.

We must address the competitiveness of this situation, as I mentioned, with the companies and the jobs. We must get the jobs that go along with renewable energy.

We have to base it on technology. Our recommendation is to increase the RD&D budget tenfold—not 10 percent, but tenfold—including geothermal, at $100 million a year—$100 billion a year or more, in geothermal alone, to achieve its potential.

And, last, we need stability. And we've said this, and I know it's been repeated here on the Hill many times in the past month. But it is true. Stability of policy is what Wall Street needs to make the long-term commitments to build this market and this industry.

These guiding principles will lead us, and the country, to success. I thank the Senate for the honor and privilege of testifying here today.

Thank you very much.

[The prepared statement of Mr. Eckhart follows:]

PREPARED STATEMENT OF MICHAEL T. ECKHART, PRESIDENT, AMERICAN COUNCIL ON RENEWABLE ENERGY (ACORE)

This is the testimony of Michael Thomas Eckhart, President of the American Council On Renewable Energy (ACORE), a 501(c)(3) nonprofit organization founded in 2001 and based in Washington, D.C.

Introduction to ACORE

ACORE has grown rapidly and presently has over 400 organizational members including technology suppliers; energy marketing companies; utility companies; end users, colleges and universities; law firms, consulting firms and other professional services firms; financial firms such as investors, lenders, and insurance; nonprofit groups and environmental organizations; trade associations (including all of the national trade associations in renewable energy); and government agencies at the Federal, state and local levels.

ACORE's mission is to bring together all of the organizations necessary to make renewable energy successful in our country. Our focus is to bring renewable energy into the mainstream of our American economy and lifestyle. As a founding philosophy that distinguishes ACORE, we are "for renewable energy" without being against anything.

ACORE convenes the renewable energy community in three major conferences each year—a trade show in Las Vegas, a high-level finance conference in New York City, and a national policy forum here in Washington, D.C.

In the most recent national policy conference on November 30, 2006, entitled "Phase II of Renewable Energy in America: Market Forecasts and Policy Requirements" we were honored to have 18 major agencies, associations, and nonprofit organizations give their outlook on renewable energy in America, now published in a report of the same title, which I enter into the record. The organizations included the following:

Nonprofit and Academic Institutions:

- American Council on Renewable Energy
- American Solar Energy Society
- Apollo Alliance
- Energy Future Coalition
- The Renewable and Appropriate Energy Laboratory, University of California at Berkeley
- Worldwatch Institute

Trade Associations:

- American Wind Energy Association
- Biomass Coordinating Council
- Geothermal Energy Association
- National Hydropower Association
- National Biodiesel Board
- Ocean Energy Council
- Renewable Fuels Association
- Solar Energy Industries Association
- U.S. Combined Heat & Power Association

Government Agencies and Research Institutes:

- U.S. Department of Energy
- Electric Power Research Institute
- Energy Information Administration
- National Renewable Energy Laboratory
- Western Governors' Association

ACORE then asked the participating organizations to form a working group, to develop a consensus outlook. This work was conducted from mid-December to mid-February 2007, and is currently being published.

ACORE is pleased to present the text of the to-be-published *2007 Consensus Outlook on Renewable Energy in America* as part of my testimony today, in the following sections. The non-profit organizations, academic organizations, and trade associations endorse this consensus outlook—this is the first time in the industry's 30-year history that a consensus has been reached. The government agencies and research institutes acknowledge that their outlooks were included but of necessity cannot and do not endorse the report.

Meeting America's Energy Needs

Renewable energy could contribute dramatically to meeting America's energy needs, providing up to 550 gigawatts (GW) of new electricity generating capacity by 2025. That amount is equal to roughly half of total U.S. generating capacity today, and—according to projections from the U.S. Energy Information Administration (EIA)—represents substantially more than the additional electric power generating capacity needed by 2025. Moreover, with only a 3 percent share of the U.S. transportation fuels market, there is room for the biofuels industry to grow significantly. The Department of Energy's Advanced Energy Initiative calls for replacing 30 percent of our current gasoline consumption with biofuels by 2030.

Renewable energy can meet the immediate needs of the U.S. while helping us achieve our economic, security, and environmental goals. America needs to scale up renewable energy use now for the following reasons.

- *America needs secure energy supplies.* The U.S. imports almost 60 percent of its oil and is faced with an aging electric grid dependent on centralized power production. In addition, EIA predicts that imports of liquefied natural gas will increase seven-fold over 2005 levels by 2030. Renewable energy sources are domestic resources, and can include distributed and smaller-scale generation, providing significant security advantages for the entire portfolio of power and fuel supply.
- *America needs to address climate change.* Scientists have shown the connection between climate change and extreme weather patterns, species extinction,

desertification, and ecological damage. They are warning us that the time to act is now. Along with energy efficiency, renewable energy can be one of the major solutions to climate change, and can begin to make a difference immediately.

- *America needs a cleaner environment.* Renewable energy will allow the U.S. economy to continue growing while meeting environmental caps and other standards. More renewable energy will mean less pollution, improved public health, protected natural systems, and lower consumption of scarce water resources than the conventional energy path.
- *America needs large-scale, economic energy supplies.* Renewable energy can make a substantial contribution, supplying on the order of 25 percent of our energy needs by 2025, given the right policies and conditions.
- *America needs energy at predictable costs.* Volatility in oil and natural gas markets creates disruptions to the economy. Renewable energy can offer long-term, fixed price supplies and the certainty of future costs.
- *America needs to grow industry and create jobs.* Pursuing a renewable energy strategy could create $700 billion of economic activity and 5 million jobs by 2025—good jobs in the high-tech, engineering, construction, installation, agricultural and service sectors that can boost economies in both rural and manufacturing areas.[1] The world market is also hungry for clean energy technologies. The U.S. should take advantage of the opportunity to develop new export potential while building the 21st Century's sustainable economy.
- *America needs to be competitive in the global marketplace.* The U.S. has some of the largest renewable resources of any country in the world. Many renewable technologies were developed in the U.S., but lost essential support. Now, our inconsistent policies threaten to sacrifice tremendous opportunities for economic development and export. If America wishes to lead in the development of today's most promising energy sources, our country must provide the essential policy environment for private sector investment and growth of renewable energy in our domestic market.

How Renewable Energy Can Meet America's Needs

To meet America's energy needs we must consider how energy is consumed in our economy. There are four broad energy-use sectors: industrial, commercial, residential, and transportation. The major applications are electricity production, heating, and transportation fuels. Here is how renewable energy serves these needs.

- *An energy source for America's electric utilities*—The estimates presented in this report suggest a potential for more than 550 GW of new renewable electricity generation capacity by the year 2025, which is substantially more than the new capacity needed by that date. This capacity will come from all of the renewable technologies: wind, geothermal, solar, water, and biomass power.
- *Distributed applications*—Increasingly, end users of all kinds are generating their own electricity and managing their thermal energy uses with an eye toward greater energy efficiency. Many methods—such as Industrial Efficiency, Green Buildings, Climate-Neutral Campuses, and Zero-Energy Homes—include a combination of efficiency and renewable energy. Examples of distributed applications of renewable energy include: building-mounted solar PV; solar heating and cooling; geothermal energy used in a home or greenhouse; biomass or wind energy on a ranch or farm; combined heat and power at an industrial facility using biomass fuels; and recycled energy at power generationsites.
- *Transportation fuels*—Analyses conducted for the Energy Future Coalition have supported the feasibility of having biofuels supply 25 percent of our transportation energy needs by 2025. The package of available transportation fuels includes ethanol, biobutanol, biodiesel, bio-based diesel fuels, and a variety of other bio-based transportation fuels. These fuels can be used to power aircraft and watercraft as well as trucks and automobiles.
- *Production of electricity and hydrogen for transportation*—In addition to biofuels, there is substantial potential for renewable energy sources to meet transportation needs through hydrogen production and adoption of transportation technologies using renewable electricity, such as plug-in hybrids, electric vehicles, and mass transit.

[1] English *et al.* (2006). *25 percent Renewable Energy for the United States by 2025: Agricultural and Economic Impacts.* University of Tennessee at Knoxville. Available at: *http://www.agpolicy.org/ppap/REPORT percent2025x25.pdf*

Public Policy to Meet America's Needs

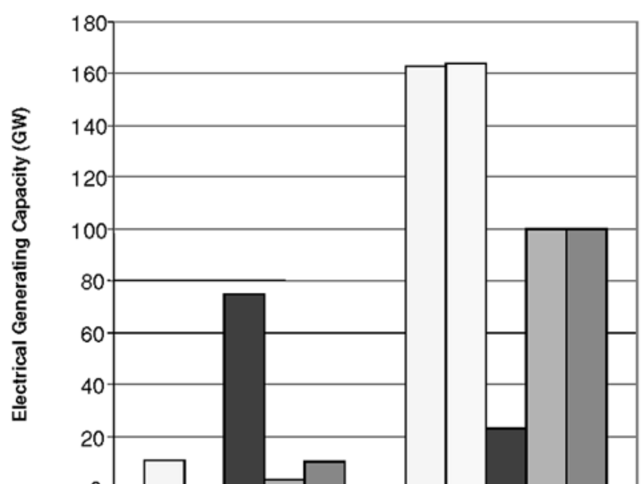
America needs coordinated, sustained Federal and state policies that expand renewable energy markets, promote and deploy new technology, and appropriately provide opportunities to encourage renewable energy use in each of the market sectors and applications mentioned above. Other countries, such as Germany, Spain, and Japan, have succeeded in building successful renewable energy industries by directing their incentive programs to the end-use markets while continuing support for research and development of new and improved technologies. The U.S. can do the same, if we establish similar long-term, market-oriented policies to "pull through" the new technologies.

Outlook on Each Renewable Energy Technology

During the successful "Phase I" period of renewable energy development that occurred from about 1975 to 2000, the focus was solely on research, development and demonstration (RD&D) of the many new technologies. Now, as the U.S. shifts into Phase II strategies for putting the technologies into use at scale, we face new challenges. Research and demonstration should be expanded, but at the same time, there is an increasing need to focus on deployment and market incentives. Expanding renewable energy will require support for the full range of renewable technologies, recognizing their many differences as well as their common foundation as sustainable technologies.

Up to 550 GW of new renewable power capacity could be available by 2025, assuming development of biomass, geothermal, hydro, solar, and wind projects as envisioned by the industry groups that participated in ACORE's National Policy Conference "Renewable Energy in America: Phase II Market Forecasts and Policy Requirements" in November 2006. (See Figure 1, below.)

Figure 1
New Renewable Power Capacity (2006-2025)



	Current (2006)	New Renewable Capacity (by 2025)
Wind	10.5	163
Solar	0.52	164
Hydro	75.0	23
Geothermal	3.1	100
Biomass	10.0	100

The following offers a summary outlook on each key renewable energy technology.

Wind Power

Wind power is providing increasing capacity to electricity markets around the world. The American Wind Energy Association (AWEA) concludes that it is feasible and affordable to increase wind capacity to supply 20 percent of this Nation's electricity by 2030. AWEA envisions that active "community wind" projects as well as small distributed wind applications will supplement large utility-scale projects. Offshore wind is expected to begin as early as 2010, and to increase thereafter.

This outlook foresees 340 GW of new wind capacity by 2030. Using an average growth rate, this would result in 163 GW of new wind capacity by the year 2025.[2]

Achieving this level of wind power will require new transmission capacity to transmit power from areas with wind resources to regional power markets where the demand exists. Continued research and development also will be needed to achieve improved efficiencies and economies of scale in wind turbine technology to serve lower-wind regions and offshore locations.

Solar Heat and Power

Solar energy is an abundant renewable resource across America, and can become a significant source of new generating capacity in a relatively short timeframe. The rapid scale-up of solar energy markets has been demonstrated in Japan, Germany, Spain, and other countries.

The outlook for solar energy in the U.S. envisions 110 GW of new solar power capacity by 2016, resulting from a 67 percent compound annual growth rate. After a rapid growth through 2015, the solar market is foreseen to stabilize with 5 GW of photovoltaic (PV) and 1 GW of concentrating solar power (CSP) added annually from 2016–2025, resulting in total solar capacity additions of 164 GW in 2025.[3]

The Solar Energy Industries Association (SEIA) envisions this scenario based on robust growth in PV installations on residential rooftops and other locations as well as larger, utility-scale CSP plants. Furthermore, solar water heating is expected to take off as it has in other countries that have embraced renewable energy.

This robust scenario requires a long-term incentive plan to encourage manufacturing and power plant development, financing, and increased industry growth. Additionally, this scenario requires that units can be interconnected as installed without additional utility or permitting costs, that net metering applies nationwide at retail rates, and that continued cost reductions be realized through continued manufacturing scale-up and economies of scale.

Continued research and development will be required to maintain the pace of achievements in improved conversion efficiencies, focusing both on current processes and manufacturing methods as well as developing nano-structured materials for the next generation of PV technology. For CSP, new transmission capacity will be required to transmit power from areas with rich solar resources to regional power markets where the demand exists. Policies that offer rewards or incentives for the adoption of technologies like solar water and space heating are also needed.

Water Power

The water power technologies expected to contribute to this outlook are conventional hydropower, hydrokinetic power, and ocean energy which includes wave, current, tidal, marine biomass, and Ocean Thermal Energy Conversion (OTEC) power.

Conventional hydropower is already the leading source of renewable electric power capacity at over 75 percent of all renewable energy sites. Its quick, reliable load-following capability and seasonal capacity can enhance the performance of other renewables by balancing variability in resources. In addition, the potential for power generation from ocean currents and tidal flow is tremendous. Plus, the new field of hydrokinetic power offers a wide range of distributed power generation options. Utilizing all the water power technologies, there is the potential to add 23 GW of capacity by 2025.[4]

There are still other areas of growth that have yet to be assessed, such as additions of capacity on man-made waterways (*e.g.,* conduit power). Advanced research, development, and demonstration are necessary to support this growth for both improvements of conventional systems and development of new technologies. Incentives for commercialization will be needed for early hydrokinetic and ocean power technologies.

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[2] These capacity numbers were estimated using an increasing, then steady installation growth rate.

[3] Solar Industry Outlook, presentation to "Renewable Energy in America: Phase II Market Forecasts and Policy Requirements," November 29–30, 2006. *http://www.acore.org/programs/06policy_presentations.php*

[4] Hydropower Industry Outlook, presentation to "Renewable Energy in America: Phase II Market Forecasts and Policy Requirements," November 29–30, 2006. *http://www.acore.org/programs/06policy_presentations.php*

Geothermal Heat and Power

Geothermal energy is poised to expand rapidly. The Geothermal Energy Association (GEA) cites the 62 new geothermal energy projects in development as evidence of the industry's most dramatic wave of expansion since the 1980s. Geothermal's status as a baseload energy source—one that is available 24 hours a day, 7 days a week—makes it a particularly appealing option for utilities.

Geothermal resources could contribute 100 GW of new capacity by 2025, tapping both identified resources and new discoveries in hydrothermal sites, co-production from oil and gas wells, and deep resources and engineered geothermal systems (EGS). Furthermore, geothermal energy for direct uses and heat pumps could provide significant additional energy not included in this total if policies support their growth.

The outlook for 100 GW of new geothermal capacity by 2025 assumes development of 20 GW from the hydrothermal resource base, development of 70 GW from co-production and geo-pressured resources, and 10 GW of deep geothermal sources and EGS systems.[5]

This scenario requires: long-term extension of the production tax credit; continued prioritization of expedited leasing and permitting decisions; expanded support for exploration and characterization of the resource base; support for development and demonstration of geo-pressured resources and co-production; and, continued development of the full range of geothermal resource and power technologies working toward the development and deployment of engineered geothermal systems.

