S. HRG. 110–246

GEOTHERMAL ENERGY INITIATIVE

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON S. 1543, A BILL TO ESTABLISH A NATIONAL GEOTHERMAL INITIATIVE TO ENCOURAGE INCREASED PRODUCTION OF ENERGY FROM GEOTHERMAL RESOURCES BY CREATING A PROGRAM OF GEOTHERMAL RESEARCH, DEVELOPMENT, DEMONSTRATION AND COMMERCIAL APPLICATION TO SUPPORT THE ACHIEVEMENT OF A NATIONAL GEOTHERMAL ENERGY GOAL

SEPTEMBER 26, 2007

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WEDNESDAY, SEPTEMBER 26, 2007

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Jeff Bingaman, chairman, presiding.

OPENING STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Thanks to everybody for being here. I'd particularly like to thank our witnesses for their willingness to testify before the committee.

This is a legislative hearing on S. 1543. The bill focuses on how to develop a more secure domestic energy program based on clean, renewable energy from geothermal resources.

In the next several decades, our Nation will continue to face concerns over our energy supply and security. This will result in even greater energy demands at a time when many existing power plants will be retired, or be replaced. There's growing concern about greenhouse gas emissions and global warming. All of this makes it critical that the United States come up with a less carbon-intensive, and balanced energy portfolio, including renewable energy, energy efficiency, and clean hydrocarbon production.

The Massachusetts Institute of Technology estimates that 50 gigawatts, or more, of coal-fired electrical capacity will need to be retired in the next 15 to 25 years, due to environmental concerns—mainly atmospheric carbon dioxide emissions. Additionally, as much as 40 gigawatts of other existing power resources may have to be decommissioned in that same timeframe. As a result, there's an even greater need for reliable, low cost, electric power and heat supply for our Nation.

Today we are very fortunate to have as a witness President Grímsson, of the Republic of Iceland. President Grímsson comes to testify before the committee today to highlight the efforts that Iceland has undertaken in producing clean, affordable, renewable energy from geothermal resources. The island Nation is the world leader in geothermal energy development, with nearly 72 percent of its entire energy consumption originating from local renewable energy sources, such as geothermal hydro-power.

The United States can also be a world leader in developing a clean, renewable geothermal resource base. Greater development of geothermal resources—whether through conventional or unconventional technologies—will go far in helping us achieve a more continuous baseload energy capacity, while also decreasing the harmful greenhouse gas emissions that we're putting in the atmosphere.

President Grímsson, welcome. Senator Domenici is delayed a few minutes, and will be here shortly, I'm informed, but let me see if either of the other two committee members who are here would like to make any statement at this time.

[The prepared statements of Senators Salazar, Sanders, and Smith follow:]

PREPARED STATEMENT OF HON. KEN SALAZAR, U.S. SENATOR FROM COLORADO

Thank you Mr. Chairman and Ranking Member Domenici for holding today's hearing on S. 1543, the National Geothermal Initiative Act. I would like to thank Chairman Bingaman and his staff for the work they did to introduce this important legislation. I would also like to thank our witnesses for sharing their time with us, particularly President Grímsson who has come to us all the way from Iceland, a country that is utilizing its renewable energy better than any other country.

Geothermal energy is a clean, reliable resource that reduces the use of fossil fuels, cuts operating costs, and does not release any greenhouse gas emissions. It is also a sustainable energy resource as the hot water used in the process can be re-injected into the ground to preserve the resource. Geothermal resources are quite versatile, and can be used for direct heating applications, and also, if the temperatures are sufficiently high, to produce electricity.

Despite the fact that our nation is the world's largest producer of geothermal energy, this resource accounts for less than 1% of the electricity generated across the entire country. Furthermore, geothermal energy is often ignored in national projections of the evolving U.S. energy supply. As our country moves forward to create a new, clean energy economy, we must take advantage of this resource and find ways in which it can be better utilized.

In Colorado, the town of Pagosa Springs has utilized geothermal energy for over twenty-five years to provide heat for many of its government buildings and commercial establishments. In addition, geothermal heat or water is used in at least 30 resorts and small businesses across the state to heat pools and buildings, raise fish, and grow vegetables. The current use of geothermal energy in Colorado is estimated to prevent the release of over 161,000 tons of carbon dioxide each year. In addition, the use of the geothermal resources is estimated to create 3,000 jobs, and the geothermal businesses pay local, state and federal taxes.

But in Colorado we could still do more. It is estimated there is enough concentrated geothermal energy to provide hot water and heat for 100,000 homes. Geothermal heat pumps are particularly beneficial in Colorado. Some school districts have, or are considering, using these systems, and utilities are looking into heat pumps as a way to meet their load reduction goals. The Delta-Montrose Electric Association (DMEA) in Colorado, a non-profit cooperative, has done great work promoting direct use of geothermal energy including ground source heat pumps (GSHPs). According to DMEA, the one million GSHPs currently in use in the U.S. today reduce our country's dependence on imported fuels by 21.2 million barrels of crude oil per year.

Colorado may also have the potential to generate electricity from high temperature geothermal resources in the Arkansas River and San Luis Valleys in western Colorado, and this resource is virtually untapped today.

This is why the National Geothermal Initiative Act is so important. If we increase our research and development of this clean and safe energy resource, we will be taking another step towards our country's energy security.

This hearing will help to highlight the importance of this resources and what it means to our nation's future. I look forward to hearing from the experts we have here today, and would like to thank Chairman Bingaman and Ranking Member Domenici once again for addressing this issue.

PREPARED STATEMENT OF HON. BERNARD SANDERS, U.S. SENATOR FROM VERMONT

Chairman Bingaman, Ranking Member Domenici, I am proud to join you as a sponsor of this bill, S.1543 which would promote the development of clean renewable geothermal energy.

We should do more to encourage research and demonstrations of geothermal energy in this country. It is a clean renewable source of energy that is dispatchable, that is, it is available for use at all times and not intermittent like some other forms of renewable energy. Geothermal energy can thus be a terrific backup energy source for wind and solar when the sun is not shining or the wind is not blowing.

This bill will be a good first step in helping our country achieve the goal of greater use of this emerging technology, one that will doubtless create lots of new jobs across our nation and reduce greenhouse emissions.

PREPARED STATEMENT OF HON. GORDON H. SMITH, U.S. SENATOR FROM OREGON

Mr. Chairman, I appreciate your convening this hearing on S. 1543, the National Geothermal Initiative Act of 2007. I would like to welcome President Grimsson of Iceland and the other witnesses who will appear before us today.

I strongly support the goals of this legislation, which is why, Mr. Chairman, I have just agreed to cosponsor this bill. I commend you for setting a strong national goal for geothermal electricity generation, and for reestablishing a program within the Department of Energy to help achieve this goal. Geothermal is a base-load resource that will help Oregon and the nation reach the goals of energy security, sustainable economic development, and reduced greenhouse gas emissions.

Oregon is a state that could benefit substantially from geothermal development. While there are no power plants in operation today, there are four projects currently under development. Oregon does have existing direct-use sites where geothermal is used for building energy needs, as well as an established Geo-Heat Center at Oregon Institute of Technology. The Western Governor's Association Geothermal Task Force estimates that by 2025, geothermal power plants in Oregon could produce 1,250 megawatts of electricity.

The United States is already the world's leader in geothermal electricity production, with 2,800 megawatts of capacity. We need to maintain that leadership, and this bill will provide the research and development, as well as other important assistance, to achieve that goal.

I remain concerned, however, that the federal agencies that administer public lands in the Western United States will not have the resources to administer their respective leasing programs effectively. For national goals to be realized, these agencies must be able to keep up with the growing demand for access to geothermal resources on public lands. We must ensure that agencies have the necessary personnel to facilitate the timely development of geothermal resources in accordance with federal environmental statutes.

Mr. Chairman, in closing I'd like to point out that while S. 1543 has an aggressive goal of using geothermal resources to generate 20 percent of our nation's electricity by 2030, this is not an entirely new goal. In 2000, then-Secretary Bill Richardson announced an initiative called "GeoPowering the West." It set a goal of meeting 10 percent of the electricity needs of the West with geothermal by 2020. We need to ensure that the Department of Energy oversees an effective program that will enable developers to turn these goals into reality.

I look forward to hearing from the witnesses today, and to working with you, Mr. Chairman, and the other cosponsors to move this legislation forward.

Senator Murkowski.

STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

Senator MURKOWSKI. Thank you, Mr. Chairman. I do have a longer statement that I wish to submit for the record. But just very briefly, I too, want to welcome you, President Grímsson. It is, indeed, an honor to have you before this committee. Your passion about how we can do better, and specifically in the area of geothermal energy has always been inspiring in our private conversations, and I'm delighted that you will be able to address the full committee today.

Mr. Chairman, I want to thank you for holding this hearing. We have set a goal in our legislation here of getting 20 percent of our power from geothermal energy, and while this may be overly optimistic, as a co-sponsor of this measure, I think that the National Geothermal Initiative Act of 2007 is a very important step for this Nation to get on with developing alternative energy.

Coming from the State of Alaska, where we have at least 50 percent of our State's communities that could theoretically tap into hot water from inside the earth to produce electricity, this is an area where we are very optimistic. Alaska has nearly a dozen proposed geothermal projects right now that could proceed, if there was additional Federal assistance to help in the identification of specific geothermal well sites, or aid in improving drilling, or assistance to develop geothermal turbines that operate more efficiently at the low water temperatures.

Some have suggested that geothermal is a mature technology. I would argue that contention. Even though we've been trying to promote geothermal technology for decades, there's still considerable work that needs to be done to lower the cost of high-temperature geothermal, to improve the technology, so that we can produce electricity from the lower-temperature water.

Mr. Chairman, again, I have so much that I want to add on this, in terms of what Alaska is doing, what we are looking to do. I'll try to include that in my questions for the witnesses, so that we can get to this very distinguished panel.

With that, I thank you.

[The prepared statement of Senator Murkowski follows:]

PREPARED STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

Mr. Chairman, thank you for holding this hearing. While the goal of this nation getting 20% of its power from geothermal may be overly optimistic, as a co-sponsor of the measure, I think the National Geothermal Initiative Act of 2007 is an important step for this nation to get on with developing alternative energy.

I come from Alaska, a state where at least 50% of the state's communities may theoretically tap hot water from inside the earth to produce electricity. Alaska has nearly a dozen proposed geothermal projects right now that could proceed, if there was additional federal assistance to help in the identification of specific geothermal well sites, or aid in improving drilling, or assistance to develop geothermal turbines that operate more efficiently at lower water temperatures.

With fuel prices at near record highs, hot water heated naturally by the earth sports a zero fuel cost. But geothermal power only provides the nation with three-tenths of a percent of its electricity at present—because of the currently high capital costs of siting and building geothermal plants.

Geothermal is not yet a mature technology. Even though we have been trying to promote geothermal technology for decades, there is considerable work still to be done to lower the cost of high-temperature geothermal and to improve the technology so that electricity can be produced from lower temperature water—expanding the applicability of the process nationwide.

For example, we still haven't updated a national geothermal mapping assessment started in 1978—and never totally conducted in detail in much of Alaska.

MIT in a recent report suggested that geothermal power holds the promise of providing low-cost electricity for most of the nation, if the federal government would increase its research and financial assistance to help prove new technology—the technology to "mine hot dry rocks" or inject water deeper into the earth to heat up, rather than simply tapping natural hot water springs or only using heated subsurface water pools closer to the surface where they are known.

This act will create a geothermal initiative that will lead to the completion of a geothermal resource base assessment by 2010. It will encourage demonstration plants to show the full range of geothermal production and push new technology in the engineering of geothermal plants.

Besides restating a federal commitment to geothermal, it will fund a national exploration and research effort and the development of geothermal information centers.

Just last year there was a major success in Alaska, where a local geothermal developer Bernie Karl, who owns a small geothermal spring resort at Chena Hot Springs outside of Fairbanks, utilized new technology designed by United Technologies to produce electricity from relatively cool water, water only 160 degrees in temperature, For just a $1.5 million federal grant, work at Chena Hot Springs has confirmed that economic electricity can be generated from relatively low-temperature geothermal resources.

That opens the door to many more communities in Alaska potentially benefiting from geothermal power and shows the importance that federal legislation provide aid for both low-temperature and high-temperature geothermal research in the future. If I have any concerns about the proposed bill it is that it doesn't specifically address low-temperature geothermal sufficiently.

Right now besides Chena, there are geothermal projects at Akutan, at Unalaska, at Mt. Spurr near Anchorage, near Naknek, at Tenakee Springs in Southeast, at Pilgrim's Hot Springs in western Alaska, all ready to potentially produce power, if there is more federal assistance to help lower the cost of their development.

Some may argue that federal aid is not needed since geothermal is a mature technology. But new technology development, according to the MIT report, could result in geothermal power providing America with 100 gigawatts of electricity within 50 years, a significant portion of its future power needs without the risk of supply disruptions or fuel price fluctuations.

And of course geothermal power produces no greenhouse gas emissions and releases no carbon to the environment—a significant advantage given current concerns over global warming.

Right now there are researchers in the Alaska Aleutians hoping for federal grant research to test whether new types of unmanned aerial vehicles can be used to pinpoint geothermal hot spots, the exact spots where wells should be sunk to tap hot water resources. For a nominal grant, this technology could be proven up that would save all geothermal projects many millions of dollars in drilling costs. This one project is an example of why more federal aid is needed and useful.

Currently seismic engineers are in the field between Naknek and King Salmon in Alaska testing the likelihood of finding enough hot water to power most of the Bristol Bay region in Alaska—an area where electricity currently costs more than 30 cents per kilowatt hour. A find could produce a major power source to bring economic electricity to 17 villages in the region.

This bill would authorize a couple hundred million dollars in federal funding for all forms of geothermal work over the next five years. That is less than we have authorized for other forms of renewable energy in the Energy Policy Act of 2005 or have proposed for biomass, wind, solar or hydrogen fuel development in EPACT.

Geothermal really is a stepchild among renewables. Along with ocean energy it received relatively little federal assistance in EPACT two years ago. But geothermal is like the stepchild that is on the verge of inheriting the family estate. If we encourage geothermal development it will pay big dividends to the nation. If we spend money now to advance geothermal technology, it will help the entire nation, not just in the West, but across the country.

I look forward to the testimony on this important type of alternative energy for the nation.

The CHAIRMAN. Thank you very much.

Senator Akaka, did you want to make an opening statement? Go ahead.

STATEMENT OF HON. DANIEL K. AKAKA, U.S. SENATOR FROM HAWAII

Senator AKAKA. Yes, Mr. Chairman.

Good morning, everyone, and Aloha. First, I would like to thank the Chairman, Chairman Bingaman, for all of his leadership and hard work in ensuring that the energy challenges and solutions facing our country have remained at the forefront of our work and discussions here at the U.S. Senate.

I commend you, Mr. Chairman, and your staff, for putting together this very important discussion regarding the production of geothermal energy, so we can discuss the possibilities in forwarding this technology as a substantial source of clean, renewable energy. I thank you very much for adding me as a co-sponsor to this bill.

I would like to extend a warm welcome to President Olafur Ragnar Grímsson of Iceland. It is an honor to have you here today, and I look forward to hearing about how you have been so successful in the transformation of your country from one that was dependent on fossil fuels, to one that is now relying on clean, renewable energy.

I am truly impressed by the substantial progress you have made in this regard, and look forward to the possibilities of our partnership with you. As we learn from your experiences and success in this regard.

I want you to know, Mr. President, that in my home State, the first geothermal energy power plant went online in the Island of Hawaii in July 1981, producing just 3 megawatts of power. Today, we have a plant providing a constant 30 megawatts of firm, renewable energy which makes up 20 percent of the Island's power use, and 31 percent of Hawaii's renewable energy resources.

This is obviously at a much smaller scale, but it is substantial when you consider Hawaii's unique energy challenges, as a small island State. As you can see, we have benefited from this technology for quite some time, and I look forward to seeing an even greater potential for this in the area of renewable energy across this country.

Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Senator Barrasso, go right ahead.

STATEMENT OF HON. JOHN BARRASSO, U.S. SENATOR FROM WYOMING

Senator BARRASSO. Thank you very much, Mr. Chairman, thank you, Mr. President for being here with us today. I am looking forward to being further educated today on the issue of geothermal energy production, looking forward to these hearings.

My philosophy, being from an energy State, where we have extraordinary natural resources and energy resources—including hydrocarbons, wind, uranium, hydropower, solar, coal—is No. 1 to support efficiency, and efficient energy use; to support research and development, and investment in new technologies, to support renewable energies, to support alternative energies; and yes, to support fossil fuels, which have served as the foundation for the energy that we all consume, and which have provided us with the standard of living that we all enjoy today.