Biomass and Bio-based Products

According to the U.S. Combined Heat and Power Association (USCHPA), biomass power projects could see a ten-fold increase from the current installed base of 10 GW. This increase would result in 100 GW of new biomass capacity by 2025.[6]

Growth is expected to take place in wholesale power generation as well as distributed production in pulp and paper mills, commercial and industrial facilities, and solid waste conversion to energy. Continued growth in farm, landfill, and wastewater treatment power projects will supplement this growth. A substantial portion of this new capacity would come from combined heat and power applications, where thermal energy that would otherwise be wasted is applied for productive uses, resulting in very high (up to 85 percent) efficiencies.

Due to the localized nature of fuel availability and thermal loads, the majority of new biomass power projects will be at distributed facilities near demand centers. In these applications, local energy resources will be used to fuel local development. Like other load-sited, distributed renewable projects, these biomass applications benefit the grid by alleviating congestion, freeing up capacity, and deferring expensive system upgrades.

Just over one-third of new capacity will require access to the transmission system. New transmission capacity will be required to transmit power from wholesale power generators in areas rich with biomass resources to regional power markets where demand exists.

Research and development will be required to achieve improved biomass conversion technology with lower capital costs, targeting both gasification and pyrolysis approaches.

The demand for biomass created by new biomass power and biofuel production would be many times greater than current levels; it is assumed that sufficient resources will be available to support these demands at economic prices. Recent studies suggest that resources will be sufficient.

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[5] Geothermal——

i. Geothermal Industry Outlook, presentation to "Renewable Energy in America: Phase II Market Forecasts and Policy Requirements," November 29–30, 2006. *http://www.acore.org/programs/06policy_presentations.php*

ii. "Geothermal—the Energy Under Our Feet," Bruce D. Green and R. Gerald Nix, National Renewable Energy Laboratory, November 2006, Technical Report NREL/TP–840–40665.

[6] Biomass——

i. Resource Dynamics Corporation, Opportunity Fuels and Combined Heat and Power: A Market Assessment, August 2006, prepared for U.S. Department of Energy and Oak Ridge National Laboratory.

ii. Larson and Raymond, "Commercializing Black Liquor and Biomass Gasifier/Gas Turbine Technology", TAPPI Journal, 1997.

iii. Biomass R&D Technical Advisory Committee, Vision For Bioenergy and Biobased Products in the United States, March 2006.

iv. Western Governor's Association, Clean and Diversified Energy Initiative, Biomass Task Force Report, January 2006.

v. Energy Information Administration, Form 860 "Annual Electric Generator Report," 2005.

Biofuels

New biomass power and biofuel production will greatly increase demand for biomass resources. However, recent studies by the National Renewable Energy Laboratory, the University of Tennessee, and Oak Ridge National Laboratory indicate that the U.S. agriculture and forestry industries have the potential to produce enough biomass resources to supplant 30 percent–40 percent of current U.S. petroleum products while meeting food, feed, fiber and export needs.

DOE has set a goal of "30 percent by 2030," and will publish a study that will examine market, policy, and technology changes required for the U.S. biofuels market to replace 30 percent of current levels of gasoline consumption by the year 2030.[7] This is an aggressive but achievable goal that will require policy commitment and technology advances. The key components of the biofuels opportunity are ethanol, biodiesel, and bio-based diesel fuels.

- *Ethanol fuel*—The U.S. produced 4.9 billion gallons of ethanol in 2006. Today, 111 ethanol plants in 19 states have the capacity to produce 5.4 billion gallons of ethanol. As of January 2007, an additional 78 plants are under construction, combined with seven expansions, which will increase industry capacity by 6.1 billion gallons. By the first quarter of 2009, the industry's annual production capacity is estimated to reach 11.6 billion gallons per year.

  This rapid growth can continue if the U.S. maintains and extends existing tax incentives for all ethanol blends, expands tax incentives for ethanol refueling infrastructure, and creates new consumer-based tax incentives to encourage flexible fuel vehicles and the purchase of ethanol. Such growth will also require the U.S. to build upon the industry's advancements in technologies to reduce energy consumption, improve biorefinery efficiency, develop new co-products, and—of crucial importance—move toward commercial deployment of cellulosic ethanol.

- *Biodiesel fuels*—The National Biodiesel Board (NBB) reports that U.S. production is on track to increase from 25 million gallons in 2004 to 226 million gallons in 2006. The number of plants has increased from 22 in 2004 to 85 in January 2007, with another 65 under construction. The industry envisions that biodiesel blends will displace 5 percent of the diesel fuel market by 2015.

  Technology is rapidly emerging to produce bio-based diesel fuels from a variety of feedstocks, including woody biomass and municipal and organic wastes. By U.S. law, these fuels are classified separately from biodiesel. Currently, there are no long-range forecasts for these bio-based fuels. However, several might be commercial before the end of 2010.

Bio-based Products

In addition to fuels, bio-based products could include solvents, cleaners, lubricants, greases, panels for cars and trucks, agricultural products, pharmaceuticals, inks and paints. Essentially, almost anything made from petrochemicals can be produced from some form of biomass, displacing usage of some level of petrochemicals.

Renewable Energy Stored in Hydrogen for Transportation

In addition to biofuels, there is substantial potential for renewable energy sources to meet transportation needs. The hundreds of gigawatts of renewable power potentially available could supply electric vehicles or charge the batteries of plug-in hybrids, power electric mass transit systems, and support hydrogen production through electrolysis for use with fuel cells. Together, the potential for renewable power to displace liquid transportation fuels is substantial.

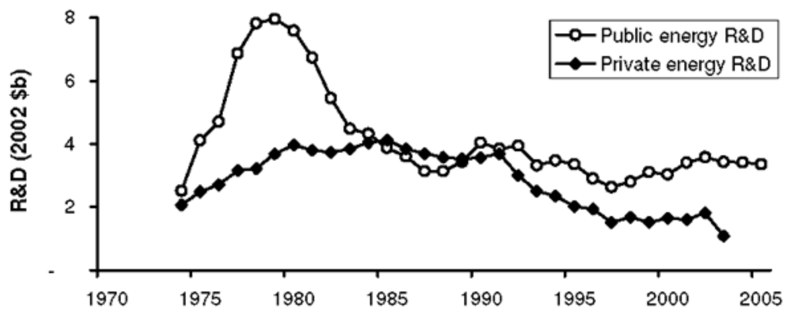
Public Policy for Technology Research, Development, and Commercialization

Why haven't renewable technologies achieved their potential? A fundamental problem with the development and deployment of renewable technologies has been the uncertainty of government policy. Support for both research-push and market-pull policies has been constrained by short-term commitments, which are destabilizing to industrial growth.

If renewable energy is to be developed to its full potential, decades of under-investment in energy research and dissemination must end. Figure 2 shows the continuing reductions in funding that this sector has received.

[7] U.S. DOE is studying the feasibility of a rapid scale-up, and will publish a "30 percent by 2030" study that will examine market, policy, and technology changes required for the U.S. biofuels market to replace 30 percent of current levels of gasoline consumption by the year 2030.

Figure 2
Public and Private Sector Funding for Energy Research and Dissemination in the U. S.



Source: Kammen, D. M. and G. F. Nemet (2005) 'Reversing the incredible shrinking energy budget", *Issues in Science and Technology*, Fall, 84–88.

Renewable Energy Market Outlook and Challenges

The assessments and analyses presented at the Phase II Conference offered valuable information about the outlook for renewable energy in the United States. Together, they form a picture of what a business-as-usual (base case) future might look like if no policy changes are implemented, and of the potential for a more aggressive renewable energy strategy (mid-range and higher potential cases). This section summarizes the range of sensitivity of the renewable energy outlook to public policy.

Business-As-Usual Outlook

The Energy Information Agency (EIA) presented the reference case from the *Annual Energy Outlook 2007,* assuming "all current standards, laws, and regulations remain as currently enacted." Under this scenario, total U.S. primary energy consumption is expected to increase from 100 quadrillion Btu (quads) in 2005 to 131 quads in 2030.

During this period, the share of renewable electricity generation is forecast to remain constant at 9 percent, while coal is expected to increase its share of electric power generation from 50 percent in 2005 to 57 percent in 2030. Ethanol use is expected to increase from 4 billion gallons in 2005 to 14.6 billion gallons in 2030, or about 8 percent of total gasoline consumption by volume—far short of what is needed. Even with currently available renewable energy technologies, this forecast is not consistent with an energy strategy that embraces sustainability, climate stabilization and a healthier environment. This official base case clearly indicates that without substantial change in policy, renewable energy is not expected to significantly increase its share of the U.S. energy market.

Mid-Range Outlook

There have been several "mid-range" conclusions, based on modest changes or extensions of policy and the assumption of conditions that are favorable to renewables.

The Western Governors' Association (WGA) conducted a two-year study of clean energy technologies in the region. WGA concluded that, in just the Western States, renewable energy could contribute upwards of 68,000 MW (68 GW) by 2020. In addition, the Electric Power Research Institute (EPRI) ran an analysis that emphasized the value in a "balanced generation portfolio" and included a CO_2 cost, beginning in 2015. This analysis estimates that electricity from new renewable resources (excluding hydropower) can reach 13 percent of demand by 2030.

The WGA estimate and EPRI "balanced generation portfolio" estimate appear to present a more aggressive strategy than the base case scenarios. However, compared to the assessments of the renewable industry and others, these would have to be considered mid-range potentials.

High Potential Outlook

Together, the renewable power estimates described in Section 3 present a dramatic picture of what would be possible under an aggressive renewable energy scenario. Additional renewable capacity could reach 550 GW by 2025. This is potentially more than the new, additional electric power generating capacity needed by that date according to EIA. Each technology has a different operating characteristic and capacity factor, so GWs do not necessarily add.

EPRI looked at a more aggressive strategy with both high natural gas prices and high CO_2 costs. This case, dubbed the "double whammy," shows further growth of new renewables in the electric supply sector. The results, excluding geothermal and hydropower power, show a renewable contribution to electricity of 16 percent by 2030, and as much as 25 percent by 2050.

The outlook for renewable fuels is equally robust. Biodiesel is growing fast. The National Biodiesel Board (NBB) has estimated that biodiesel could displace 5 percent of petroleum diesel in a near- to mid-term timeframe. The Renewable Fuels Association (RFA) has presented an overall outlook for its sector, noting the dramatic growth in the industry today. This growth is expected to be sustained, with ethanol reaching 14 to 15 billion gallons in the mid-term future. But this is not the full potential of the resource. RFA asserts that 30 percent of motor fuel could come from renewable sources by 2030, which would be 60 billion gallons of annual production. In addition, the advent of plug-in hybrid vehicles and other electricity-based transportation systems and technologies would allow renewable power to contribute to displacing the need for imported oil.

Support from Leading Organizations

A growing trend is emerging in American leadership. Many leading national campaigns and organizations support an aggressive shift to increasing the use of renewable energy. Although the details may vary, the goals are the same: creating jobs and economic growth, improving energy security, cleaning the environment, and stemming global warming. Time after time, when serious, credible experts assess the potential for renewable energy, they reach independent conclusions that are consistent with the transition to greater levels of renewable energy:

- *20% by 2020:* The Union of Concerned Scientists (UCS)' call for a national renewable portfolio standard—resulting in 180,000 MW (180 GW) of renewable power by 2020—shows that natural gas prices would decrease, creating a net benefit to the economy.[8]
- *25% by 2025:* The 25 x '25 Initiative, supported by the Energy Future Coalition (EFC), commissioned a report by the University of Tennessee which shows that 25 percent renewable energy by 2025 is affordable and achievable and will create 3–5 million new jobs and spur $700 billion in economic activity.[9]
- *Over 30 percent by 2030:* For its recently released report, "Tackling Climate Change in the U.S.",[10] the American Solar Energy Society (ASES) asked experts in efficiency and each renewable technology "to come up with their best estimates of what their technology could do [by 2030] . . . with an aggressive climate-driven scenario in mind" (ASES, p.12). Independent assessments of the potential for CSP, PV, wind, biomass, and geothermal technologies came up with a combined contribution to the U.S. electricity grid of 2,208 Terawatt hours/year by 2030, about 40 percent of the EIA's projected demand for electricity under a "business as usual" scenario (*i.e.,* not accounting for energy efficiency improvements). The potential contribution from energy efficiency is even greater.

Many of these campaigns, as well as the Apollo Alliance's outlook for 3 million jobs from clean energy solutions, are also supported by diverse coalitions which include business, labor unions, production agriculture, religious groups, conservation and environmental organizations, public health advocates, and local, state, and nationally elected officials.

Future Success in Each Technology

Achieving the high-potential scenarios will depend on progress made to advance each technology's performance, lower its cost, and overcome challenges of market acceptance at scale. Identifying and overcoming the various obstacles for each tech-

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[8] Statement of Alan Nogee, Director, Union of Concerned Scientists Clean Energy Program, before the U.S. House Committee on Energy and Commerce, Subcommittee on Energy and Air Quality, February 16, 2005. *http://www.ucsusa.org/clean—energy/renewable__energy__basics/renewable-energy-and-electricity-testimony–2005.html*

[9] English *et al.* (2006). *25 percent Renewable Energy for the United States by 2025: Agricultural and Economic Impacts.* University of Tennessee at Knoxville. Available at: *http://www.agpolicy.org/ppap/REPORT percent2025x25.pdf*

[10] *Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030.* Charles F. Kutscher, Editor. American Solar Energy Society, January 2007. 180 pp. Searchable pdf at *www.ases.org/climatechange*.

nology and end use sector should be a priority for Federal and state policies. None of the known impediments to achieving our goals appear insurmountable if there is the political will to support renewable energy. Here are some examples.

- *Wind power*—The challenges include: improved access to transmission; long-term production tax credit (PTC) extension; new state or national renewables portfolio standards (RPS) and effective implementation of existing RPS; continued research support; development of an off-shore regime in supportive manner; continued priority on Federal lands; and recognition of bird/bat mitigation success.
- *Solar energy*—The challenges include: local covenant restrictions; consistent and effective net metering polices at the state and Federal levels; silicon availability and price; new state or national RPS and effective implementation of existing RPS; research and support for reduced balance of systems cost; infrastructure development; competition with foreign markets; inclusion in state and Federal renewable laws; modification of the investment tax credit to remove the cap and extend multiple (8–10) years; and other factors.
- *Water power*—The challenges include: regulatory streamlining and resolving licensing issues for the new technologies (ocean, tidal, and instream power); research and development support for both the next generation of conventional hydropower equipment and the new technologies; long term extension of the Section 45 PTC and inclusion of ocean, tidal and instream projects, equitable treatment in state RPS efforts; and transmission support.
- *Geothermal energy*—The challenges include: long-term PTC extension; new state or national RPS and effective implementation of existing RPS; restoration of DOE Research Program; support for exploratory drilling program and characterization of the U.S. hydrothermal resource base; demonstration of geopressured and oil field co-production; consistent work toward Enhanced Geothermal Systems demonstration; funding and prioritization of public land leasing and permitting; and inclusion in state renewable initiatives.
- *Biomass power*—The challenges include: extension of the biomass PTC, and the inclusion of a thermal credit to promote high efficiency combined heat and power applications; new state or national RPS and effective implementation of existing RPS; access to sustainable supply of feedstock, including from public lands; inclusion in state renewable efforts without excessive restrictions; continued research support; credits for other attributes (pollutant and criteria pollutant reductions, greenhouse gas emissions reductions, and recovered thermal energy) and, in the case of distributed biomass applications, recognition of grid benefits in tariff design and cost allocation; inclusion of landfill gas and appropriate municipal solid waste (MSW) technologies as creditable renewable energy systems; and reasonable interconnection standards.
- *Biofuels*—The challenges include: deploying first-of-a-kind biorefinery technology; increasing cellulosic biofuels research, development, deployment, and commercialization funding; expanding and modernizing fueling infrastructure; and increasing the number of flexible-fuel vehicles on the road.

Market Drivers

It must be recognized that achieving any scenario is subject to significant uncertainties in key market drivers. Important factors include the following.

- Volatility in oil and gas prices
- Pace and scale of action on climate change
- Extent of technology breakthroughs
- Policies/opportunities abroad

This section has presented a sense of the *range* of possible future outcomes for renewable energy in the U.S. Within the context of marketplace uncertainties, the major determinant of future market share for renewable energy is public policy.

EIA's low/base-case scenarios assume no change in policy, and the resulting renewable development is minimal.

- Mid-range scenarios assume a continuation of the positive policies that are in place, plus market conditions favorable to renewables.
- The high-potential scenarios require favorable market conditions and a sustained commitment of public policy to see renewable energy scaled up to higher levels of contribution to U.S. energy supplies.

America's renewable energy industries are ready to take the U.S. in a new direction. Now the right public policies are needed to help chart this route.

Benefits of Renewable Energy for the U.S. and the World

When the high-potential scenarios that are described in Sections 3 and 4 are achieved, resulting benefits to the U.S. and the world will include increased energy supply, improved national security, better health, reduced risk of climate change and environmental impacts, and greater economic prosperity.

- *Energy supply*—The consensus outlook calls for 20 percent of U.S. electric power supply by 2020 based on the UCS proposal for a national RPS, 25 percent of U.S. energy supply by 2025 based on the EFC proposal for energy from rural America, and 30 percent or more of U.S. energy supply by 2030 implied by the ASES assessment of climate change mitigation.
- *National security*—The reduction of imported energy provides a more secure future. We can reduce imported oil from 60 percent today to a much lower level, and preclude the importing of natural gas via liquefied natural gas (LNG). Energy independence has long been a "top priority," but for the past 30 years has proved an elusive goal. If we can tap the potential of our domestic renewable energy resources, we can make real progress toward achieving true energy independence.
- *Environment and health*—A renewable energy future is an environmentally sound future with cleaner air, cleaner and more abundant water, lower chemical contamination, improved human health, and a safer environment for our children and grandchildren. A key benefit that is often overlooked is the fact that renewable energy reduces our consumption of increasingly scarce clean water supplies.
- *Climate change*—As America turns to address global climate change, we find ourselves facing an enormous problem of potentially unprecedented impact. By capturing the potential of renewable energy and improving energy efficiency, we can drastically reduce greenhouse gas emissions and make the U.S. a world leader in mitigating the risks of climate change.
- *Economic prosperity*—Renewable energy is domestic energy and can be deployed using U.S. technology, capital and labor. With biofuels, we support companies and jobs in the Midwest instead of the Middle East. With renewable power, we employ U.S. workers to install U.S. technology and deliver U.S. services. The Apollo Alliance and other organizations estimate that renewable development can result in as many as 3 million U.S. jobs. All renewable energy technologies are "New Wealth Industries" with major economic multipliers, as the technologies are manufactured domestically and their products move to consumers through a variety of processes.

Guiding Principles for Public Policy

The potential for renewable development, according to this consensus outlook, is much greater than previously published. The potential for renewable energy development is enormous, and is ready to be tapped. The sustainable solution is renewable energy and energy efficiency. But we must start now.

What kinds of public policy are needed for renewable energy to thrive? In summary, as a vision of renewable energy in America, the following are principles on which to base public policy.

- *Resolve*—We should act with decisiveness in favor of renewable energy and other energy technologies that support our national goals for security, growth, environment, climate, and jobs.
- *Comprehensiveness*—We need a comprehensive national renewable energy strategy that addresses the full range of technological and market issues, reflects the regional diversity of renewable energy resource economics and opportunities, and helps and rewards state and local governments for bold and effective coordinated action.
- *Competitiveness*—We should continue to utilize the competitive market as the most powerful driver of change, and increase U.S. competitiveness on renewable energy in the global marketplace.
- *Integration*—Our energy policies should address both the challenges of oil dependence and of global warming in an integrated way.
- *Results-oriented*—We need to build the infrastructure of a more sustainable society, including but not limited to:

- ◦ *Electric Power Generation:* We should support long-term incentives and other policies to catalyze investment in new renewable power for all technologies and both central station and distributed generation.
- ◦ *Electric Transmission:* We should build a modernized transmission system, similar to our national highway system, which links our domestic renewable energy sources with the cities and other demand centers.
- ◦ *Electric Distribution:* We should enhance electric distribution systems to allow optimal utilization of on-site distributed renewable technologies at the point of energy use.
- ◦ *Renewable Fuels:* We should support investment both in next-generation biofuels technology and the infrastructure to bring it to market.
- ◦ *Energy Efficiency:* We need to recognize that energy efficiency and renewable energy work together and offer many of the same fundamental benefits—environmental cleanliness, domestic resources, security, and platforms for economic growth—justifying policies that encourage more efficient buildings, industrial processes, and vehicles, as well as power generation using combined heat and power.

- *Technology*—The U.S. needs a tenfold increase in budget for an accelerated national R&D program that balances near-term needs with investments in longer-term research and science that will produce the next generation of technologies, and that returns the U.S. to global leadership on these technologies.
- *Stability*—There is an overarching need for long-term and stable policy commitments that allow industry, the financial sector, and individual Americans to make long-term investments in factories, bio-refineries, renewable power plants, and more efficient buildings and homes. Stability and long-term commitment are the new watchwords for renewable energy policy.

These guiding principles will allow our country to successfully transition toward a scale-up of the use of renewable resources to power and fuel America. This is a bold joint statement on the potential that the U.S. has before it, to seek solutions and make them a reality. It should be now clear that renewable energy has the potential to provide a substantial share of America's energy needs—beginning immediately.

Senator KERRY. We thank you, Mr. Eckhart. Thank you very much.

Dr. Sridhar?

STATEMENT OF K. R. SRIDHAR, PRINCIPAL CO-FOUNDER/CEO, BLOOM ENERGY

Dr. SRIDHAR. Thank you, Chairman Kerry, Ranking Member Ensign, Senator Stevens. It's an honor to have this opportunity to share my views on energy innovations, obviously a topic that I am extremely passionate about.

My name is K. R. Sridhar, and I'm the Principal Co-Founder and CEO of Bloom Energy, a California-based fuel-cell company. As an entrepreneur, I am here to talk to you about the ability of technology innovations to have a disruptive impact on the energy crisis that we are facing. The global energy crisis that we are facing, is also the biggest market opportunity of the century, and disruptive technologies are the ones that are going to help us achieve energy security, reliability, and abundance without compromising either the environment or the pocketbook.

I'm also here to tell you that it's absolutely essential, from a global perspective, that we generate more energy, not less, as we move forward. Why is that important? Because there's a direct correlation between energy consumption and economic growth. There is also a direct correlation between energy consumption and quality of life. This country was founded on the basic principle that every generation will have a better life, moving forward, than the previous generation. We also built our superpower status by exporting technologies that offered a better life for citizens of the world.

Imagine if you had told the Internet pioneers that they had to live with the low-speed dialup modems and could not have had more bandwidth. Do you think we would have had the revolutionary changes we have witnessed over the decade? I think not.

Now I think the time has come for the same thing to happen for energy. We must find and attack the biggest problems, and not shy away from them. For example, most of the media attention is focused on the energy crisis surrounding transportation, but we know that roughly two-thirds of our CO_2 emissions as well as energy consumption—comes from stationary applications. Within the stationary power space, we have focused on conservation and consumption, but transmission and distribution inefficiencies, and the inefficiencies of large-scale powerplants, are things that we have not addressed. And it's also clear, from a report from the Edison Institute, that several hundred billion dollars need to be spent in order to stabilize the grid to make up for the expanding needs we have, as well as to bring it to the reliability that we would be looking for.

So, all these point to a great market opportunity, which is distributed generation. Distributed generation refers to energy generation at the point of use, as an alternative to centralized power generation with transmission and distribution infrastructure.

We have seen distributed technologies revolutionize other fields. If you take computing, mainframe computing, evolved to PDAs, laptops, and computers. What has that done to the whole industry to increase access and to make that a lot more efficient? Look at telecom. The land lines with the centralized infrastructure is giving way to the mobile market. What has that done to telecom? The same thing will happen globally to energy when we go to distributed generation.

Senator KERRY. When go to what?

Dr. SRIDHAR. When we go to distributed generation, being able to generate at the point of use. OK?

And that is the single biggest opportunity, not just in this country for expansion, but in, also, the developing world, where they don't have the capital to put in the infrastructure. They will leapfrog, similar to them leapfrogging from not having phones to having mobile phones.

That brings me to my company, Bloom Energy. Senator Ensign especially asked me to give an update since my last June appearance of what we have done so far.

By leveraging breakthrough innovations in material sciences, we have some of the most efficient energy generators providing significantly reduced operating costs, and dramatically lower greenhouse emission gases. And we do it at the point of use. It is a distributed generation technology of fuel cells.

Our company has been around for just under 5 years, completely venture-backed. And, in this time, we have made tremendous strides using Silicon Valley volume manufacturing knowhow, Silicon Valley's rapid business-building experience, as well as top-notch fuel cell expertise.

Since I last testified, we had our first deployed systems celebrate their one-year anniversary in the field. Those first systems have demonstrated grid caliber reliability and availability. We have demonstrated an ability to run our systems on multiple fuels, including storable fuels for military applications and renewable fuels, like ethanol. It goes to the point that Mr. Eckhart made about how it needs to be regionalized and thought about that way.

And we also have an ability to store large amounts of transmitted electricity locally, and then to be able to use it efficiently when we need to use it. When we go into some of the other technologies, like solar and wind, one of the biggest issues is energy storage.

So, in terms of where we need to go, what are we looking for? We need to cross the proverbial chasm that startups need to cross, of taking a technology that's just been developed and getting it into commercialization.

Here, we would ask for the Government to specifically focus on four things.

The first thing is consume. The U.S. Government is the single largest consumer of energy. Be an early adopter and a leader. Set performance standards. Be technology agnostic. And if any technology meets those performance standards, consume.

Number two, create long-term policy. I think people have talked about it. One plus one plus one in incentives is not equal to three. And we need long-term policy.

Third, Level the playing field for us. I think Senator Ensign mentioned what has happened to the legacy industries, and how much money we are already spending for those legacy industries. We are not asking for a handout, we are asking for a level playing field in the market, fairness.

And, most importantly, be technology agnostic. In your policies sometimes advertently winners and losers are picked. A very good example will be the investment tax credit. In the last energy bill, there was no cap on the investment tax credit for solar, but for fuel cells there was a $1,000 per kW investment cap. It must be the marketplace that picks winners and losers, and not policy.

So, that's our request. Again, we think that this is the greatest opportunity and technology innovations will make great strides.

Thank you.

[The prepared statement of Dr. Sridhar follows:]

PREPARED STATEMENT OF K. R. SRIDHAR, PRINCIPAL CO-FOUNDER/CEO, BLOOM ENERGY

Thank you Chairman Kerry, Ranking Member Ensign, and Members of the Subcommittee for the honor and opportunity to speak with you today and share my views on energy innovations . . . a topic that I am passionate about.

My name is K. R. Sridhar and I am the Principal Co-Founder and CEO of Bloom Energy, a California-based fuel cell company intent on making a revolutionary change in America's energy future.

You have asked me to come before you today and share my thoughts on how technological innovations in the energy industry can help address our global energy crisis and also to provide you an update on the progress Bloom Energy has made since my last testimony before this Committee in June 2006.

I am here to state my view that the global energy crisis is also the biggest market opportunity of this century and that disruptive technological innovations will allow us to achieve energy security, reliability, and abundance without compromising the environment or the pocketbook. I am also here to tell you that it is absolutely essential that we find ways to generate *more* energy not less, as we move forward.

Why? Because there is a direct correlation between energy consumption, economic growth, and quality of life.

This country was founded upon the principle that each generation can have a better life than the generation before it. We built this Nation into a superpower by exporting technologies that offered a better life to all citizens of the world.

Will we now deny the next generation their energy consumption and all of the benefits it brings? Can we deny developing nations like China or India their chance for economic growth and improved quality of life?

Imagine if we had told the Internet pioneers that they had to live with low speed dial-up modems and that they couldn't have more bandwidth. Do you think we would have had the revolutionary changes we've witnessed over the last decade?

We must find a way to consume *all* of the energy we need to fuel economic growth without environmental, or geopolitical consequences and this can only be achieved with disruptive technological innovations.

But the key is for innovation to find and attack the biggest problems and not to mask or shy away from them.

For example . . . most of the media attention surrounding our energy crisis focuses on transportation. Much of the public is convinced that our gas guzzling SUVs are the biggest culprits and that hybrid vehicles and ethanol fuel are all that's required to solve our problems. In fact the reality is that almost two-thirds of our energy consumption and two-thirds of our harmful CO_2 emissions come from *stationary* applications.

Even within the stationary power space, the emphasis tends to be on conservation and consumption, while much of the risk, cost, and waste comes from the aging transmission and distribution infrastructure and the inefficiencies associated with large centralized power plants. According to the Edison Electric Institute, approximately $200 billion will need to be spent in the next 10 years to expand, upgrade, and modernize the antiquated grid transmission and distribution infrastructure just to keep up with demand and prevent significant outages like the northeast blackout of 2003.

All of this makes it clear that one of the greatest areas of opportunity for energy innovation is in distributed generation.

Distributed generation refers to energy generation at the point of consumption. As a clean alternative to central power plants and their transmission lines, on-site generation capabilities improve reliability and quality, conserve capital, and reduce operating costs by eliminating transmission infrastructure.

We've seen distributed technologies revolutionize other industries. Computing evolved from centralized mainframe computers to distributed servers, laptops and PDAs. Telephony evolved from centralized wired-line infrastructure to wireless mobile. It is inevitable for the same thing to happen to energy, but before widespread adoption will occur, distributed generation technologies must first evolve to a point where they are clean, affordable, and dependable.

Which brings me to my company, Bloom Energy.

At Bloom Energy our mission is to make clean reliable energy affordable. Our on-site power generation systems utilize an innovative fuel cell technology with roots in NASA's Mars program. By leveraging breakthrough innovations in materials science, Bloom Energy systems are among the most efficient energy generators; providing for significantly reduced operating costs and dramatically lower greenhouse gas emissions. By generating power where it is consumed, Bloom Energy offers increased electrical reliability and improved energy security.

Our company has been around for just under 5 years and in that time we've made tremendous strides by combining top-notch fuel cell expertise with Silicon Valley volume manufacturing know-how and rapid business-building experience.

Since I last testified before this Subcommittee;

- We've had our first deployed systems pass their 1 year anniversary in the field at the University of Tennessee Chattanooga. Those *first* systems have demonstrated grid-caliber reliability.
- We've demonstrated an ability to run our systems on multiple fuels including storable fuels for military applications and renewable fuels like ethanol.
- We've more than doubled our staff.
- We've ramped our system production by almost 10×.
- We've seen our product costs decline by almost 10×. And, perhaps most excitingly,

- We've seen customer interest skyrocket. Not just environmentalists, but also mainstream corporate America, utilities, and independent system operators are all very interested in our technology.

While these are exciting milestones for our young company and extremely positive for the fuel cell industry, there are still challenges remaining to mature our product, and to compete with legacy technologies.

This is where the Federal Government can help. Specifically, let me focus on four key areas.

First, consume.—As the single largest consumer of energy in the country, the Federal Government needs to be an early adopter and leading consumer for viable new energy technologies. Congress should establish a merit-based procurement law for Federal agencies to deploy new technologies that meet a minimum set of performance criteria.