Mr. Chairman, I'm compelled by the submitted testimony that geothermal energy must be part of the overall domestic energy supply of our Nation. Many benefits seems clear. Geothermal energy appears to be a reliable and a flexible source of domestically produced energy.

Nonetheless, looking at the proposal before us today, Mr. Chairman, I must say, I'm concerned that the goal established may go beyond simply a challenge to government, industry and consumers. I am concerned that this may be an unrealistic bar.

While the goal is simply a statement of desired attainment, the mandates to the Secretary of Energy, and the Secretary of Interior go further than that. Back in the Wyoming legislature, Mr. Chairman, I adhered closely to the idea of a balanced budget. Even in Washington, there is likely a politically imposed, finite level of resources that we are willing to expend.

In light of that, I am concerned, Mr. Chairman, that the proposed legislation could inadvertently or even intentionally reduce our Nation's research and development in other potentially equally important areas of domestic energy production.

In conclusion, Mr. Chairman, I support geothermal energy. I look forward to the testimony of the panelists before us today. I remain cautious—I'm cautious of the proposed goal, I'm cautious of what this means to our Nation's total energy portfolio. I'm cautious of what this means to limited research and development dollars, and cautious about potential unintended consequences if the expectations are overly exuberant.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much.

Senator Craig, did you wish to make a statement before President Grímsson testifies?

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Mr. Chairman, thank you, I will be most brief, and ask that my statement be a part of the record.

For someone from Idaho to be here, interested in geothermal, is pretty obvious. In 1890, the first geothermal wells were drilled in Idaho, we now have over 350 buildings in my State that are heated by geothermal, and we have more geothermal power coming online in Idaho soon, in a 13-megawatt structure. Idaho grows increasingly optimistic of its opportunities because of its geothermal capability.

We also recognize the obstacles, the costs involved, timelines for bringing these very expensive plants online, and all of that.

So, the bill that we're here to have testimony on today, the 20 percent goal that you've put in that bill, Senator Bingaman is a—I call it an aspirational goal. A lot of us are aspirational today about where we want to take our country, when it comes to energy, or climate change involvement—our President speaks of that, we speak of that. Twenty percent is not achievable if we don't come down into the system and allow it, not unlike what we've done for nuclear, to be able to afford it. To offset, you know, wind goes up in 6 months. A geothermal plant, 3 to 5 years from the drilling. Lots of costs out there before cash-flow starts. Nuclear, of course, has a much longer lead time than that.

So, I appreciate what you're doing here, and I'm very excited about hearing from the President and what is going on in his great country. Thank you.

I'll ask unanimous consent my full statement be a part of the record.

[The prepared statement of Senator Craig follows:]

PREPARED STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

IDAHO'S HISTORY WITH GEOTHERMAL

- In 1890 the Boise Water Works Company completed two wells in Boise to create the nation's first district heating system.
- Today 4 district heating systems in Boise provide geothermal heat to about 350 buildings, including the State Capitol.
- Boise continues to explore expanding the use of geothermal heat:

—Boise State University is discussing heating 4 new buildings with geothermal.

IDAHO'S GEOTHERMAL ELECTRICITY PRODUCTION

- Raft River in Southern Idaho was selected by DOE as a demonstration "binary cycle" plant in the 1970's.
- In 1980 the Raft River plant was the world's first geothermal binary operation—commercial scale 7 megawatt (MW) plant.

—Closed due to poor economics (low oil prices).

- In 2002 U.S. Geothermal Inc. purchased the facility with full commercial operation in mind:

—Re-opened wells with support from DOE on a cost sharing basis.
—Commercial 13 MW plant is scheduled to be on-line by the end of 2007.
—Levelized cost of 6.2 Kw/h—(PURPA)
—Currently, exploring further expansion—potential of 110 MW at this site in the future.

GEOTHERMAL OUTLOOK

- The expansion of geothermal resources is a high risk financial initiative—drilling geothermal wells can be compared to prospecting for oil or natural gas.

—Cost from $5—$10 million to drill and identify a good source—takes 1 year or more.
—Its takes 2 years to build a plant at a cost of approx. $40 million.

- Compared to the wind or solar industry, geothermal requires much more up front financing to verify its resources.
- We need to explore ways of reducing the upfront financial risks of these geothermal projects, lets focus on those areas of S. 1543:

—Funding discovery and characterization of resources.
—Funding for cost shared drilling.
—Funding for enhanced exploration and development technologies.
—Funding our National Labs and programs like the "Intermountain West Geothermal Consortium"—lead by BSU.
—Develop the supporting infrastructure—transmission lines etc.

- Setting artificially high goals is meaningless and could lead to a boom and bust cycle that could set this valuable resource back.

—Clean Portfolio Standard (CPS) would be more meaningful.

- This is a domestic continuous base load renewable power source that has little environmental impact—a source too important to not develop.

The CHAIRMAN. It will be included, as will all of the others.

Senator Tester, did you have a statement to give before President Grímsson speaks?

STATEMENT OF HON. JON TESTER, U.S. SENATOR FROM MONTANA

Senator TESTER. I did, thank you, Mr. Chairman. I want to thank you for having this hearing, and I also want to thank the witnesses for coming today.

President Grímsson, very, very good to see you. I really, really appreciate you making the trek to testify and give us your perspective here today.

You know, you truly have a vision for your country, and I think that this country can learn from your vision. Hopefully, we can move forward with some good, progressive, geothermal energy policies that will help this country move towards energy independence.

Geothermal energy is one of the most promising forms of energy in this country, particularly in the West and the South. We produce about 3,000 megawatts in this country, but we can produce much, much more. But we lack so much. We lack an assessment of our national geothermal resource, we need assistance in developing known geothermal opportunities—which you can help us on both of those—and quickly advancing technology, such as enhanced geothermal technologies, and you can help us on all of those, as a matter of fact.

We have good resources in Montana, but not the best. We currently use ground-source heat pumps to heat thousands of homes, and we have dozens of commercially operating hot springs resorts. But, with a little bit of help from you, and others, we can develop more geothermal energy, in the forms of electricity and district heating systems.

I truly do look forward to your testimony here today, and I'm still going to try to twist your arm to get you to Montana. I know you are sending a delegation out there, and we look forward to their visit.

Thank you very much.

The CHAIRMAN. President Grímsson, as you see, you're being welcomed by one and all here on the committee, and we very much appreciate your testimony. Why don't you go right ahead?

STATEMENT OF HON. OLAFUR RAGNAR GRÍMSSON, PRESIDENT OF ICELAND, REYKJAVIK, ICELAND

Mr. GRÍMSSON. Thank you very much, Mr. Chairman, for this warm welcome, and it is indeed both an honor and a privilege for me to be invited to give this testimony here today to your distinguished committee, both on my country's story in this regard, but also perhaps on how the United States can take important steps in increasing the use of geothermal energy.

I have also, in recent months, enjoyed the opportunity to meet many Senators in their offices to discuss this opportunity, and I also want to thank all of you for that courtesy that you gave me earlier this year, respectively.

Iceland is, indeed, an interesting case, because we have transformed or energy system from being—in the early years of my life—over 80 percent dependent on coal and oil, into one in which now 100 percent of our electricity production and the house heating in the country is from clean energy resources. Over 70 percent of our entire energy consumption—including shipping and transport and any other area—is from indigenous renewable resources. All of this has happened in the lifetime of a single generation.

It is my firm belief that other countries can, and many are, in fact, following our example, and the lead in this respect. The United States has the potential to utilize geothermal energy in a major way, contributing not only to your energy system, but also to the security—the national security of the country, limiting the dependence of imported fossil fuel, reducing the risks causes by fluctuating oil prices, and also providing opportunities for new infrastructures, supporting both cities and regions and individual States within the United States, where the resources are located.

I hope the committee will—through your deliberations—come to realize how technical, scientific, business, and policymaking cooperation between Iceland and the United States can, indeed, in many ways, help the United States to achieve this transformation, and thus become one of the leading clean energy countries in the world, but at the same time strengthen the U.S. economy and enhance the security of the Nation.

But let me also emphasize here in the beginning—geothermal energy is not only reliable, it's also secure, it is very cost-effective, it is, in fact, a very good business, and it is a clean energy resource which can provide significant amounts of power to industries, households and businesses in many different parts of the United States.

But, it has also this very valuable characteristics of being very flexible. So, we can in many places, provide large-scale solutions, where in others it can serve a small town, a big city, a few industries, or even a single household—there's no other energy resource that has this flexibility as the geothermal has.

A single geothermal can also be used as a base for many different profit-making business ventures—not only for producing electricity and the heating system for houses—but also to develop tourist centers, spas, hotels, health clinics, produce cosmetics and skin products, as well as greenhouses, cultivation, and snow melting. It's very important when one is examining the geothermal power that these multiple business opportunities that are involved in a single resource make it, perhaps, in my opinion, the most profit-making energy potential of those countries and regions that are blessed with this resource.

We know that in international energy tables, it's often classified as "new renewable." But this is not really the case, because people have—in many parts of the world, from the dawn of civilization—used hot water and hot springs for many different purposes. Electricity has been commercially available from geothermal sources since the beginning of the last century.

But, especially in the last three decades, we have seen enormous progress in this area. The Reykjavik Energy Company, which is the leading company in this field in my country, now currently operates the world's largest and most sophisticated geothermal district heating system in the world, only rivaled in size by a project which Icelanders are now building in the city of Xian Yang, in China. It is, indeed, fascinating for us in Iceland to observe the strong interest in which the Chinese leadership now takes in this area.

As you probably know, the Iceland's energy use per capita is among the highest in the world. The proportion of this provided by renewable energy sources exceeds the figures for all other countries.

But, it's also worth recollecting that it was the oil crisis in the 1970s, fueled by the Arab-Israeli War and the Iranian Revolution, that caused Iceland to change its energy policy in a fundamental way.

The economic benefits from this process—from utilizing geothermal energy—can be seen when the total payments for hot water used for space heating are compared to the consumer cost of oil. The present value of Iceland's total savings made between 1970 and 2000 is estimated to be more than 3 times the country's Gross National Income for the year 2000. A strong indication of how it makes both good business, and strong economic sense to enter into this area.

Other countries can, indeed, do the same. Geothermal resources have been identified in over 90 countries in the world, and According to the excellent MIT report, "A View Toward Geothermal Energy," the potential in the United States from enhanced geothermal system is, in fact, a prominent part of the future energy outlook of this country.

But the key that is important to realize, the keys to a successful geothermal development are efficient and comprehensive interdisciplinary geothermal research, and proper resource management during utilization.

Let me, therefore, conclude my opening statement by identifying some areas where cooperation with Iceland could benefit the United States in the creation of a major U.S. geothermal program.

First, extensive research on geophysical exploration, assessment of low temperature—but also high temperature—and deep and conventional geothermal resources, including the so-called hot, dry rock, and supercritical geothermal resources.

Second, developing and extending existing drilling technology, for example, by drawing on the vast experience gained in the oil and the gas industry.

Third, cooperation between research institutions and universities and financial sectors as now, for example, exists in the Iceland Deep Drilling Project, which has comprehensive involvement from U.S. partners.

Fourth, studying more comprehensive and efficient management of geothermal resources without over-exploiting them.

Fifth, modeling the nature of geothermal systems based, for example, on the methods and the tools already being developed at the Lawrence Berkeley Laboratory in California with a significant contribution from Icelandic scientists.

Sixth, facilitating investments by Icelandic energy companies, banks, and investors, in cooperation with American energy and utility companies, State government, city council and regional authorities. The strong interest from the Icelandic business sectors to enter into such cooperation with American partners is, I think, a strong manifestation of their belief that this is an extraordinarily good profit-making business.

Seventh, supporting the ongoing research project between Iceland and American scientists on how geothermal portholes can be used for CO_2 capture and sequestration, by pumping the CO_2 down the portholes, into the basalt layers which exist both in Iceland and the United States, and where the CO_2 would turn into solid rock, and not escape to the surface later on. It's the only carbon sequestration project in the world which is based on turning the CO_2 into solid rock, without any risk of it escaping later on.

There are—as you can see—a number of areas where cooperation between Iceland and the United States can play an important role to the benefit of both our countries. Here, I believe, the U.S. Senate could take a very important lead.

I hope that my testimony—but also our willingness in Iceland to provide further information—will help the Congress in these important deliberations. In order to support that, I have here with me today the head of the Icelandic Energy Authority, who represents the scientific community in my country, and in this respect, we believe very strongly that new energy cooperation along these lines, between Iceland and the United States, could indeed be a fascinating and a great homage to our longstanding alliance and friendship, but also help to strengthen the U.S. economy, and also the security of your country.

With these words, let me conclude my opening statement. I have also submitted a larger written version with more detailed information, but I am ready to answer any questions that the distinguished Senators are willing to put forward.

Thank you very much, Mr. Chairman.

[The prepared statement of Mr. Grímsson follows:]

PREPARED STATEMENT OF HON. OLAFUR RAGNAR GRÍMSSON, PRESIDENT OF ICELAND, REYKJAVIK, ICELAND

1. INTRODUCTION

It is an honour and a privilege for me to be invited to give testimony to your distinguished committee on my country's story and to discuss how the United States can take important steps in increasing the use of geothermal energy.

I will be describing how Iceland transformed its energy system from being based on peat, imported coal and oil to one in which 100 percent of its energy production is based on clean energy resources, with roughly 72% of its entire energy consumption coming from indigenous renewable sources (54% geothermal, 18% hydropower). The rest of Iceland's energy requirements, for the fishing fleet and transportation, are met by imported fossil fuel.

This change has happened in the lifetime of only one generation, and thus my country has developed from being one of the poorest countries in Europe into one of the most affluent in the world.

It is my hope that many other countries can follow our lead and understand that what is one day considered a tough challenge can become a reality if the right forces and the right policies are put to work.

For the United States of America, geothermal energy can become a major energy resource, contributing to the security of the country, limiting dependence on the import of fossil fuels, reducing the risks caused by fluctuating oil prices and providing opportunities for new infrastructures supporting the cities and regions where the resources are located.

I hope to outline how technical, scientific, business and policy-making cooperation between Iceland and the United States can help the US to achieve this transformation and thus become one of the leading clean energy countries in the world and at the same time strengthening the US economy and enhancing the security of the nation.

I will also show that geothermal energy is a reliable, flexible and green energy resource which can supply significant amounts of power to households and industry. Furthermore, it uses land economically, gives social returns and it is cost-effective.

It is reliable because it provides base-load power 24 hours a day and is available throughout peak hours.

It is flexible and can be tailored to needs accordingly. This is a clear shift from the public debate, which has been preoccupied by "big solutions" in the field of energy, centred on coal, oil and nuclear programmes. In many places, geothermal energy can provide a "big" solution, but in many others it can serve a single city, large industries, a small town or as little as a single household. This flexibility can bring significant advantages.

It is green: When coal is used to produce an equivalent amount of energy, the CO_2 emissions are 35 times greater, according to information from the NREL. Emissions from geothermal power plants contain mostly water vapour and they do not emit particulates, hydrogen sulphide or nitrogen oxides.

It uses land economically: Geothermal plants require by far the least land for electricity production per energy unit compared with all other available renewable sources.

It gives social returns: Many more jobs are created through the harnessing of geothermal energy than by developing other types of renewable energy resources.

And it is cost effective: The cost of electricity produced with geothermal energy in the US is expected to be between five and eight cents per kWh. This is more expensive than the cost of our geothermal power in Iceland which is closer to two or three cents, but according to a new market report from Glitnir Bank it is still far lower than the cost of energy from solar or other renewable sources. This would represent a significant saving for individuals and communities.

2. CLIMATE CHANGE-ENERGY SECURITY-CLEAN ENERGY

For many years now, I have been warning that in the coming decades we will see catastrophic effects of global climate change if humanity does not take immediate precautionary action. Unfortunately, when I first spoke about this threat in my New Year address to the Icelandic nation in 1998, not many people had yet begun to take the issue with sufficient seriousness. Now, however, the world's leading scientists no longer question the reality of climate change but only how much time remains until we reach the point of no return.

For a country such as Iceland, climate change can have disastrous consequences. As an island high in the Northern seas, we are dependent on the Gulf Stream bringing warm water from the Gulf of Mexico. As with other island states and coastline territories, rising water levels can have a devastating effect on our future livelihood. Like most other countries, Iceland has experienced irregularities in weather patterns. We are fighting the biggest desert in Europe and we have the largest glaciers in Europe, which have been rapidly retreating in recent years, allowing us to witness the effects of climate change at first hand and encouraging us to be in the forefront of global action, creating solutions with the best possible partners.

In discussions on climate change that have taken place internationally, frequent reference has been made to the significance of the polar regions, where evidence of the impact of global warming has been most pronounced.