Second, create and continue long-term policy incentives.—Thanks to a combination of government programs, consumer interest in new energy technologies is growing, but stable, long term and predictable incentives are critical to translate this interest into action.

Third, level the playing field with old incumbent technologies.—According to the Governmental Accountability Office, between 1968 and 2000, the U.S. petroleum industry alone received between $134.9 and $149.6 billion in incentives. If just a fraction of that were applied to clean new energy technologies today, imagine what we could do.

And finally, adopt a position of technology neutrality.—Many Federal incentives specify eligible technologies and exclude others. The rationale for these inclusions or exclusions is not always merit-based. For example the current Federal investment tax credit applies to commercial installations of both solar and fuel cells, but the fuel cell credit is capped while there is no cap for solar. This discriminatory fuel cell cap has the unintended consequence of hindering commercialization of promising new technologies.

I believe that the marketplace, not Federal policy, should pick technology winners and losers. To the greatest extent possible, Federal policy should establish a level playing field that enables all promising energy technologies to compete on their merits.

If we can accomplish this we will have successfully converted one of the greatest crisis facing our Nation and world into one of the greatest opportunities. One that fuels economic and job growth, encourages students to pursue math and sciences, fosters innovation, and ensures competitiveness.

I am optimistic. Together the Federal Government and entrepreneurial innovators can reshape our energy landscape. We can make energy affordable, accessible, abundant, sustainable, and secure. The dream is poised to become a reality.

Thank you!

Senator KERRY. Thank you very much. Appreciate that.

Dr. Katzer?

STATEMENT OF DR. JAMES R. KATZER, THE LABORATORY FOR ENERGY AND THE ENVIRONMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Dr. KATZER. Thank you. Senator Kerry, Members of the Subcommittee, my name is Jim Katzer, and I am a visiting scholar at MIT. For the last 2 years, I've been working with a group of MIT faculty, looking into the future of coal. I will focus on technology and costs associated with the capture and geological sequestration of carbon dioxide from coal-based power generation today. This is referred to as CCS. Please note that all costs are from a point set of estimates and will vary with plant design and operating parameters, with location, and with coal, but we think that the differences are broadly indicative.

Coal represents a paradox in power generation. On one hand, it is cheap and in countries with large populations and limited oil and gas supplies; on the other hand, it can cause significant environmental impacts and produces large quantities of carbon dioxide.

The U.S. has 27 percent of the global recoverable coal reserves, and, last year, over 50 percent of our electricity was generated from coal. Coal is certain to play a major role in meeting electricity demand growth out into the future.

The primary technology for electricity generation from coal today is pulverized coal, PC, combustion. It is a well established, mature technology. A new plant today can generate electricity for about 4.8 cents per kilowatt hour. Capturing CO_2 from this type of plant increases the cost of the electricity by about 3 cents per kilowatt hour. The capture technology is not new, but is used today to a smaller scale. There is a high probability that innovation will reduce this cost significantly as we would move into its application on a larger scale.

IGCC—as Senator Kerry has noted—is a recent competitor to PC. For a new IGCC plant, the projected cost of electricity is about 5.1 cents per kilowatt hour under our conditions. Cost and gasifier availability with IGCC are issues. With gasification, CO_2 capture is easier, and, therefore, less expensive. The increase in the cost of electricity is about 1.4 cents per kilowatt hour for IGCC, versus 3 for PC. Thus, the COE, cost of electricity, for IGCC with capture is less than for PC with CO_2 capture. These numbers will depend on coal type and on plant location. The technologies used in the ICC approach are all commercial, but there is room for innovation, and this—I am certain—will happen with operational experience, supported by R&D.

A third option for CO_2 capture and power generation is to utilize pure oxygen in coal combustion to reduce the cost of CO_2 capture. This technology is in early development stages in Europe, and there are no evident technological problems to its progressing smoothly forward. The cost of electricity for this approach appears to be between the other two. There is lots of room for innovation here.

All three approaches are close enough in cost that no one can be ruled out today, particularly when considering the broadly different coal types that we have in the U.S. Thus, we should not pick winners, because it is not possible to predict how technology development and commercial innovation may evolve.

Once captured and compressed, the CO_2 is transported by pipeline for deep injection for geologic sequestration. These are the last two steps in CCS. The good news is that the U.S. appears to have enough geologic storage capacity to deploy CCS on a large scale for a long time. Furthermore, CCS can typically be done on a fairly local basis.

Although there are a large range of questions related to geologic CO_2 sequestration, they all appear to be resolvable with the appropriate work. Importantly, there are no problems that appear irresolvable related to geologic CO_2 sequestration. In fact, it appears that CO_2 sequestration is likely to be safe, effective, and competitive with other options on an economic basis.

Now let me look at the costs. If we start with IGCC for power generation, we said the cost was about 5.1 cents per kilowatt hour, without capture. Capture adds about 1.4 cents per kilowatt hour to that. Pipeline transport should add less than .2 cents per kilowatt hour to that. And the drilling and associated costs for injection of the CO_2, the sequestration step, should add something of order 0.6 cents per kilowatt hour to the cost. The total added cost for CCS is, therefore, about 2.3 cents per kilowatt hour, or about a 50-percent increase in the cost of the electricity at the plant gate, the bus-bar cost. This puts the total cost of electricity at about 7.3 cents for IGCC from bituminous coals.

There are no economic show stoppers here associated with CCS, as you can see. And the technology is all known. This would put coal-based power generation, with extremely low air emissions and 90-percent CO_2 reduction, in the same range as wind power, which, in the U.S., averages between 6 and 10 cents a kilowatt hour. However, these costs will most likely come down, due to innovation, when CCS begins to be applied commercially.

How do we make CCS an acceptable reality that can be smoothly applied and considered to be a robust technology commercially? We first need to demonstrate the integrated CCS system for the major generation technologies, integrated with CO_2 sequestration, in several different geologies. This would require three or four major CCS demonstration projects in the U.S., combined with appropriate R&D support. These need to be started quickly and moved ahead aggressively.

Enabling CCS is critical to the use of our domestic coal supply in an environmentally positive manner, as we will need to do. Establishing a commercial, innovative CCS technology base in the U.S. would provide U.S. industry with technology marketing opportunities to the rest of the world.

I thank you for the opportunity to present this material this afternoon.

[The prepared statement of Dr. Katzer follows:]

PREPARED STATEMENT OF DR. JAMES R. KATZER, THE LABORATORY FOR ENERGY AND THE ENVIRONMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (MIT)

Senator Kerry and Members of the Subcommittee. Good afternoon. My name is James Katzer, and I am a Visiting Scholar in the Laboratory for Energy and the Environment of Massachusetts Institute of Technology. For about the last 2 years, I have been working with a group of MIT faculty who have been looking at the future of coal. I am pleased to have been invited to discuss key aspects of this work with you today. I will focus on coal-based power generation technology combined with the capture and sequestration of carbon dioxide emissions. I am submitting my written testimony herewith.

Coal presents the ideal paradox in power generation. On one hand, it is cheap, abundant, and concentrated typically in countries with large human populations and limited oil and gas. On the other hand, its use can have significant environmental impacts, requires capital-intensive generating plants, and produces large quantities of carbon dioxide. Both U.S. and global electricity demand will continue to grow at a brisk rate, and coal is certain to play a major role in meeting this demand growth. The U.S. has 27 percent of the total global recoverable coal reserves, enough for about 250 years at current consumption. Over 50 percent of U.S. electricity was generated from coal last year. Figure 1 shows the projected growth in coal consumption for the recent EIA forecast under business as usual. It is inevitable that we will see increased coal consumption and CO_2 emissions there from.

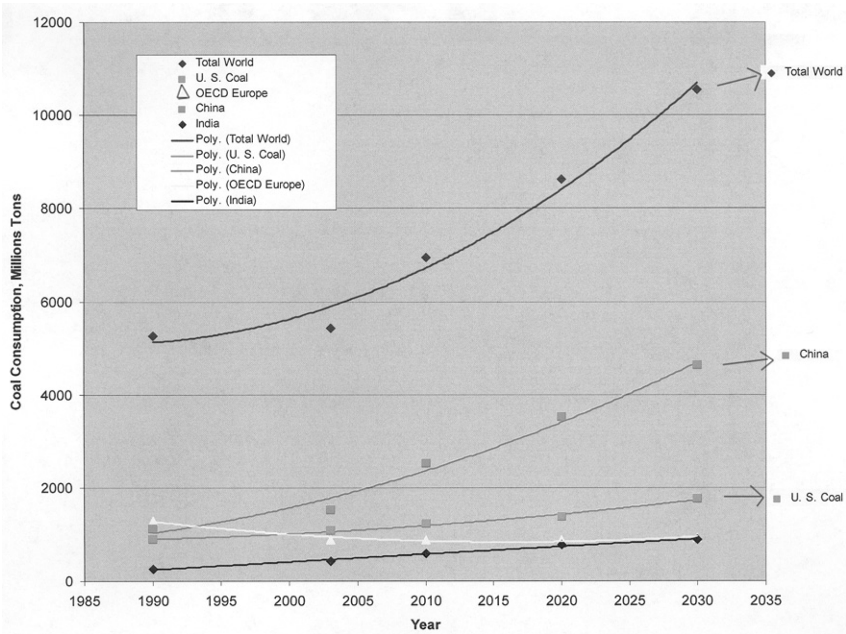

Figure 1. Coal Consumption Projections

It is important to understand the magnitude of commercial CO_2 capture and sequestration associated with power generation because its scale offers unique challenges and opportunities in the research, development and demonstration arena. A single 1000 MWe coal-based power plant emits between 5 and 8 million tonnes of CO_2 per year, or about 130,000 bbls per day of supercritical liquid CO_2. This would become 200 to 300 million tonnes of CO_2 over the 40 year life of the plant and require a reservoir storage volume of about 1.5 billion bbls of liquid CO_2.

Generation Without and With CO_2 Capture

The primary technology used to generate electricity from coal today is pulverized coal (PC) combustion. It is well-established, mature technology. The efficiency of generation depends on a number of design and operating variables, on coal type and properties, and on plant location. New plant designs have significantly higher operating efficiencies than the current fleet average, but the limit for the near term is probably being reached.

Integrated Gasification Combined Cycle (IGCC) is a competitor to PC generation. Four coal-based IGCC demonstration plants, each between 250 and 300 MWe, have been built, each with government assistance, and are operating well. In addition, there are 5 refinery-based IGCC units, two at 500 MWe each, which are gasifying petroleum coke, or refinery asphalt, residua, tars, and other residues to produce electricity. These units often also produce steam and hydrogen for the refinery. IGCC is well-established commercially in the refinery setting. IGCC can also be considered commercial in the coal-based electricity generation setting, but in this setting it is neither well-established nor mature. As such, it is likely to undergo significant change as it matures. Currently, a major concern with coal-based IGCC is gasifier availability.

Because a large number of variables, including coal type and quality, location, etc, affect generating technology choice, operation, and cost, the technology comparisons here center on one point-set of conditions. This includes one coal, Illinois #6 coal, a high-sulfur bituminous coal and generating units designed to achieve criteria emissions levels somewhat lower than the lowest recent permitted plant levels. For example, the designs used here achieve 99.4 percent SO_x and 99.9+ percent particulate removal. These technologies are first compared without CO_2 capture and then with 90 percent CO_2 capture. Plant capital costs are based on detailed design studies between 2000 and 2004, and on industrial experience during that period. This was a period of relative cost stability. No attempt has been made to account for recent cost escalations in materials, engineering, and construction costs. These have been substantial. *However, the important issue here is the relative numbers among and between the various technologies, and these are probably best based on the 2000 to 2004 period.* Here the focus is on technologies that are either commercial or well on their way to becoming commercial.

PC Combustion: PC generating efficiency is about 35 percent for subcritical generation, about 38 percent for supercritical generation, and about 44 percent for ultra-supercritical generation. Increased generating efficiency means less emissions per unit of electricity, including less CO_2 emissions. In moving from subcritical to ultra-supercritical generation, the coal required per unit electricity is reduced by about 22 percent, which means a 22 percent reduction in CO_2 emissions and also reduced criteria emissions. Most PC units in the U.S. are subcritical. We have no ultra-supercritical plants in operation, or under construction. On the other hand, Europe and Japan, which have higher coal costs and stronger culture supporting high efficiency, have built almost a dozen ultra-supercitical units over the last decade. These units are operating as well as subcritical units, but with much higher generating efficiency. The key enabling technology here is improved materials to allow operation at higher severity conditions. An expanded U.S. program to advance materials development and particularly improved fabrication and repair technologies for these materials would advance the potential for increased PC generating efficiency for our changing future.

Application of advanced emissions control technologies to PC units can produce extremely low emissions, and emissions control technology continues to improve, including the potential for high degrees of mercury control. In general, the issue of PC emissions is not a question of technology capability but the breadth of its application.

For Illinois #6 coal at $1.50 per million Btu and detailed design study capital costs using EPRI economic TAG guidelines and assumptions, the estimated cost of electricity (COE) for a supercritical PC is about 4.75 ¢/kW_e-h.[1,2] Table 2 summarizes the performance and cost parameters for the several generating technologies. For supercritical generation about 1 ¢/kWe−h, or about 20 percent, is associated with going from no emissions control to the high level of emissions control used here. Reducing emissions by a factor of two further would add an estimated 0.2 ¢/kW_e-h increasing the COE to about 5.0 ¢/kW_e-h.

Table 2. Performance and Costs of Generating Technologies

	Subcritical PC		Supercritical PC		Oxy-Fired PC	IGCC	
	W/O Capture	W Capture	W/O Capture	W Capture	W Capture	W/O Capture	W Capture
PERFORMANCE							
Efficiency (HHV)	35.0%	25.1%	39.2%	29.3%	30.2%	39.3%	33.4%
Heat Rate, BTU/KWe-h	9,754	13,602	8,709	11,652	11,305	8,687	10,222
CO_2 emitted, g/KWe-h	913	127	815	109	106	813	96
COSTS							
Total Plant Costs, $/KWe	$1,277	$2,232	$1,330	$2,143	$2,054	$1,429	$1,893
Cost of Electricity							
Inv. Charge, cents/KWe-h @ 15.1%	2.59	4.53	2.7	4.35	4.16	2.9	3.84
Fuel, cents/KWe-h @ $1.50/MMBTU	1.46	2.04	1.31	1.75	1.7	1.3	1.53
O&M, cents/KWe-h	0.75	1.6	0.75	1.6	1.75	0.9	1.05
Total COE, cents/KWe-h	4.80	8.17	4.75	7.69	7.61	5.10	6.42

Basis: 500 MW_e plant net output. Illinois # 6 coal (61.2% wt C, 25,350 kJ/kg (HHV), 85% capacity factor, COE is bus bar cost. Based on design studies between 2000 and 2004, a period of cost stability, updated to 2005$ using CPI inflation rate, does not account for rapid increases due to materials, engineering, and construction costs since 2004.

IGCC: The promise of IGCC has been high generating efficiency and extremely low emissions. There are a number of critical options associated with gasification technology and its integration into the total plant that affect efficiency and operability. Of these, the gasifier type and configuration are the most important. Table 1 summarizes the characteristics of gasifier types. Entrained-flow gasifiers, which are extremely flexible, are the basis of each of the IGCC demonstration units. Figure 2 shows the configuration of an IGCC employing full quench cooling of the gasifier exit gases. This configuration with high quality coals will produce about 35–36 percent generating efficiency. Figure 3 illustrates the addition of a radiant syngas cooler to raise steam for the steam turbine, which increases the electricity output and raises the generating efficiency to 38–39 percent. Adding convective syngas coolers to recover additional heat as steam is also shown in Figure 3. It can increase the generating efficiency to the 39–40 percent range. Existing IGCC demonstration units, which employ different practical combinations of these options, operate at generating efficiencies from 35.5 percent (Polk) to 40 percent (HHV) (Wabash, U.S. & Puertolanno, Spain). IGCC is not yet mature, and there is still potential for efficiency gain. However, commercial IGCC generating efficiency is unlikely to exceed that of ultra-supercritical PC in the intermediate timeframe. The design/engineering firms and the power industry need to gain experience with IGCC to develop better designs and achieve improved, more reliable operation. Furthermore, gasifier designs for lower rank coals (subbituminous coal and lignite) are not well established, and costs seem to be relatively significantly higher for these coals than for PC units.

Table 1. Characteristics of different gasifier types

	Moving bed*	Fluid bed**	Entrained flow***
Outlet temperature	Low (425-600 °C)	Moderate (900-1050 °C)	High (1250-1600 °C)
Oxygen demand	Low	Moderate	High
Ash conditions	Dry ash or slagging	Dry ash or agglomerating	Slagging
Size of coal feed	6-50 mm	6-10 mm	< 100 µm
Acceptability of fines	Limited	Good	Unlimited
Other characteristics	Methane, tars and oils present in syngas	Low carbon conversion	Pure syngas, high carbon conversion

* Lurgi is an example
** KBR transport reactor, BHEL, KRW are examples
*** GE, E-Gas, Shell are examples

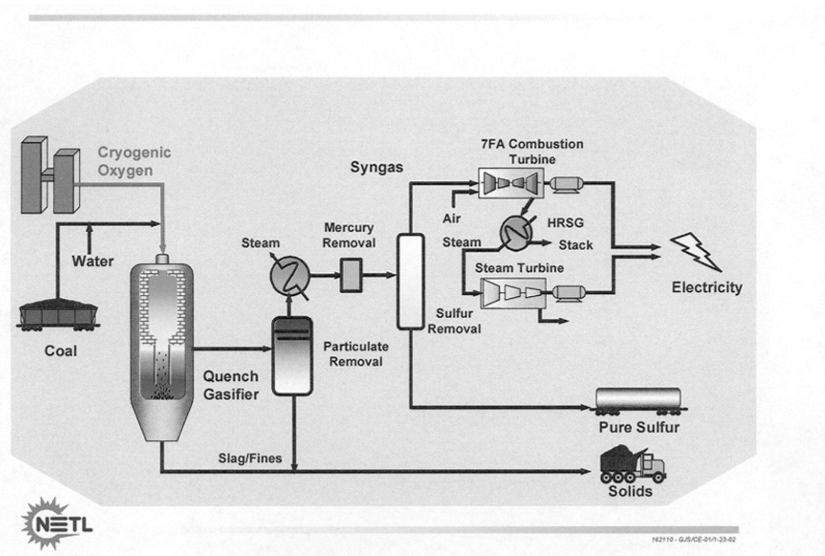

Figure 2. IGCC Plant with Entrained Flow (GE) Full Quench Gasifier

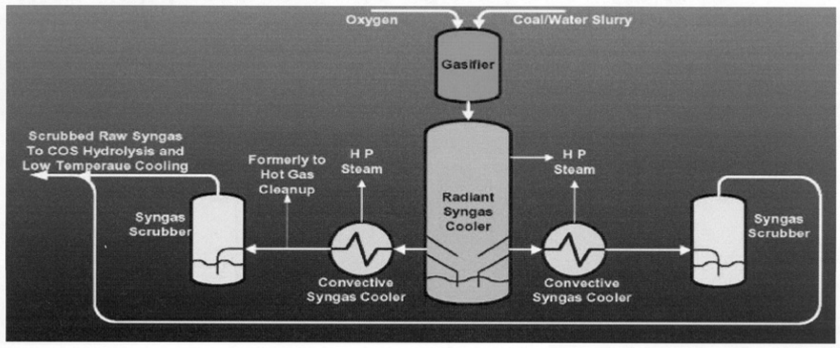

Figure 3. Heat Recovery Options for Entrained-Flow Gasifier

An IGCC unit with radiant and convective syngas coolers using Illinois #6 coal, operating at 38 percent efficiency, and achieving high levels of criteria emissions control produces electricity for about 5.1 ¢/kW_e-h (Table 2) or about 0.3 ¢/kW_e-h higher than a supercritical PC.[2,3] IGCC would not be the choice based on COE alone, independent of gasifier availability concerns. Requiring high levels of mercury removal, reducing criteria pollutants by one half from the very low levels that we are already considering and including the cost of emissions credits and offsets increases the COE for the PC, narrowing the gap, but does not suggest a shift in technology choice based on COE in the absence of CO_2 capture. However, IGCC has the potential for order-of-magnitude criteria emissions reductions, 99.5+ percent levels of mercury and other toxic metals removal, lower water consumption, and highly stabilized solid waste production. These may become a larger factor in the future. Achieving these order-of-magnitude criteria emissions reductions is expected to increase IGCC COE, but this increase is not expected to be large. Companies considering construction of a new coal-based generating facility need to bring all these considerations into their forward pricing scenarios to help frame the decision of which technology to build. CO_2 will probably be an added consideration shortly.

CO_2 Capture: CO_2 capture will add significantly to the COE, independent of which approach is taken. Today, CO_2 capture would appear to change the choice of technology in favor of IGCC for high rank coals. For lower rank coals this choice may not be so clear, particularly as the PC CO_2 capture technology improves. Thus, it is too early to declare IGCC the winner for all situations at this time. History teaches us that one single technology is almost never the winner in every situation. The options are:

- *Capture the CO_2* from PC unit flue gas. In this case, the CO_2 is at a low concentration and low partial pressure because of the large amount of nitrogen from the combustion air. To capture and recover the CO_2 using today's amine (MEA) technology requires a lot of energy. Energy is also required to compress the CO_2 to a supercritical liquid. This large energy consumption reduces plant electricity output by almost 25 percent and reduces generating efficiency by about 9 percentage points. The added capital and the efficiency reduction increase the COE by about 60 percent or about 3.0 ¢/kW_e-h to about 7.7 ¢/kW_e-h[1] (Table 2). In this situation a marked reduction in the CO_2 capture and recovery energy would have a significant impact on PC capture economics. Focused research on this issue is clearly warranted.
- *Combust coal with oxygen (Oxy-fuel combustion)* to reduce the amount of nitrogen in the flue gas. This allows the flue gas to be compressed directly liquefying the CO_2 without a costly separation step first, reducing energy consumption. However, the technology requires the addition of an air separation unit which consumes significant energy substantially offsetting the energy gains achieved by eliminating the CO_2 separation step. This technology is in early development stage, is advancing well, and at this point appears to hold significant potential for both new-build capture plants and for the retrofitting existing PC plants. The estimated COE for oxy-fuel combustion is about 7.0 ¢/kW_e-h,[1] includes compression to supercritical liquid, but not transport or sequestration. This is about 0.7 ¢/kW_e-h less than for air-blown PC combustion with capture. The technology requires further development and demonstration along with detailed design studies to allow effective evaluation of its cost and commercial potential.

- *Use IGCC, shift the syngas to hydrogen, and capture the CO_2 before combustion* in the gas turbine. IGCC should give the lowest COE increase for CO_2 capture because the CO_2 is at high concentration and high partial pressure, and this is what design studies show. The needed technologies are all commercial in refineries and natural gas processing plants, although they have never been fully integrated on the scale that it will need to be applied here. For Illinois #6 coal, the estimated COE is 6.5 ¢/kW_e-h [1,2] which is a 1.4 ¢/kW_e-h increase over non-capture IGCC and is about 1.2 ¢/kW_e-h less than supercritical PC with capture. Oxy-fuel combustion falls in between these two. However, an IGCC unit designed for power generation without CO_2 capture is significantly different from one designed for power generation with CO_2 capture. Retrofitting the former to a capture unit is not straightforwardly simple.
- *Lower Rank Coals:* As Figure 3 shows, moving from bituminous coal to sub-bituminous coal and to lignite results in an increase in the capital cost for a PC plant and a decrease the generating efficiency (increased heat rate). However, for IGCC, these trends are significantly larger, such that currently-demonstrated IGCC technologies become more substantially disadvantaged relative to PC for subbituminous coals and lignite without CO_2 capture, and their advantage with CO_2 capture is eroded somewhat. Over half of the U.S. recoverable coal reserve is either subbituminous coal or lignite. Thus, there is a substantial need for improved IGCC technology performance on lignite, other low rank coals, and biomass. Options include, but are not limited to, improved dry-feed injection into the gasifier, coal drying, fluid transport reactors and other gasifier configurations. Development should be at the PDU scale before moving to demonstration.

Thus, when CO_2 capture is considered, the differences among IGCC, oxy-fuel PC and air-blown PC become significantly less than discussed above for bituminous coal. In this situation all three of the technologies with CO_2 capture must be considered to be in the early stages of development, and it is simply too early to select one of these technologies as the winner vs. the others

CO_2 Transport and Sequestration

Capture and compression of CO_2 to a supercritical liquid-like fluid was considered above. Next, CO_2 transport by pipeline and injection for geologic sequestration are considered. For more details on the geological aspects of sequestration, refer to the recent testimony of Dr. Julio Friedmann before the House Energy Committee, Energy and Air Quality Subcommittee Hearing, March 6, 2007 [4] and the recent MIT Coal Report. [1]

The good news is that the U.S. appears to have enough geological storage capacity to deploy CO_2 Capture and Sequestration (CCS) at a large scale for a long time. The best projected storage sites are deep saline aquifers which can hold large volumes of CO_2. Further, many of these potential geologic storage areas are under sites with large coal-fired coal plants and where additional coal plants are expected to be built. This suggests that transporting CO_2 long distances, via pipeline will not be required, but that sequestration will be within a reasonable distance from a power plant capturing it. Further, pipeline transport of CO_2 is well established; there are about 3,000 miles of dedicated CO_2 pipelines used for commercial CO_2–EOR projects today in the U.S. The cost of transport is also well understood and predictable.

Figure 4 illustrates what a potential CCS power plant project, with appropriate siting might look like. For a good reservoir the radius around the plant for sequestration may be less than 25 miles. Longer transport distances to use CO_2 for EOR may occur in some cases, but because of the scale of CCS, it is expected to be a relatively small contribution to CO_2 sequestration, although the oil recovered from CO_2–EOR would add value to the project, offsetting some of the cost.

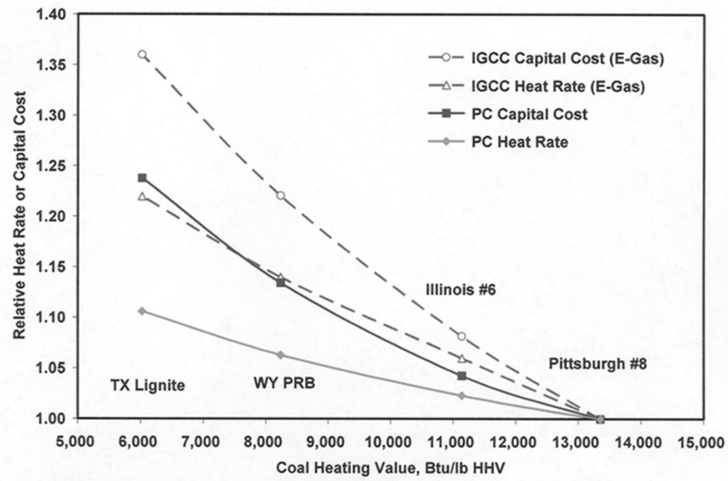

Figure 4 Effect of Coal Type (Rank) on Capital Cost and Heat Rate for PC and IGCC

Today, there are three commercial projects using CO_2 storage (Sleipner in Norway, In Salah in Algeria, and Weyburn in Canada) each injecting over a million tonnes of CO_2 per year. Sleipner has been injecting CO_2 into a deep saline aquifer under the North Sea for 7 years. Other projects are planned, including FutureGEN.

Although there are a large range of questions related to sequestration, they all appear to be resolvable with the appropriate work. Importantly, there do not appear to be any irresolvable open technical issues related to geologic CO_2 sequestration. In fact, it appears that geologic CO_2 sequestration is likely to be safe, effective, and competitive with other options on an economic basis. CCS is actionable almost immediately and can be sustained for many years while our energy base undergoes transition to new carbon-free technologies. CCS is one method of reducing CO_2 emissions growth from coal-based power generation or even reducing total coal-based CO_2 emissions over time while maintaining the contribution of coal, a cheap, domestic energy source, can make in providing a substantial portion of our base-load power.

Table 3 summarizes estimated costs for CCS as applied to Illinois #6 coal-based power generation. Costs are given in $ per tonne of CO_2 and in ¢/kW_e-h. The capture and compression costs vary with coal type and with generating technology. When they are added to the COE generation without CO_2 capture, the result is the COE for generation with CO_2 capture. The higher capture cost for PC generation is evident, compared with IGCC.

Table 3. CO_2 Capture and Sequestration*

	PC		IGCC	
	$/tonne CO_2	¢/kW_e-h	$/tonne CO_2	¢/kW_e-h
Capture	33	2.4	15	1.1
Compression	7.4	0.53	5	0.36
Transport	2	0.19	2	0.18
Injection	7	0.69	7	0.64
Totals	49	3.8	29	2.3

*Costs are estimates for existing CCS technology with Illinois #6 coal; They will vary with coal type, generating technology and with site and reservoir properties. Here they are meant to be indicative of relative magnitude.

The cost of transport and injection will vary with site (location) and with reservoir properties. Transport costs for the configuration in Figure 5 could be from less than a \$ per tonne to several \$ per tonne; \$2/tonne was chosen. Estimated sequestration costs including drilling the needed wells and the CO_2 injection operation range from \$5 to \$8 per tonne CO_2; \$7/tonne was chosen. The table shows how these costs translate to ¢/kW_e-h, assuming the same site (Figure 5). PC transport and sequestratrion costs are marginally higher because more CO_2 is involved. However, in both cases the transport and sequestration cost is less than 0.9 ¢/kW_e-h. In overview, for PC generation with Illinois #6 coal the cost of CCS is about 3.8 ¢/ kW_e-h; for IGCC the cost is about 2.3 ¢/kW_e-h. Each step in CCS adds cost, but there are no economic show stoppers present. For IGCC, CCS increases the bus bar cost of electricity by about 50 percent. These costs will most likely come down significantly when CCS begins to become practiced industrially. The innovative spirit of industrial practitioners and competitive pressures will bring a lot of innovation to every step in CCS. However, this will not happen until there is a real need to practice it commercially. It is important to note that to achieve today's best emissions performance (99.9+ percent PM reduction, 99.4+ percent SOx reduction and 95+ percent NO_x reduction) adds about 1 ¢/kW_e-h to the cost of electricity generation with no emissions control. This area has seen a tremendous improvement in performance and in cost reductions since these technologies began to be applied. The same can be expected for CCS. This area offers the U.S. a chance to develop technologies that can be marketed to the rest of the world.