At the Reykjavík Ministerial Meeting of the Arctic Council, an inter-governmental organization embracing the countries in the North, including Iceland, the United States and Russia, in November 2004, the eight member states received the main findings of the Arctic Climate Impact Assessment (ACIA). This report, completed during Iceland's Chairmanship of the Arctic Council, is the world's most comprehensive and detailed regional climatic and ultraviolet radiation assessment to date and documents impacts that are already being felt throughout the Arctic region. It clearly demonstrates that the Arctic climate is now warming rapidly, presenting a range of challenges for human health, culture and well-being among the people of the region.

The importance of the ACIA, which drew on the work of more than 300 leading researchers, indigenous representatives and other experts from fifteen nations, goes well beyond its regional relevance. According to the authors, Arctic warming and its consequences will have worldwide implications, affecting in a profound manner vegetation patterns, biological diversity, marine transportation, access to resources and the survival of coastal communities, to name only a few examples.

Barely three years after the ACIA was presented, it would seem that future projections, based on its findings, may have been somewhat conservative. In our own Icelandic neighbourhood, the Greenland ice cap is melting at an accelerating rate, with potentially catastophic consequences in terms of global sea-level rise. As the leading ACIA scientist, Robert Corell, recently observed, one Greenland glacier alone, at Ilulissat, is now putting enough fresh water into the sea to provide drinking water for a city the size of London.

Therefore, the message from the North is clear; all countries need to start taking the issue of global climate change seriously and work together in a deliberate way towards the adaptation to, and the mitigation of, its accelerating impacts.

This explains the vital interest that Iceland has in working with other nations to campaign hard against climate change and play a role in persuading others, policymakers, scientists, experts, corporate leaders and other individuals to take action.

There are many steps that need to be taken. In this hearing, the focus will be on the aspect where I believe my country can make a significant input. I see the increased utilization of clean energy resources as one of the most vital parts in the fight against climate change.

The International Energy Agency (IEA) forecasts that US$ 20 trillion in new investment will be required to meet world energy needs by 2030. Much of this investment will be needed in the world's fastest-growing economies and expectations for China alone amount to 18% of the total. Innovative policies and technologies present significant opportunities to ensure economic growth and social development while minimizing the unwanted consequences of investments, such as urban air pollution, resource depletion, health damage, water stress and climate change. Geothermal energy can play an important role in this aspect in many parts of the world.

We have approached the issue of energy in Iceland from the point of view of the importance of achieving energy security. As geothermal energy and hydroelectric power have been developed within Iceland's borders, this means that we have become independent of fuel imports for electricity production. Thus we have less reason than many other nations to worry about fluctuating prices of oil except as they affect the transport sector and the fisheries fleet, and in these areas too, we are working on decreasing our dependence on oil.

3. GEOTHERMAL UTILIZATION

Although geothermal energy is categorised in international energy tables among the "new renewables", it is not a new energy source at all.

People have used hot springs for bathing and washing of clothes since the dawn of civilisation in many parts of the world. Late in the nineteenth century, people began experiments utilizing geothermal energy for outdoor gardening and early in the twentieth century, geothermal sources were first used to heat greenhouses. Around the same time, people started using geothermal energy to heat swimming pools and buildings.

Electricity has been generated by geothermal steam commercially since 1913, and geothermal energy has been used on the scale of hundreds of MW for five decades now, both for electricity generation and direct use. The scale of utilization has increased rapidly during the last three decades.

Conventional electric power generation is mostly limited to geothermal fields with a fluid temperature above 150°C, but considerably lower temperatures can be used with the application of binary fluids which utilize the geothermal fluids down to about 80°C. The unit sizes of steam turbines are commonly 20-50 MWe. The efficiency of geothermal utilization is enhanced considerably by co-generation plants which produce both electricity and hot water for district heating and other direct uses.

In many countries, the most significant direct application is for district heating, using the geothermal fluid directly or extracting the heat with the aid of heat exchangers or heat pumps. In Iceland, most of the direct use of geothermal heat is in the form of central heating; 85% of all houses in Iceland are heated this way.

Geothermal water also has many other applications, including swimming pools, soil warming, fish farming, animal husbandry, aquaculture pond heating and industrial heating and processing such as drying of timber, wool and seaweed.

Reykjavík Energy currently operates the world's largest and most sophisticated geothermal district-heating system in Reykjavik, Iceland's capital city. In terms of size, it will be rivalled only a project that Icelanders are building in Xian Yang in China.

A single geothermal resource can be used as the basis of many different profit-making ventures, from delivering hot water to municipalities to developing tourist centres with spas, hotels and health clinics. This has been done at the "Blue Lagoon", a geothermal site in Iceland, where cosmetics and skin balms made from the silica precipitates in the run-off water have been developed into a significant source of income.

3.1 Sustainable Utilization of Geothermal Resources

Geothermal energy is a renewable energy source, meaning that the source itself has the potential to recover following utilisation. It may be utilised in either a sustainable manner or an "excessive" manner.

Excessive production from a geothermal field—in excess of the capacity of the resource to recover—can only be maintained for a relatively short time. After a period of prolonged excessive use, production must be brought down to, or below, the level of maximum sustainable use. Stepwise development is employed to avoid excessive production.

Stepwise development takes into consideration the individual conditions of each geothermal system, and minimises the long-term production cost. The cost of drilling is a substantial component, both in the exploration and the development of geothermal fields. With the stepwise development method, production from the field is initiated shortly after the first, successful wells have been drilled.

The production and response history of the reservoir during the first development step is used to estimate the size of the next development step. In this way, favourable conditions are achieved for the timing of the investment in relation to the timing of revenue, resulting in lower long-term production costs than could be achieved by developing the whole field in a single step.

A combination of the stepwise development method with the concept of sustainable development results in an attractive and economical way to utilize geothermal energy resources.

4. GEOTHERMAL DEVELOPMENT IN ICELAND

Iceland is a country of 300,000 people, located on the mid-Atlantic ridge, between Europe and America. It is mountainous and volcanic, with much precipitation. The country's geographical peculiarities have endowed Iceland with an abundant supply of geothermal resources and hydropower.

Iceland's energy use per capita is among the highest in the world, and the proportion of this provided by renewable energy sources exceeds that in most other countries. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply. Almost three-quarters of the population live in the south western part of the country, where geothermal resources are abundant.

The current utilization of geothermal energy for heating and other direct uses is considered to be only a small fraction of what this resource can provide. The potential to generate electricity is more uncertain. Hydropower has been the main source of electricity, but in recent decades geothermal power plants have also contributed an important share of production. In 2006, geothermal plants generated one fourth of the total 9,920 GWh produced. In 2009, the total production is forecast to be about 15,000 GWh, with 20% generated in geothermal plants. At the same time, 80% of the electricity will be used in the energy intensive industry.

Iceland possesses relatively extensive untapped energy reserves. However, these reserves are not unlimited. Only rough estimates are available as to the size of these energy reserves in relation to the generation of electricity. Therefore, there is considerable uncertainty when it comes to assessing to what extent they can be harnessed with regard to what is technically possible, cost-efficient, and environmentally desirable.

For the potential generation of electricity, these energy reserves are estimated at roughly 50,000 GWh per year, some 60% coming from hydropower and 40% from geothermal resources. By 2008, the generation will amount to about 30% of that total potential.

A master plan comparing the economic feasibility and the environmental impact of the proposed power development projects is being prepared. It is hoped that this comparison will aid in the selection of the most feasible projects to develop, considering both the economic and environmental impact of such decisions, including which rivers or geothermal fields should not be harnessed due to their value in terms of natural heritage and recreation. Final results are expected by 2009.

4.1 Space Heating

In a cold country like Iceland, home heating needs are greater than in most countries. Coal imports for space heating were begun after 1870. The use of coal for heating increased in the beginning of the twentieth century, and coal was the dominant heat source until the end of World War II. Iceland's dependence on oil began with the twentieth century.

Oil for heating purposes first became significant after World War II. By 1950 about 20% of families used oil for heating, while 40% used coal. At that time about 25% enjoyed geothermal heating services. In the 1950s, the equipment to utilize oil for heating improved, obviously leading to increased consumption.

As a result, coal was practically eliminated from space heating in Iceland around 1960. At the same time, control systems for central heating developed rapidly, and the first automatic temperature regulators for radiators became common.