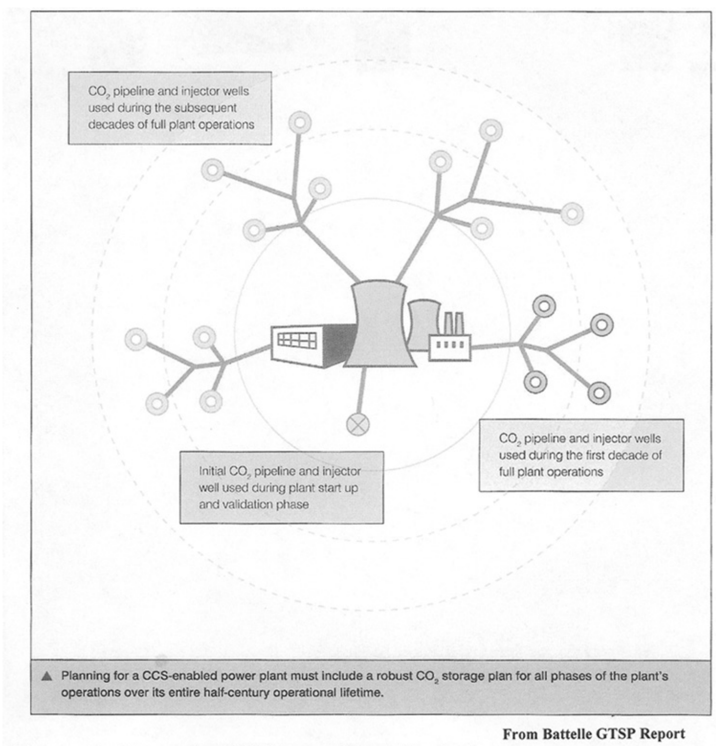

Figure 5, Example CCS Power Plant Project

The remaining issue with respect to CCS is the establishment of a monitoring, regulatory, legal, and permitting framework under which this can be done in a business-like context. This can be done along with demonstrating the full-scale, integrated operation of CCS. This will require an effective Research, Development and Demonstration program aggressively applied to 3–4 demonstration projects. These projects should apply different CO_2 generation and capture technologies and involve sequestration of CO_2 in different geologies at the rate of 1 million tonnes CO_2 per year for several years.

Summary

Considering CO_2 capture and sequestration from coal-based power generation, there are no apparent irresolvable technical problems in the entire CCS chain from coal-in to power-out and CO_2 in geologic storage. There do not appear to be any economic show stoppers in the chain either, although at the current time it appears that applying CO_2 capture and sequestration will increase the bus bar cost of electricity by about 50 percent. Today, this would put coal-based power generation with extremely low air emissions (99.9+ percent reductions) and 90+ percent CO_2 emissions reduction in the same cost range of wind power (range 6–10 ¢/kW_e-h in the U.S.). However, to make CCS an accepted reality that can be smoothly applied, it is necessary to demonstrate the integrated CCS system for the major generation technologies with CO_2 sequestration in several different geologies. This requires three or four major demonstration projects in the U.S. combined with appropriate R&D to support them. These need to be moved forward aggressively.

With respect to the generation and capture part of the CCS chain, the technology systems to capture CO_2 from coal-based power production are all available, but they require further development and integrated demonstration. Of the three competing systems (PC with CO_2 recovery from flue gas, Oxy-fuel combustion with flue gas direct compression, and IGCC with pre-combustion CO_2 capture) it is too early to choose winners because it is not possible to predict how technology development and commercial innovation may evolve. Further, one technology system may be well suited for bituminous coals, whereas another may apply best to low rank coals and lignite.

With respect to sequestration, there is enough technical knowledge today to select safe and effective storage sites for large volumes of CO_2 storage over extended time periods. However, national deployment of commercial CCS involves technical challenges and concerns due to the operational scale that is required. The aggressive research, development, and demonstration program recommended here could resolve both the technical and legal issues within 10 years and provide the foundation for a legal and regulatory framework to protect the public without undue burden to industry.

In the program recommended above the generation and capture, and the sequestration demonstration components should be integrated together as much as possible to facilitate learning for actual CCS as it will need to be applied commercially. This program could be viewed as an insurance policy that the U.S. is investing in so that the technologies and legal/permitting framework are available when needed. Further, as this moves into commercial practice it is expected that innovations and cost reductions will occur. Enabling CCS is critical to the use our domestic coal supply in an environmentally positive manner, as we will need to do. Establishing a commercial, innovative CCS technology base in the U.S. should provide marketing opportunities to the rest of the world.

Thank you again for the opportunity to present this material to you and your Committee. We face many energy challenges in the future, and I firmly believe CCS will help us meet them.

Citations and Notes

[1] MIT, *The Future of Coal; Options in a Carbon-Constrained World.* 2007, MIT: Cambridge.

[2] Dalton, S., *The Future of Coal Generation, in EEI Energy Supply Executive Advisory Committee.* 2004.

[3] NCC, *Opportunities to Expedite the Construction of New Coal-Based Power Plants.* 2004, National Coal Council.

[4] Friedmann, J., *Technical Feasibility of Rapid Deployment of Geological Carbon Sequestration, in House Energy and Commerce Committee, Energy and Air Quality Sub-Committee.* 2007: Washington, DC.

Senator KERRY. Well, we thank you. And let me follow right up with you, Doctor Katzer.

Why don't I take a 6-minute round, and we'll sort of go round and come back and—since there are only three of us, we can sort of open it up a bit.

So, how do we do that? You recommend, sort of, getting—I've heard this discussion about quickly getting, maybe, ten demo projects out there, whatever number, make it happen. Is this something you're suggesting that we should give an incentive to the private sector to do? Is this something we should do? Should it be a joint venture? What's your sense of the structure?

Dr. KATZER. Well, first, the demonstration projects themselves, we think, should be run by some form of pseudo private/public company, a new quasi-government CCS corporation, that would do them; they should not be handled or managed by DOE. There is a significant amount of R&D associated with these that is needed and that would need to be integrated with them. DOE should be primarily responsible for this, and the DOE budget would need to be increased significantly and focused on these areas.

I think there's no problem identifying what needs to be done and moving it forward; I think that is fairly easy. I think moving forward aggressively is going to be one of the major challenges that the Senate must address.

Senator KERRY. And why is that? Why is it so hard to move forward aggressively?

Dr. KATZER. We have not set firm policies and time tables, politically.

Senator KERRY. Do you think it's urgent that we move forward aggressively?

Dr. KATZER. It is extremely urgent that we move forward agressively.

Senator KERRY. Then why is it so hard?

Dr. KATZER. By doing what we recommend the U.S. is essentially buying an insurance policy so that it has technical options it can use down the road when it decides it needs to. And if you don't do that, you simply push everything back. I will simply note that FutureGen was probably hatched in 2002. It was proposed formally in 2003. It's now 2007, and to the best of my knowledge a gasifier has not been chosen yet. Thus, all the details of what it's going to look like are really not on the table yet so that serious engineering work cannot be completed. It's proposed to start up, I think, in 2011. And if you then have 4 years of operations for learnings, you're now out to 2015. This is the urgency issue you need to address.

Senator KERRY. Well, so, how does AEP decide it's going to go ahead and do the IGCC, which is effectively a 20- to 30-percent premium—I mean, it's an add-on, but they're willing to accept that. They're going out into the marketplace, and the consumers are going to just, you know, share the cost.

Dr. KATZER. Yes, and they've gotten the utility commissions to agree that that's permissible.

Senator KERRY. Correct.

Dr. KATZER. And the driver for them was to do a very detailed risk analysis to say, "Things will change, CO_2 is going to become an issue that we'll have to deal with, and we need to begin to move down that learning path."

Senator KERRY. Well, they're right about that, correct?

Dr. KATZER. I would suggest they are, yes.

Senator KERRY. Therefore, what's the formula for getting everybody else to buy in? Is it a mandate from the Federal Government? Is it——

Dr. KATZER. I think it's not a mandate.

Senator KERRY.—incentive?

Dr. KATZER. What is needed is a clear signal of what the policies are going to be. And we've heard, several times here today already, that industry needs a clear signal of what policies are going to be, or what they are, and then these policies need to be in place for an extended period of time, and not change under pressure.

Senator KERRY. Is the clearest——

Dr. KATZER. This provides a basis so that they can plan.

Senator KERRY. Is the clearest and most effective signal an economywide tradable cap?

Dr. KATZER. That would work.

Senator KERRY. Isn't that a pretty effective signal?

Dr. KATZER. That is a pretty effective signal.

Senator KERRY. Aren't a whole bunch of companies already spontaneously——

Dr. KATZER. A relatively large and wide-ranging number of companies have made recommendations that the U.S. establish an effective carbon policy.

Senator KERRY.—adopting that?

Dr. KATZER. They are recommending a move in the direction of putting some kind of price on carbon, yes.

Senator KERRY. What do they know that we don't? Or are they accepting something that we won't?

Dr. KATZER. I think they're accepting something that ultimately Congress, Senate and the House, will have to come to grips with, yes.

Senator KERRY. With respect to—Mr. Eckhart, I—or—yes—renewables, these ten companies. In the 1970s—1979, I remember, when President Carter initiated the first round of, sort of, response to oil crisis, Congress made a very significant commitment to incentives for renewables and alternatives. And, in fact, a lot of tenured professors left their positions and went out to Colorado and became, you know, participants at the laboratory. And then, lo and behold, President Reagan appeared, and they cut the guts out of those subsidies. At that point in time, we were the world's leader in photovoltaics and alternatives renewables, were we not?

Mr. ECKHART. We were.

Senator KERRY. And, as a consequence of that loss of Government commitment to the effort, that lead shifted to Japan and Germany, did it not?

Mr. ECKHART. And for other reasons, yes.

Senator KERRY. What were the other reasons?

Mr. ECKHART. Well, in 1979—incidentally, I personally did a complete survey of the solar cell industry in the United States, personally visited every company, and I can report to you that last year I looked up that study, and only one company listed in that study—and that was the national study in 1979—is still in existence in its own name. One. Inspire Corporation, up in Boston, by the way.

Senator KERRY. And what does that tell you?

Mr. ECKHART. Well, what happened was, we adopted, in our country, a philosophy that the Government role is to fund R&D and put technology on the shelf, and then, somehow, someone else will take it from there. But other—what happened is, other governments around the world didn't have that philosophy. They adopted the philosophy that they would pick up on our technology investment and incentivize their markets to buy it, which caused companies to go into business to sell it. And so, when Germany put their renewable energy law with the feed-in tariff in place to pay for electricity from solar energy into the market, it allowed German companies to sprout up, and they created an industry on our technologies.

Senator KERRY. And it's fair——

Mr. ECKHART. And that's what happened.

Senator KERRY.—it's fair to say that in the 1990s, when the Soviet Union disappeared and the former Eastern Bloc countries suddenly came into their own, as they looked at the devastation around them from the communist management, if you want to call it that, of their environment, they turned to Germany and Japan for the technologies to clean up the Danube and the various, you know, communities. So, we lost a lot of jobs, in the end, both ways.

Mr. ECKHART. We did. And we——

Senator KERRY. We lost them on the front end and the back end, did we not? Is there a lesson in that for where we ought to be now?

Mr. ECKHART. Yes, there is.

Senator KERRY. What's that?

Mr. ECKHART. This is a worldwide competitive industry sprouting up, as we speak. And it is taking root in the countries where the governments are encouraging markets to take place; that is, to adopt the technologies. And if we sit back and just fund R&D, and don't work with the American people to adopt these technologies, we will not enjoy the companies, the industry, and the jobs that come along with that. It's our choice.

And we have to choose right now, because we're in—for example, in wind power, there have been two rounds of building factories. The first round happened in Denmark, Germany, Spain, India, where the markets were. The local companies built up, and they went public, and they're very big right now. The second round is happening this year, in China, because they have a government rule of 70-percent local content. To sell a wind turbine, you must make 70 percent of it in China. Every Western company has to build a factory in China to play in that market. So, all the money available to build factories is, this year, going to China. We've missed round one, and we've missed round two. We must get round three, which is the next wave of factories. We must get it, or we will not have a true wind industry here. With all those jobs. We're talking about well over 100,000 jobs around the world went to other countries. The same thing in PV.

And you mentioned the Soviet Union and Germany. Today in Germany, there's a U.S. company, venture-capital-backed, that just went public on the NASDAQ. They have a lot of capital. They're building their new factory. Where? East Germany. Why? Because the West German incentives to build factories in East Germany are so lucrative that the German Government is, in effect, paying the full cost of the factory just to employ people.

Other governments aren't playing by our rules, and we have to look globally as to what the industry is into, and do the right thing here in this country.

Senator KERRY. Last question before I cede to Senator Ensign.

Can you tell us what the state-of-the-art is, at this point, with respect to deepwater turbine—deepwater wind?

Mr. ECKHART. That's—that is the area where R&D is needed in wind, making those—you mean placing offshore wind in deep water.

Senator KERRY. In deeper than 50 feet, yes, if you're looking for offshore, so you don't run into the NIMBY issues and so forth.

Mr. ECKHART. That—just to go offshore approximately doubles the cost of the machinery and the cost of the——

Senator KERRY. How technically developed is that ability to place deepwater towers? I gather they've got some kind of a weighted balance system or something. Are you familiar with it?

Mr. ECKHART. I am. And it is the area that deserves a lot of R&D investment right now, and it should be cost-shared between the wind turbine companies and the Government——

Senator KERRY. Thank you——

Mr. ECKHART.—50/50.

Senator KERRY.—very much.

Senator Ensign?

Senator ENSIGN. Thanks, Mr. Chairman.

Dr. Sridhar, I want to explore with you and with some of the other witnesses, the part of your testimony about not having the Government pick the winners and losers. There is a delicate balance here. The innovation process begins with basic research. I know that all of us believe that the Federal Government plays a very vital role for us is in supporting basic research. The delicate balance is then to provide the proper incentives for bringing the technologies that result from basic research to the marketplace without government picking the winners and losers. The Government is not very good at picking the winners and losers. the market, not the government, should determine . . . which are the better technologies out there. I would like a few comments, starting with you, Dr. Sridhar and Dr. Katzer, and then Mr. Eckhart and the other witnesses on the delicate balance between the important role government should play in supporting basic research while not picking winners and losers in the technology field.

Dr. SRIDHAR. OK. So, on fundamental R&D, I think the Government has a huge role to play. This is, like you said, a multifold win; it's not just in developing technology, it creates the next generation of scientists, engineers, it stimulates math education, science education, technology education. This is where the future of the country is. Funding that kind of R&D in national labs, in universities, it's a great place. Funding that kind of R&D in industries is a bad decision, because we're taking taxpayer money and giving it to corporations, and our incentive is already very large in the marketplace. It's a $1.6 to $2 trillion market. Companies already have plenty of incentives to develop energy solutions.

Last year, close to $3 billion worth of venture capital money in this country went into clean tech. And that number is increasing. So, private equity dollars will pick the companies to incubate, based on those technologies. And they will bring it to a point—there's plenty of venture capital involved, and they have a much better track record—if we go back to the last three decades, time and again, they have a very good track record of figuring out how to bring the best R&D into a place where the technology is demonstrated.

Senator KERRY. Can you just square that, if you don't mind, with what Mr. Eckhart just said, about the experience of the—putting it on the shelf and then we just left it, and everybody else took it?

Dr. SRIDHAR. Yes. So, if you look a few years ago, the total amount of venture capital money in this business was next to nothing. When my company, 5 years ago, was funded on SandHill Road, we were probably the only energy company that was funded. Last year, 2006, $3 billion was invested in green tech. So, that train has already left the station. So, his comment is extremely valid for the 1970s, not so today, because of the market opportunity.

Now—did I answer your question? OK. Now, if we go forward, what happens? The venture capitalists are in the business of taking a company to demonstrate that it can do something. But, in the early marketplace, when your volumes are low and when your cost is high, and you need some amount of acceptance and some level of risk-taking on the offtaker side, those early adopters. This is where the Government plays a very big role. This is where those other governments that Mr. Eckhart talked about have been in the forefront, and we have not been doing as good a job, if you take Japan and Germany and other countries as an example.

So, what is happening is, even these venture-backed companies, as they try to expand manufacturing, as they try to go into the first markets to make themselves viable,to cross the chasm, they're finding it a lot easier to do that offshore than they are out here, which would be a terrible shame, because this is the greatest job-creation opportunity and economic opportunity of the 21st Century.

Senator ENSIGN. I'm a little confused, and I think the Chairman might have been, as well, in reconciling—the other countries are giving incentives. Aren't they picking the winners and losers, then? We are trying to set policy to—this is that delicate balance that I'm talking about—incentivize new technologies, but not pick the winners and losers. "What do we need to do differently?" I guess is the bottom line.

Dr. SRIDHAR. Absolutely. If you set a performance standard that basically says, if you're buying power generators for powering Federal buildings, you're not going to say, "I want your geothermal, I want wind, I want fuel cells, I want solar." You're going to say, "Up to a certain percentage of what we are going to buy, we are going to buy as long as it meets this efficiency metric, it meets this emission metric, and it is indigenous, you know, in terms of fuel for energy security, and we would prefer a U.S.-based company." Once you do that, whether literally it's a monkey sitting in a box pedaling a wheel to get you the electrons, or something else, you're not picking it. The market is going to pick that winner or loser. OK? So, that is——

Dr. KATZER.—that is the differentiation between what those other countries are doing and what we are doing.

Senator ENSIGN. Similar to setting——

Dr. SRIDHAR.—and what we——

Senator ENSIGN.—like Nevada set an RPS standard of 15 percent.

Dr. SRIDHAR. Absolutely.

Senator ENSIGN. They didn't choose the winners and losers, they just set the standard, and then it's up to the power company and others to come up with the technologies in the marketplace to satisfy that standard.

Dr. SRIDHAR. Absolutely. And I think the market is very efficient at doing that in this country. And the other thing that I would add to that would be to say that—don't even set it like the CAFE standards, where the number is fixed. Pick a number, have a certain percentage that needs to be met. If it is easily met by Q3 of the year, raise the bar. If it is not easily met, lower the bar. But keep raising the bar. This is how this country is going to stay competitive.

Senator ENSIGN. Dr. Katzer, could you address this from an academic standpoint? In your testimony, you talked more about one particular industry, based on electricity generation from coal; I think it's because we have so much coal in the United States. But any thoughts on what Dr. Sridhar's been talking about?

Dr. KATZER. Yes. But maybe from a little different perspective.

What we were looking at here, and what I was speaking about, is an area where we have, say, three different competing power generation technologies with CCS. They each are composed of proven commercial components, most of which, but not all, have been integrated together and have been demonstrated. They've never really all been put together in the form that's needed and at the scale that's needed to be applied in power generation. And if you take one high quality coal, for instance, bituminous coal, for CO_2 capture there's a clear technology leader right now. It may or may not continue to be the clear leader for the future with CO_2 capture. That's IGCC. But if you move to subbituminous coal, Powder River Basin, or lignite, or move up into Montana, the disadvantages which IGCC begins to suffer relative to PCC narrows the gap so that there is very little difference between the two. And, in that case, you don't want to be picking one technology versus another. You really would like to play them all off against each other. And you can be certain—for certain regions or for certain coals one technology may be the winner; for other coals and different parts of the country, another technology may be the winner. And then there's a third large factor, the innovation that will come along from getting the creative juices of industry and competition really flowing when they begin to do CCS on a commercial basis. With this you just cannot predict what will happen. You need some way to allow all of those technologies to play out in the marketplace, and that will be the most efficient approach.

If I could add one other point to this. There is an important Government role in all this and that is to continue R&D in support of these technologies, as well as to fund R&D for new ideas, and new technologies that could, in fact, upset the applecart. But to wait for those new technologies that could upset the applecart to come along is something in this area we think is a bad idea. We don't think there's time to do.

Senator ENSIGN. Well——

Dr. KATZER. For instance they may not appear; and we will gain a lot of innovation and cost reductions by moving on the other technologies.

Senator ENSIGN.—I'd love the rest of you to be able to respond.

Senator KERRY. Go ahead.

Senator ENSIGN. I think I may have gone over my time.

Senator KERRY. Go ahead. Go ahead.

Senator ENSIGN. Thank you, Mr. Chairman. Can the other witnesses on the panel quickly comment?

Dr. PRELI. Yes, I'd like to comment on the—on two things.

First is the role of Government. In the basic R&D phase, I think the Government has a lot to say about that. But even in the next phase, which is the development of applications, we like the 50/50 kind of arrangement, where you're still exploring a technology, and yet you're trying to find out what it would be good for. At that point, companies like ours are willing to invest large sums of money to do product development. So, in the third phase, once the products are in development, we think the role of the Government is to help provide incentives to get it out into the marketplace.

Then, when the industry can stand on its own, the role of the Government becomes simply codes, standards, regulations, and things like that. So, we believe that Government and industry have a cooperative arrangement throughout the development lifecycle, with most of the effort by Government in the beginning, most by industry at the end. But it's a continuum. One other comment I'd like to——

Senator ENSIGN. Bit how do we choose which one of those products to fund along the way?

Dr. PRELI. Right.

Senator ENSIGN.—you know, wind, solar,——

Dr. PRELI. I think what you do is——

Senator ENSIGN.—clean coal, which one of those products?

Dr. PRELI.—you cast—you cast a very wide net, and you manage a portfolio of technologies. As those become more or less promising, you let some fall by the wayside and encourage others, the ones that are showing true benefit in the application phase. And I think it's—if you look at it from a portfolio management mindset, then you can more easily decide which ones to put more money in, less money. Even the ones you put some less money in, though, the time will come where perhaps a breakthrough makes them far more attractive.

One other point I would like to make. I studied the Japanese a lot, in both solar and fuel cells. I think what you'll find is, the difference between them and us is that they have long-term planning and incentive situations that start high and go low. And so, I think you'll find that they've been very successful with this, with solar, and it looks like they may be successful with small fuel cells, where they are fielding, now, thousands of units per year, while in the U.S. we're limited to virtually none.

Senator ENSIGN. Let me just point one quick thing out in all of this that I want to give the panel and those of us policymakers up here. I remember when everybody was just starting to use PCs frequently, and France decided that everybody was going to have basically the same system. They got way ahead of the rest of the world, and people were saying, "Look what France is doing. They're going to be ahead of us." And people were saying, "We should be doing the same thing." Well, within a year or two, France all of a sudden made this huge investment, because the government decided it picked the winners and losers, and France ended up way behind as a result.

What if Japan is making the wrong choices? Isn't the market more efficient at picking the winners and losers? This is the balance that I'm talking about. At what point in that development, then, does the market become more efficient than the Government?

Dr. PRELI. Well, I think the market is very, very efficient, and that's why we have—all of our laptops are Japanese batteries, and our hybrid cars are Japanese, and now the Americans are starting to catch up. And our photovoltaic cells are Japanese and German. I think what they do is, they tend to stick with——

Senator KERRY. Sounds like a recommendation——

Dr. PRELI.—it longer.

Senator KERRY.—to listen to the Japanese.

[Laughter.]

Dr. PRELI. And if you look at the roots of all of those technologies, they were born in America.

Senator ENSIGN. Go ahead, Mr. Eckhart.

Mr. ECKHART. Oh. I would add a comment. I think we're at the beginning of a threshold of a whole different era of public policy, and it would be this, that every energy-generation machine produces two things: energy in some useful form, and pollution in some form. And what we haven't done, because we've presumed away how we pay for energy, we're not valuing those two things. And I think, with our sophistication, going forward, if we monetize both the energy benefit and the environmental benefits of what we're buying, then we're neutral to technology. Let the technologies compete. In other words, a coal-fired power plant produces a very reliable output of electricity in very dependable, measurable quality; it also produces two-thirds pollution. A solar energy device produces a different kind of electricity, and a very different pollution profile. If we can learn to monetize those—all those variables, then—and we set public policy on the buying of energy as to its reliability, its quality, and so on, and as to its pollution, we monetize all these things and set public policy on that, then let industry compete for what we're buying. You know, coal will have its place if we want—if we're prizing reliability and bulk power generation and base load. It's going to win some of the marketplace. But solar is going to win if we monetize that nonpollution factor. This is what Germany, I think, is pointing toward. But I wouldn't copy them either. I think there's an opportunity for the U.S. to create a policy regime here for the long term that heads us toward dealing with climate change and the environment and economic growth, all together.

Senator KERRY. So, what happens if you don't have a long term, when your leading climatologist tells you you've got a 10-year window, and you have a margin of about .5 degrees centigrade that is allowable for a continued increase in temperature, and perhaps, you know, 90 parts per million of atmospheric greenhouse gas addition? Don't you have to move more rapidly? Don't we, as public people, have a moral responsibility to say, "We've got to meet this goal and make some choices"?

Mr. ECKHART. I have spoken with Al Gore and other people about the 10 years, and that's a political motivator, that we get moving fast. I would prefer that we say that the train has already left the station and we have to act yesterday. Everything we do, or don't do, depends on how severe the problem gets.

Senator KERRY. But let me continue on that, because I want to pick up on what Senator Ensign is saying. Look, I've—in all the years I've been here, I've always advocated not picking winners and losers. In every policy we've tried to adopt, we haven't tried to pick a winner or loser. But there is a distinction between, quote, "picking a winner or loser" in a particular technology in a particular field and making a clear policy judgment that carbon producing, fossil fuel burning is not what we want, and we have to have clean and/or alternative. Now, that's not picking a winner or—in a sense, it's picking a winner or loser, in a macro term. We've got to do that. I don't think we have any choice but to do that. You said to monetize—it would be great if we could monetize it. The best way that I can of monetizing it is to have a carbon cap. That effectively monetizes it, doesn't it?

Mr. ECKHART. Exactly.

Senator KERRY. Doesn't it?

Mr. ECKHART. It does.

Senator KERRY. And it does it fairly simply. We're not sitting there actually establishing the price, per se. It's going to happen in the marketplace. But we're at least beginning to establish some cost to the downside of what we're doing. Heretofore, we've had phony pricing of goods.

Mr. ECKHART. Exactly.

Senator KERRY. Goods are priced, but they don't reflect the real cost to any of us, because the citizen is picking up the back-end cleanup, the cancer, the hospitalization, the asthma, all the rest of it. That's the cost. So, somehow you've got to find a way to get the real cost in there. And then the marketplace can go to work and say, "Well, that's not really worthwhile." But, in that regard, it seems to me, solar, in macro terms, and the alternative renewable, and wind, are the only things we know of to really—and geothermal—we ought to embrace with some major tax credit or some kind of policy that says, "You choose if you want solar or if you want wind or if you want this." But, in macro terms, we ought to be directing the policy and creating a framework for those choices, shouldn't we? I'd like everybody to answer that. Is anybody opposed to that?

Mr. PRINDLE. I could offer an opinion on that, Senator When we look at the policy picture and we look at the carbon imperative, particularly, the good thing about carbon, from a policy point of view, is that it tells you how good you have to do in the energy market, because it tells you what the trajectory has to be of carbon emissions. And so, that helps us decide, "Well, we've got to accelerate energy efficiency at least this rate, we've got to accelerate renewable development at at least comparable rate in order to hit some kind of carbon target." And so, in a sense, the carbon imperative, I think, has given us a performance target for energy markets, overall. And, you know, from the energy efficiency point of view, we think cap-and-trade is a good overall framework, and yet energy efficiency occurs down at the customer end-use level. And so, if you set it—if you set the cap at the power-plant level, you can't actually claim that end-use efficiency savings is a carbon credit, because it's not a direct carbon emission reduction. And so, there are some things you have to do around the edges——

Senator KERRY. Sure.

Mr. PRINDLE.—applying standards and so on.

Senator KERRY. Which is why you have to have a fairly significant——

Mr. PRINDLE. Right.

Senator KERRY.—energy efficiency component. And I think most of the bill——

Mr. PRINDLE. Right.

Senator KERRY.—Senator Snowe and I have a bill, and there are a couple of others out there, they all embrace that kind of efficiency——

Mr. PRINDLE. So, it's a kind of a hybrid. You need carbon cap-and-trade as a——

Senator KERRY. I understand. It's not——

Mr. PRINDLE.—framework——

Senator KERRY.—the whole deal.

Mr. PRINDLE. Right.

Senator KERRY. Believe me, I understand. It's not the whole deal.

Mr. PRINDLE. Right.

Senator ENSIGN. Mr. Chairman, could I add one——

Senator KERRY. Sure.

Senator ENSIGN.—thing to your——

Senator KERRY. Yes.

Senator ENSIGN.—question that maybe the witness——

Senator KERRY. Absolutely.

Senator ENSIGN.—could address? Because I haven't heard it today, and it at least needs to be discussed, although that's a little dangerous coming from Nevada, but it's nuclear power. Nuclear power, obviously, has certain negative aspects, as far as my State's concerned, but it at least needs to be part of the discussion.

Mr. PRINDLE. Well, I'll just add that. We don't take a position on particular supply technologies, but what we do look at is the capability of energy markets to deliver resources under today's conditions. And what we see is that it's just tougher than ever to bring power plants, to bring LNG facilities, to bring pipelines and transmission lines into service. There are capital problems, siting problems, permitting, and so on. And so, the markets are really constrained. And so, from that point of view, we view energy efficiency as the first fuel, in that it buys enough time to bring—whether it's nuclear, clean coal, renewables, even natural gas—to market. In any of those cases, you're going to—we're going to need to moderate demand growth to have a chance to catch up with where demand growth has been taking us.

Senator KERRY. Do the rest of you want to—go ahead.

Dr. SRIDHAR. Senator, I think you've heard this stated many times before, but it's worth stating again. For this particular problem, there is no one single silver bullet as the solution. And, for that reason, I don't think there is one single policy that's going to solve the problem either. So, from a cap-and-trade perspective, it does two things. At the end of the day, that increases cost. And when cost goes up, in a way it addresses the conservation issue, because you don't waste something that's expensive. So businesses are going to react to that from that perspective, of making sure that they use it, but they don't waste it.

Now the thing that we've got to be extremely aware of, which is what you're going after, which is the global warming issue——

Senator KERRY. Can I just say, Doctor——

Dr. SRIDHAR. Yes.

Senator KERRY.—it doesn't necessarily—I mean, there's a capital cost, but, in fact, a lot of companies, by doing the efficiency piece, are reducing the emissions, effectively meeting a cap, and lowering cost.

Dr. SRIDHAR. Absolutely.

Senator KERRY. Saving money.

Dr. SRIDHAR. Absolutely. So, what I'm trying to say is, that's the low-hanging fruit that's going to get you the first fraction of what you're looking for. But I'm going past that——

Senator KERRY. Ultimately, you get into a——

Dr. SRIDHAR. Yes.

Senator KERRY.—demand curve that goes——

Dr. SRIDHAR. Yes. Yes.

Senator KERRY. I understand that.

Dr. SRIDHAR. I'm trying to go past that, you know, because that, alone, is not going to solve the global warming——

Senator KERRY. And that's where the technology has to save us.

Dr. SRIDHAR. So there are two things. Number one, when we do that, it also buys us the moral right in a global platform to say, "We, as the largest consumer of energy, are doing something about it," so now we can speak to the world with a moral authority, saying, "We are putting our money where our mouth is, we are putting our policy where our mouth is." So, I think, from that perspective, it's very good.

But that leads to the important thing that global warming is really a global problem, and the CO_2 knows no boundaries, and it does not require a visa to get into this country. So, we are going to have the same CO_2 that comes from anywhere else. And therein, finding technologies that can create clean energy at equal or lower cost, and not have to pay for green, has to happen. And the history of technology suggests that it always happens. So, while we are doing things on cap-and-trade and anything else, I think a very robust parallel process of figuring out where the next breakthrough is going to come, technologically, is extremely important.