The first uses of geothermal energy to heat houses can be traced back to 1907. In Reykjavik, large-scale distribution of hot water for heating homes began in 1930. In addition to the development in the capital area, many communities around the country built their heating distribution systems in places where hot springs, or successful drilling, yielded suitable geothermal water. Community schools in the countryside were also preferably located close to supplies of geothermal water, which was available for heating and swimming.

When the oil crisis struck in the early 1970s, fuelled by the Arab-Israeli War, the world market price for crude oil rose by 70%. About the same time, roughly 90,000 people enjoyed geothermal heating in Iceland, around 43% of the nation. Heat from oil still served over 50% of the population.

The oil crises of 1973 and 1979 (following the Iranian Revolution) caused Iceland to change its energy policy, dropping the emphasis on oil and turning to domestic energy resources: hydropower and geothermal heat. This policy meant searching for new geothermal resources, and building new heating services across the country. It also meant constructing transmission pipelines (commonly 10-20 km long) from geothermal fields to towns, villages and individual farms.

4.2 Electric Power Generation in Iceland

Generating electricity with geothermal energy in Iceland has increased significantly in recent years. Three of the plants are co-generation plants producing both electricity and hot water for district heating. One of them uses a water-ammonia mixture as its working fluid (Kalina-process), extracting heat from 120°C geothermal water for electricity generation followed by a series of other direct uses for industrial processes of boiling and drying, district heating, swimming pools, fish farming and snow melting, reducing the temperature of the water to 25°C before it is finally discarded.

As a result of a rapid expansion in Iceland's energy-intensive industries, the demand for electricity has increased considerably. Fig. 5.4* shows the development from 1970-2005, and planned production up until 2008. Total electricity production in 2005 from geothermal sources came to 1,658 GWh, which was 19.1% of the country's total electricity production. Enlargements of the existing power plants and two new plants increased the installed capacity by 210 MWe in 2007, bringing the total capacity up to 410 MWe.

4.3 Benefits of using geothermal heat instead of oil

The economic benefits of the policy of increasing the utilization of geothermal energy can be seen when the total payments for hot water used for space heating are compared to the consumer costs of oil.

Direct annual savings stood at a peak level from 1980 to 1983, about $200 million per year. They rose above $200 million in 2000, and savings continue to climb as oil prices increase. In 2000, the present value of the total savings between 1970 and 2000 was estimated at $8,200 million or more than three times Iceland's national budget in 2000. The economic savings garnished by using geothermal energy are substantial, and have contributed significantly to Iceland's prosperity.

Assuming that geothermal energy used for heating homes in 2003 was equivalent to the heat obtained from the burning of 646,000 tons of oil, the use of geothermal energy reduced the total release of CO_2 in the country by roughly 37%.

Besides the economic and environmental benefits, the development of geothermal resources has had a desirable impact on social life in Iceland. People have preferred to live in areas where geothermal heat is available, in the capital area and in rural villages where thermal springs can be exploited for heating dwellings and greenhouses, schools, swimming pools and other sports facilities, tourism and smaller industries. Statistics show improved health of the inhabitants of these regions.

The significant fluctuations of oil prices caused by political unrest in key oil-producing regions should encourage governments to focus on indigenous energy sources to meet their basic energy requirements.

4.4 Heat Pumps

Until recently, geothermal energy has been economically feasible only in areas where thermal water or steam is concentrated at depths of less than 3 km in restricted volumes, analogous to oil in commercial oil reservoirs. The use of ground-source heat pumps has changed the economic norms. In this case, the earth is the heat source for the heating and/or the heat sink for cooling, depending on the season.

This has made it possible for people in all countries to use the earth's heat for heating and/or cooling. It should be stressed that heat pumps can be used basically anywhere.

It is considered likely that heat pumps will become competitive where water above 50°C is not found. In such places, heat pumps can be used instead of direct electrical heating to raise the temperature of warm spring water.

4.5 The Public Sector's role in developing geothermal energy in Iceland

Governments in Iceland have encouraged exploration for geothermal resources and research into the various ways geothermal energy can be utilized. This work began in the 1940s at the State Electricity Authority, and was later, for decades, in the hands of its successor, the National Energy Authority (Orkustofnun), which was established in 1967. The aim has been to acquire general knowledge of geothermal resources and make the utilization of this resource profitable for the national economy.

This work has led to great achievements, especially in finding alternative resources for heating homes. This progress has been possible thanks to the skilled scientists and researchers at the National Energy Authority. This research is now in the hands of a new state institute, Iceland GeoSurvey, which was born out of the

* All figures and tables have been retained in committee files.

National Energy Authority in 2003. New and effective exploration techniques have been developed to find geothermal resources.

This has led to the development of geothermal heating services in regions that were thought not to contain suitable geothermal resources. Iceland's geothermal industry is now so developed that the government can play a smaller role. Successful power companies now take the lead in exploitation, either developing geothermal fields that are already being utilized, or finding new fields.

The Icelandic government set up an Energy Fund by merging two funds in 1967 to further increase the use of geothermal resources. Over the past few decades, this has granted numerous loans to companies for geothermal exploration and drilling. Where drilling failed to yield the expected results, the loans were converted to grants.

The country's larger district heating services are owned by their respective municipalities. Some 200 smaller heating utilities have been established in rural areas. Recent changes in the ownership structure of many district-heating systems in Iceland have had their effect. The larger companies have either bought or merged with some of the smaller systems. Also it is becoming increasingly common to run both district heating and electricity distribution in a single municipally-owned company. This development reflects increased competition in the energy market of the country.

5. GEOTHERMAL ENERGY WORLD-WIDE

The people of Iceland live in a harsh natural environment in terms of the weather and the danger of earthquakes and volcanic eruptions; however, nature also provides them with access to the heat inside the earth for energy production. But Iceland is not unique in this respect: the same opportunities exist in many countries and can benefit their people if they are fortunate enough to make use of them.

Geothermal resources have been located in some 90 countries and there are quantified records of geothermal utilization in 72 countries. Electricity is produced from geothermal sources in 23 countries. Five of these obtain 15-22% of their national electricity totals from geothermal sources. In 2004, the worldwide use of geothermal energy amounted to about 57 TWh/a of electricity (Bertani, 2005), and 76 TWh/a for direct use (Lund et al., 2005).

Electricity production increased by 16% between 1999 and 2004 (an annual growth rate of 3%). Direct use rose by 43% during the same period (an annual growth rate of 7.5%). Only a small fraction of the geothermal potential has been developed so far, and there is ample space for accelerated use of geothermal energy both for direct applications and for electricity generation.

Over two billion people, a third of the world's population, have no access to modern energy services. A key issue for improving the standard of living of the poor is to make clean energy available to them at prices they can afford. The world population is expected to double by the end of the 21st century. To provide sufficient commercial energy (not to mention clean energy) to the people of all continents is an enormous task.

More and more countries are seriously considering how they can use their indigenous renewable energy resources. The recent decision of the Commission of the European Union to reduce greenhouse gas emissions by 20% by 2020 compared with the 1990 level throughout its member countries implies a significant acceleration in the use of renewable energy resources. Most of the EU countries already have considerable geothermal installations.

5.1 Geothermal energy for development

The top fifteen countries in electricity production from geothermal sources include ten developing countries. The top fifteen countries in direct use of geothermal energy include five developing and transitional countries.

In the electricity sector, the geographical distribution of suitable geothermal fields is restricted and mainly confined to countries or regions on active plate boundaries or with active volcanoes. Central America is one of the world's richest regions in geothermal resources. The geothermal potential for electricity generation in Central America has been estimated at about 4,000 MWe (Lippmann 2002), and less than 500 MWe have been harnessed so far. Geothermal power stations provide about 12% of the total electricity generation of four countries in the region: Costa Rica, El Salvador, Guatemala and Nicaragua.

With an interconnected grid, it would be easy to provide all the electricity for these four countries from renewable energy sources. With its large untapped geothermal resources and its significant experience in both geothermal and hydro development in the region, Central America may become an international example of how to reduce overall emissions of greenhouse gases over a large area. Similar developments can be foreseen in the East African Rift Valley and in several other countries and regions rich in high-temperature geothermal resources.

Geothermal energy can play a significant role in the electricity production of countries and regions rich in high-temperature fields which are associated with volcanic activity. Examples can be found in many developing countries of rural electrification and the provision of safe drinking water and the development of schools and medical centres in connection with the exploitation of geothermal resources. Thus, the projects are in line with the United Nations' Millennium Development Goals.

Kenya was the first country in Africa to utilize its rich geothermal resources and in the foreseeable future will be able to produce most of its electricity from hydro and geothermal sources. Several other countries in the East African Rift Valley can follow suit. Icelandic experts from Reykjavik Energy are now developing the geothermal fields in Djibouti. Indonesia is probably the world's richest country in geothermal resources and will be able to replace a considerable part of its fossil-fuelled electricity plants with geothermal stations in the future.

The main commercial application of geothermal energy for direct use in Kenya is in flower farms near the Olkaria geothermal power station where greenhouses are heated during the night and kept dry using geothermal heat. Around 60,000 people work on the flower farms in the region and it is estimated that some 300,000 people derive their livelihood from them. The flower companies, which export cut flowers (mainly roses) by air to Europe, provide the staff and their families with good housing, water, electricity, schools and medical centres.

Another interesting example of the benefits of geothermal development in Africa is in Tunisia where greenhouses replace cooling towers to cool irrigation water from 2-3 km deep wells in the Sahara desert. Due to the Earth's thermal gradient, the temperature of the water from the wells is up to 75°C and needs to be cooled to 30°C to be used for irrigation. Some 110 hectares of greenhouses have been built in the oasis. The main products are tomatoes and melons which are exported to Europe. This has created many jobs for men and women. Here the geothermal energy development is a by-product of the irrigation project.

5.2 Direct use of heat world-wide

In the direct use sector, the potential is very large, as space heating and water heating constitute a significant part of the energy budget in large parts of the world. In industrialised countries, 35 to 40% of total primary energy consumption is used in buildings. In Europe, 30% of energy use is for space and water heating alone, representing 75% of total building energy use.

As I have mentioned, the European Union's commitment to reduce greenhouse gas emissions by 20% by the year 2020 opens up a huge potential for further applications, and most EU countries already have considerable geothermal installations. The same applies to the USA, where the use of ground source heat pumps is widespread both for space heating and cooling.

The largest potential is, however, in China. Owing to geological conditions, there are widespread low-temperature geothermal resources in most provinces of China which are already widely used for space heating, balneology, fish farming and greenhouses during the cold winter months and also for tap water in the summer. It is very important for proponents of the various types of renewable energy to work together in order to find the optimal use of energy resources in the different regions of the world.

5.3 Iceland as an active international partner

Capacity building and transfer of technology are key issues in the sustainable development of geothermal resources. Many industrialised and developing countries have significant experience in the development and operations of geothermal installations for direct use and/or electricity production. It is important that they open their doors to newcomers in the field. We need strong international cooperation for the transfer of technology and the financing of geothermal development in order to meet the Millennium Development Goals and tackle the threats of climate change.

Iceland has made a significant contribution to transfer technology from its geothermal industry to other countries, to enable them to build up capacity in geothermal science and engineering. The Government of Iceland and the United Nations University (UNU) decided in 1978 to establish the UNU Geothermal Training Programme in Iceland (UNU-GTP). Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, reservoir engineering, chemistry of thermal fluids, environmental studies, geothermal utilization, and drilling technology (www.os.is/unugtp/). The aim is to assist developing countries and Central and Eastern European countries with significant geothermal potential to build up groups of specialists covering most aspects of geothermal exploration and sustainable development. The UNU-GTP is financed mostly by the Government of Iceland.

The Government of Iceland has secured core funding for the UNU-GTP to expand its capacity-building activities by holding annual workshops/short courses in geothermal development in selected countries in Africa (these started in 2005), Central America (these started in 2006), and later in Asia (where they will probably start in 2008).

In many countries in Africa, Asia, Central America and Central and Eastern Europe, UNU-GTP graduates are among the leading specialists in geothermal research and development. They have been very successful, and have contributed significantly to energy development in their parts of the world.

Icelandic geothermal experts have been on missions of various lengths (ranging from a few weeks to several years) to over 70 countries around the world. The countries are: Albania, Algeria, Argentina, Azerbaijan, Bulgaria, Burundi, Cape Verde, Canada, Chile, China, Costa Rica, Croatia, Djibouti, Egypt, El Salvador, Eritrea, Ethiopia, the Faeroes (Denmark), France, Georgia, Germany, Greece, Greenland, Guadeloupe (France), Guatemala, Honduras, Hungary, India, Indonesia, Iran, Jordan, Kenya, North Korea, Le Reunion (France), Lithuania, Madagascar, Macedonia, Malaysia, Martinique (France), Mongolia, Nepal, New Zealand, Nicaragua, Norway, Panama, Papua New Guinea, the Philippines, Poland, Portugal (Azores), Romania, Russia, Saba (Dutch Antilles), Salomon Islands, Serbia, Slovakia, Slovenia, St. Lucia, St. Vincent, Syria, Sweden, Taiwan, Tanzania, Thailand, Tunisia, Turkey, Uganda, USA, Vanuatu, Vietnam, Yemen, and Zambia.

In the beginning most of the missions were for United Nations agencies, but the number of projects with direct contracts between Icelandic companies and agencies/companies in the respective countries has grown steadily during the last fifteen years and has been accelerating over the past few months.

The projects have involved project management, geothermal exploration, drilling and well testing, field development, reservoir evaluation and resource management, design and construction of geothermal power stations and district heating systems and also specialist courses on various aspects of geothermal research and development.

6. THE GEOTHERMAL POTENTIAL OF THE UNITED STATES

It is not generally known that the United States is the global leader in geothermal electric power production. Production in the US came to about 18,000 GWh_e in 2005, out of a world total of about 57,000 GWh_e. For comparison, the Philippines ranked number two with about 9,200 GWh_e and Iceland number 8 with about 1,500 GWh_e. Direct use of geothermal energy is also considerable in the US. It is ranked number three after China and Sweden and contributes about 8,700 GWh_{th} to the World total of 75,900 GWh_{th}. Table 1 shows the top 10 countries in geothermal energy utilization.

Geothermal electric power plants are located in California (2,492 MW), Nevada (297 MW), Utah (26 MW), Hawaii (35 MW) and Alaska (0.4 MW) with current installed gross geothermal capacity at about 2,851 MW.

6.1 US Geothermal Capacity in Perspective

The total installed capacity in North America is about 3,517 MW, of which 2,851 MW is installed in the US and 666 MW in Mexico. Globally, the installed capacity is about 8,933 MW (8,9 GW). The total potential for North America is considered to be 30,000 MW (30 GW), which means that only 12% of the estimated potential is now being utilized (Glitnir Energy Research, 2007 and Geothermal Energy Association, 2007).

Active volcanoes and high-temperature geothermal systems are manifestations of terrestrial energy flow from the mantle to the surface of the Earth. The volcanic and geothermal activity is more intense at plate boundaries than within the tectonic plates and the distribution in the world in fairly well known.

The world potential for geothermal electric power generation is estimated at about 148,800 MW, or 149 GW. The figures presented here are considered to be conservative, since geothermal assessments have only been carried out for a limited number of countries and regions. Theoretical considerations based on the situation in Iceland and the US reveal that hidden resources suitable for electric generation are expected to be 5-10 times larger than the estimate of identified resources (Stefansson, 2005). The production potential presented here only takes account of the current state of technology, and not Enhanced Geothermal Systems or Hot Dry Rock techniques.

According to the MIT report "The Future of Geothermal Energy", geothermal energy from Enhanced Geothermal Systems (EGS) in the United States could have a major impact on the national energy outlook. According to the report, this energy could provide over 100 GW of cost-competitive base-load electricity in the next 50 years.

Unfortunately, the utilization of EGS is not yet considered cost-effective but significant advances towards commercial viability have been demonstrated in international projects (e.g. in Germany and Australia). This has led US experts to become optimistic about achieving commercial viability in the US, given reasonable governmental investments to support research, development and demonstration projects over the next 10 to 15 years.

The main areas in which R&D needs to be focused in the United States are drilling technology (drilling through high-temperature rocks), power-conversion technology (broadening the temperature range that can be utilized) and reservoir technology (stimulating flow through reservoirs and improving downhole pumps). Successful demonstration projects are needed for future growth of the industry.

6.2 Current Projects and Potential

The current installed geothermal capacity in US is about 2,851 MW in five states: California, Nevada, Utah, Hawaii and Alaska, with Idaho and Wyoming soon to be added to the list. Most geothermal activity is in California and Nevada, which have the greatest geothermal potential. At least 69 geothermal projects are in the initial drilling exploration, production drilling or construction phase. Of these projects, 31 are in Nevada. The estimated generation capacity of these projects is about 2,500 MW.