You asked the question, because there's a time clock ticking on this, Do we pick winners and losers here? Well, it's extremely difficult for the Federal Government to do what a venture capital model would do. The venture capital model says, you know, "Internet security is extremely important. I don't know what's going to succeed or not. I'm going to invest in 15 companies."

Senator KERRY. Sure.

Dr. SRIDHAR. "Maybe two of them will succeed, other 13 fail. I don't care."

Senator KERRY. Well, I agree. But, you see, where we're missing each other is—we have no disagreement of that. I'm not trying to come into the field of Internet security and say, "Let's pick this." But I am trying to say Internet security is important.

Effectively, what I'm saying here is, I mean, everything that I've read on this, we—I mean, solar is big-time free, renewable, clean, it's about 30 cents—30-plus-cents a kilowatt now. If we were to get that down in half or more, we'd begin to, you know, become competitive, you know, it would be out there more.

Two, wind. We know that wind is a big future potential resource, but there's only about 6 percent of the country has an availability to put in place, but that's pretty significant. It's a big growth piece. It's going to be part of the mix, correct? So, we've got two pieces we know are clearly going to be part of the mix.

Geothermal, unclear as to how we do what you're talking about, but clear that it's there—great, renewable, free, so forth and so on, except for the capital cost of getting at it, obviously—we ought to embrace.

I mean, beyond that—and then, the question was raised by the Senator, on nuclear—I think there is going to be some pressure on nuclear. But Wall Street is going to decide that one, because the economics of it aren't great yet. And then, you have the proliferation and waste issues that just remain monumental. So, I don't think it's going to be the big embraced vision of the future, but it's going to be part of the mix. I think there are 160-plus plants that are currently in design, globally. I think there are some—I forget the number here in the United States—pretty significant number right here, maybe 40 or—I can't remember exactly the number. But there are fairly decent number of plants that are going to be built here.

What we can't allow to happen—we just can't allow it to happen—is having China build one pulverized coal-powered plant per week. Can't do it. And until TXU cut a deal, we didn't have any ability to go in and begin to say it. We still, I don't think, are where we need to be with that, because we're still going to build, apparently, three plants, and not according to the IGCC or other standards. So, we're going to have to take the lead here in order to leverage China or other countries. And that's why I think the Government has a responsibility, because of the short window, to pick the biggies that are out there and create some sort of incentive for your venture capital and others to go rushing in, and you'll decide which one of these is really going to ultimately work.

But what's the matter with—if you have a 10-year window and the urgency we have and the size of the problem we have to overcome—with creating that framework? Is there some problem with that?

Dr. SRIDHAR. Absolutely no problem. As long as you base it on performance standard and say, like you said, wind, solar, anybody can compete with that and win; and whoever comes to the table with the best-value proposition wins.

Senator KERRY. Yes, Mr. Eckhart?

Mr. ECKHART. Senator, I think there's a combination of two things that will get you what I think you want, which is the cap-and-trade, to get us moving on carbon; and second is to move toward performance-based incentives, the monetization of environmental benefits. That combination will both force action with the carbon cap-and-trade, providing a business environment, and, second, shift the incentives toward buying the benefit, not pushing technology. If we're buying the benefit, if we're putting public money on buying clean energy, no-polluting energy, rather than on pushing individual technologies, then the Government is out of the business completely of picking technology winners and is, instead, encouraging the country to shift toward a cleaner, lower-carbon environment. That combination of performance-based incentives and the carbon cap-and-trade, I think, will rocket this thing forward, if we can just do those two things.

Senator KERRY. Well, that's good—that's a good thought.

With respect—I mean, would you go anywhere, other than those that I mentioned, in terms of what you put into the pot of those incentives you're creating?

Dr. PRELI. Well, I think if you're performance-based on your incentives——

Senator KERRY. Well, let me give you an example. For instance, there are—there's an increasing awareness of the potential tension in overly encouraging ethanol, for instance, corn-based at least, and so forth, in terms of land use, water use, energy use, and the production thereof, and so forth. How do we handle that, in your judgment, if you're going to encourage renewables? Are you going to let the market decide that, or should we be guiding that somehow, in terms of good ag policy, as well as good environmental policy?

Dr. PRELI. Well, I think it's—that's a matter of setting the ground rules. So, if you're careful about your well-to-usage analysis, then you will be able to determine the environmental impact; cellulosic ethanol versus corn ethanol, for example.

Senator KERRY. We're not there with cellulosic ethanol.

Dr. PRELI. And I think that's exactly the point, is that you would make a decision on, How far do you want to go with corn-based ethanol, and how much effort do you want to put into the other technologies that might have a much bigger impact? So—and you can get to the decision, I think, rather easily by looking at CO_2 production along the value stream. And you can evaluate the other technologies in exactly the same way. I think what you'll find is that there are some near-term things you can do that help a little, but you probably should do them, and you should also be investing in some of these longer-term things that will get you to the amounts of CO_2 reduction you need. And DOE has mapped that out, last fall, in their climate change report. The amount of CO_2 reductions are—the volume is staggering. And no technology that exists today really can practically accommodate those. So, a lot more needs to be done to make current technologies far more efficient, and even to develop new technologies.

Senator KERRY. Of?

Dr. PRELI. Energy production with a smaller CO_2 footprint.

Senator KERRY. OK. Energy production, generally, with a smaller footprint.

Dr. PRELI. That's right.

Senator KERRY. Your Chena—"Cheena" or "Chayna"?

Dr. PRELI. "Cheena."

Senator KERRY.—Chena Hot Springs Resort operation, is it 30 cents a kilowatt hour?

Dr. PRELI. They pay 30 cents a kilowatt hour if they're firing up diesel generators to produce the electricity. They pay about 7 cents a kilowatt hour with the geothermal.

Senator KERRY. Gotcha. OK. I was curious about that. Is UTC involved in other kinds of research, other than the cell? The——

Dr. PRELI. Sure. We have a big focus on co-generation equipment, which is point-of-use heating, cooling, power, all from one system. And that's something you can do very easily. We can use microturbines, we can use reciprocating engines on natural gas, we can use fuel cells. And those systems all can get you from a 30-percent-or-so efficiency all the way up to 80 to 85 percent, because you're using a lot more of the input energy. So, distributed generation is a real good way, in the short term, to dramatically reduce energy use.

Senator KERRY. Well, that's been something that we've long—in the electricity deregulation, we sort of pushed for that concept.

Dr. PRELI. That's right. And the Government really can help by making it easier to do these co-gen——

Senator KERRY. Right.

Dr. PRELI.—the amount of work to site a co-gen application—even though the benefits are tremendous, the amount of work to do that, with the current rules and regulations, is sometimes ominous.

Senator KERRY. Right.

Dr. PRELI. Or onerous.

Senator KERRY. Dr.—yes.

Dr. SRIDHAR. Can I add to Dr. Preli's comment? If you're building refrigerators, the way it exists today in the DG market is for every county, every zip code will have to custom make it for a certain local law. We need uniform interconnectivity standards. And that doesn't exist in the DG field. And that's a huge——

Senator KERRY. In the—which field?

Dr. SRIDHAR. In the distributed generation field.

Senator KERRY. I see. Yes.

Dr. SRIDHAR. So, that's an important policy issue.

Senator KERRY. Fair enough.

Mr. PRINDLE. We did a study of state distributed generation, interconnection policies, as well as the utility rate policies that go along with them, because when you try to bring a facility—interconnect it into the grid, you have to pay for studies, fees, permits, time delays. And then, utilities will often charge you, well, some would say, predatory rates for standby or supplemental power, to make the project essentially uneconomic. And some States do better than others. I'm happy to say Massachusetts is one of the better ones. But there are some States that have a ways to go in modernizing their interconnection policies. And in the Energy Policy Act, there was a limit as to how much federalism could move on imposing those on state utility commissions.

Dr. KATZER. I want to make a couple of relevant comments.

Senator KERRY. Dr. Katzer—yes.

Dr. KATZER. Yes, Senator Kerry. I want to make two comments. In our forward modeling that was part of this study, and that focused on how to stabilize CO_2 concentrations, it is clear that first off you need all of the above. And, in fact, energy conservation and efficiency is the biggest piece of the wedge as it comes out. Biomass and renewables are also large. And you need CCS, which is where we spend most of our focus on coal to power, and other products such as fuels and petrochemicals.

Senator KERRY. CCS being, carbon capture and sequestration.

Dr. KATZER. Yes, carbon capture and sequestration.

CCS can be applied to other stationary emissions of CO_2. But that was not a focus of our study, but much of the same technology and many of the same issues apply.

Senator KERRY. Besides IGCC, didn't you talk about an alternative methodology?

Dr. SRIDHAR. Pulverized coal.

Dr. KATZER. Yes, pulverized coal, with CO_2 capture added at the back end of the future gas train.

Senator KERRY. At the back end.

Dr. KATZER. And oxy-fuel, which allows compression of the whole flue gas directly without CO_2 separation.

Senator KERRY. Right.

Dr. KATZER. Oxy-fuel reduces the cost of capture without having to do any separation. We need all of these technologies to supply your energy demand and to meet constraints on CO_2.

The other piece of this, though, is, that our energy and emissions modeling involved the world as a whole; that is a global model. If you now look at the world as it really is, you've got China with over a billion people doing what it is doing, as you mentioned. You've got India with another 1.1 billion people, and the economy's growing rapidly. With China, we've seen what has happened, since coal is their primary resource, and they're just using it in enormous quantities. They've doubled their amount in the last 10 years.

Senator KERRY. I know.

Dr. KATZER. That is a few years.

Senator KERRY. I know.

Dr. KATZER. India, coming along. I think, you know, if we can establish an effective, lower-cost way to capture and sequester carbon, that is CO_2, from coal, we have a bargaining position to deal internationally with these countries, and to get them on the train somehow.

Senator KERRY. I couldn't agree——

Dr. KATZER. If we don't do it, we have no bargaining leverage.

Senator KERRY.—with you more.

Dr. KATZER. And to establish bargaining position we have to do it fast; we have to establish the technology and get on the innovation curve.

Senator KERRY. If we don't do it——

Dr. KATZER.—If we don't, we're losing our technology position in the world.

Senator KERRY.—it's "Katie"——

Dr. KATZER.—Technology and political leverage.

Senator KERRY.—"bar the door." I totally agree with you. That's the urgency of this.

Yes, Mr. Eckhart?

Mr. ECKHART. Senator, back to the 10-year issue or starting yesterday. The reality is—and nothing against other longer-term questions, but the reality is—and I would submit that the only strategies to deal with these problems in the next 10 years, and to have any impact in the next 10 years, is, number one, energy efficiency; number two, renewables. That's the whole deal, in the short term, to actually begin to impact. And I would recommend a plan that I know you know well, which is the California Action Plan, that mandates that the utilities there, and the energy companies, must maximize on efficiency first, must then fill out, completely, their growth with renewables, and only turn to fossil fuel generation if those two can't be done.

Senator KERRY. Well, we passed a—you know, we passed a renewable portfolio standard in the Senate. It was lower than what I wanted. I heard your—in your testimony, you talked about 2020. I proposed 2020 as part of the campaign in 2004. I thought it should be a national standard, 3 years ago, that we needed to have a goal of 20 percent renewables by the year 2020. It was achievable, and based on the California experience. They were already at 13 and 14 percent, 3 years ago. And, you know, they've been leading the way on this.

So, we are going to—I've talked to Jeff Bingaman, and we're working on this. I think—we're going to go for 15 percent, at least, renewable portfolio standard this year, and try and get it in place, and we'll put a national standard in place. So, we need that. But I have to tell you, I'm not sure that either of those two are going to be enough without, you know, some sort of an urgent leverage with respect to the China/India piece. And it may be that, with respect to China and India—I mean, if you can't push the curve fast enough on, you know, CCS and on one of these technologies to deal with it, you may have to wind up suggesting to them that we—everybody help them build a nuclear plant. I hate to say that. But I—but right now my preference would be to do that than build the coal plant, because it's that dangerous. I mean, that's really—if you don't get IGCC in place. Now, can we? I think, yes. I do not believe—I'm told that, for every dollar spent on alternative renewable, geothermal, et cetera, you get a much better return than you're ever going to get in a nuclear plant. So, clearly the nuclear doesn't have to be the choice. And preference shouldn't be, because we haven't worked out a sufficient proliferation regime or a sufficient waste regime.

But these are—these issues can't be left dwindling very—you know, few folks—you know, to be speaking about it, nationally and publicly—the governments have got to sit down and start to really move on this, negotiate it. And, regrettably, we've got one that still thinks the Earth is flat, so it's a problem.

Dr. SRIDHAR. Senator, the problem with India and China is, even if we had to resort to nuclear, that cannot be the only option, because you would need one new nuclear power plant in construction started every 2 weeks——

Senator KERRY. Correct. And you won't get there——

Dr. SRIDHAR.—every 2 weeks.

Senator KERRY.—fast enough. In addition, I think——

Dr. SRIDHAR. Yes.

Senator KERRY.—you also have major fuel problems——

Dr. SRIDHAR. Yes.

Senator KERRY.—because you don't have enough——

Dr. SRIDHAR. Yes. We don't——

Senator KERRY.—fuel, in the long run.

Dr. SRIDHAR. So, that can be "a" solution, but not the "only"——

Senator KERRY. Right.

Dr. SRIDHAR.—solution.

Senator KERRY. A piece of it. No, I'm not suggesting it's the—ultimately, you've got to get into the clean and alternative. I understand. I was just talking short term.

Mr. ECKHART. I'd like to agree with your comments on China. We were there recently, and many times in dealing with them, and I recently said they're—you know, they've made a commitment to 15-percent renewables by 2020, and we coined a phrase there that we're not going to deal with the problem until China commits to being 15 percent nonrenewables by 2020. If they're 85 percent nonrenewables, we have the problem you pointed out, the 1,000 megawatts a week of coal-fired power, which will live in infamy forever.

I'd like to add, on the RPS, the national RPS, the possibility that you would consider a national RPS that encourages every State of the Union to have an RPS of some level, even if it's 0.1 percent, but that every State shall have an RPS of some kind. Even in the South, they have plenty of ag waste, biomass, that they could have some participation. And that would be a solution I have not heard discussed.

And, second, you might add to that——

Senator KERRY. As opposed to a national standard?

Mr. ECKHART. Well, maybe the national standard is to have a——

Senator KERRY. If we have a national standard, every State's going to effectively have to meet it.

Mr. ECKHART. Well, if it—well, a national goal is certainly argumentative, but if the Federal Government simply required that every State have a standard, and then created a trading system to trade the renewable energy certificates between the States, so that Wall Street could monetize that, create a futures market, and then we're monetizing environmental benefit——

Senator KERRY. That's an interesting idea. It's a possibility. Sure.

Mr. ECKHART. Appreciate it if you could take that up or—maybe——

Senator KERRY. Yes.

Mr. ECKHART.—with the staff, later.

Senator KERRY. We will. Appreciate that.

Well, listen, I thank you all. It's—this is the challenge, I'll tell you. If you want to pick the domestic challenge—sure, we've got budget issues and Medicare, Medicaid, healthcare, you name it, but they're going to pale beside the consequences of this.

And if you look at the—you know, you read the Stern Report and other analyses, it is clear that the cost of not doing anything is 5 to 20 times the cost of doing something. And when you look at the 1-percent-of–GDP prediction about potential cost, this becomes sort of a no-brainer. I mean, it—we've got to get going.

So, I appreciate your testimony today. It's been very, very helpful. We appreciate your work. We will follow up with you. There are going to be further hearings, and we're going to continue to push this pretty intensely around here.

Thank you.

We stand adjourned.

[Whereupon, at 4:15 p.m., the Subcommittee was adjourned.]

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