6.3 The kinds of expertise and cooperation needed using current technology

The keys to successful geothermal development are efficient and comprehensive interdisciplinary geothermal research (both during the exploration and production phases), together with proper resource management during utilization. Today, Iceland is producing electricity from geothermal resources at a cost of about 2-3 US cents per kWh—as compared to some 7-9 US cents/kWh for most geothermal plants in the USA. There may not be one single reason for this discrepancy, rather it may be due to a combination of several factors.

One important difference between the USA and Iceland is that in Iceland, wherever applicable, a "holistic approach" is used to harness geothermal resources. This means using a sequence of applications so that as much energy as possible is extracted out of the ground before disposing of the spent geothermal fluid. Starting with electricity production from the flashed geothermal steam, or from turbines using binary heat-exchangers, the heat content of the fluids is exploited in industrial processing, domestic space heating, greenhouse heating, fish farming, snow melting, etc., before the fluid is finally disposed of.

This concept can be taken a step further, e.g. by cultivating algae on a large scale using both geothermal warm water and CO_2 to induce growth. The algae can then be used as food for aquatic life-forms, or to produce bio-fuel by utilizing the geothermal steam, and so on.

The holistic approach does not stop there; in Iceland, tourism is linked to the geothermal production plants, with balneology, health centres, cultural and educational centres, and cosmetic products based the geothermal chemicals, and so on. There is no limit to the spin-offs.

Probably the best Icelandic example of this holistic approach is demonstrated by the Svartsengi power plant, which produces both electricity and hot water for domestic space heating. The geothermal effluent from the plant has been used to create the world famous "Blue Lagoon", with multiple spin-off revenues in health care, cosmetics, tourism and education.

While a holistic approach of this kind, with a large component of space heating, may be more suitable in a relatively cold country like Iceland similar approach could also be applied in parts of the USA that have a warmer climate, e.g. by using the effluent energy for large-scale cooling and refrigeration and other spin-offs tailored to the specific environment.

Another important characteristic of the Icelandic geothermal industry is a willingness to share information, rather than keeping it proprietary. There is hardly any closed file; almost everything is published one way or another, and experience and expertise are carried from one geothermal field to the next, to the mutual benefits of all the energy companies involved. More or less the same geoscience companies serve the whole industry, and geoscientists in different disciplines work hand-in-hand from exploration to production. This culture may be partly related to the smallness of the nation—but essentially, open-file reporting has little to do with population size.

Yet another factor needs to be mentioned. In geothermal prospecting worldwide, some targets are easy to reach and others are less so. Many of the most accessible and attractive geothermal prospects, in locations such as national parks and reserves, etc., must be left intact due to ever-growing environmental restrictions, while others which are less promising can only be approached after protracted and costly permitting procedures. This affects the overall economics of the industry.

In one sense, it seems somewhat paradoxical that, at the same time we are seeking sources of green and renewable energy in order to reduce the emission of greenhouse gases, we are also limiting their development by environmental regulation which, in some cases, may be unduly restrictive. Different, and probably more costly, measures will be necessary to resolve this environmental dilemma. International collaborative efforts on environmental issues of the geothermal industry would be desirable.

7. AREAS OF POSSIBLE US-ICELANDIC COOPERATION

7.1 Geothermal Exploration and Assessment

The 1970s resource estimates by the United States Geological Survey indicated that low-to medium-temperature geothermal resources are located widely throughout the USA, but many of them were not economic. Given the escalating cost of competing fossil fuels since then, a re-evaluation of the nature, extent, and economic potential of these resources would be prudent.

There are considerable known conventional high-temperature geothermal resources in the western states, and also in Hawaii and Alaska. Most are associated with young volcanic rocks, which should be attractive targets for the generation of electric power. In some of these locations geothermal production is already taking place, including California where 5% of the installed electrical generating capacity is geothermal. More effort is evidently needed to remove technical, regulatory, environmental, and fiscal barriers to the further economic development of these resources.

However, to make a really significant impact on the overall renewable energy picture, new approaches to geothermal development will be necessary. In the USA a recent comprehensive assessment of the potential for “enhanced” or engineered geothermal systems (EGS) within the USA, indicates that a cumulative capacity of more than 100,000 MWe from EGS can be achieved in the United States within 50 years with modest government investment.

In Iceland, a different approach to the future of geothermal energy is under way; this involves investigation of the economic potential of producing supercritical geothermal resources by the Iceland Deep Drilling Project (IDDP). Supercritical geothermal production, in which water and vapour are in the same phase under heat or pressure, is an especially attractive component of enhanced geothermal systems. The environmental and economic incentive is to produce an order of magnitude more energy from geothermal wells occupying the same area as conventional resources, but at less than half an order of magnitude of increased cost.

Such deep, unconventional, geothermal resources (DUGRs) are not restricted to Iceland. For example, in the USA, the resource base of conventional hydrothermal resources is estimated to be 2,400-9,600 Exajoules (1 EJ = 10^{18} J), whereas the supercritical volcanic EGS resource base is estimated to be as much as 74,100 EJ, excluding geothermal systems in national parks (DOE, 2007). A systematic survey of the potential of DUGRs in the USA is therefore desirable, and plans should be developed to investigate these potentially large resources further.

Despite the fundamental differences between the geology of Iceland and the United States, there are topics where collaboration would be of mutual benefit, in data sharing, e.g. on methods of geophysical exploration and assessment of both low-temperature, high-temperature, and Deep Unconventional Geothermal resources. As an example, one such cooperative venture between universities in North Carolina and Iceland GeoSurvey geoscientists on geophysical methods in geothermal exploration has been in progress for some years now.

7.2 Drilling technology

Drilling technology is another area where cooperation between the USA and Iceland is needed. The development and application of the drilling techniques involved in the multilateral completion of wells is an example. These have been developed by the oil industry, but seldom in the geothermal industry.

Multilateral completions are used to improve output when the well yield is inadequate. In this way, the heavy investment in steel casings and cement in the upper parts of such well are not lost. This is not a common practice in the geothermal industry. However, one can envisage scenarios where the drilling of such multilateral wells would lead to considerable economic improvement, at the same time having lower environmental impact by reducing the need for surface installations.

Other possible areas for cooperation in drilling involve advances in coring techniques in exploration and research wells, for example in relation to the IDDP. Continuous core drilling is slow and extremely costly compared to conventional rotary drilling which is used almost exclusively in the geothermal industry.

Similarly, cooperation on improving techniques of well stimulation would be desirable. Other technical developments of mutual interest that are greatly needed are in the areas of high-temperature logging, measurement while drilling, and downhole fluid sampling. Sandia National Laboratory (SNL) in the USA has had a long-term programme of technological development in these areas. Further collaboration between SNL and Icelandic geothermal scientists would be highly desirable.

7.3 Science and research

In Iceland there is a healthy collaboration between government and industry that could provide numerous opportunities for participation by US government agencies. One excellent example where the USA is already cooperating with Iceland in geothermal research is the Iceland Deep Drilling Project (IDDP).

In 2005, the United States National Science Foundation committed USD 3.2 million to support the acquisition and scientific study of drill core samples to be recovered by the IDDP. This has enabled a team of US investigators to participate in the project.

Further cooperation between the DOE, the USGS, and the NSF and the Icelandic GeoSurvey (ISOR) and the National Energy Authority of Iceland (Orkustofnun) on scientific investigation as part of such advanced geothermal research and development projects would be mutually beneficial.

Iceland is a favourable locale for scientific studies related to geothermal systems. For example, more than 100 international scientists and engineers are already involved in the IDDP project, in collaboration with the Icelandic energy industry. Many of these scientists and engineers are from US universities and institutes, which will draw funds from domestic US sources. The US NSF is already supporting some of these scientists, and also a considerable part of the cost of core drilling for scientific studies.

7.4 Technological advancement

The success of the geothermal industry is partly linked to the use of long-proven technology. Nevertheless, there is always a need for improvements. On the cost-effectiveness side, advancement in casing technology and cementing technique in drill holes would be most beneficial.

The IEA International Implementing Agreement on Geothermics is an example of an international effort that could lead to technological advancements in drilling and geothermal harnessing. Within the US, one of the roles of the Geothermal Department of the DOE has been to participate in this implementing agreement. Drilling costs is one of the chief factors affecting the geothermal economy.

7.5 Management of geothermal resources

Some cooperative studies involving US scientists and engineers and their Icelandic counterparts are already under way in the areas of reservoir management, reservoir modelling and tracer techniques. In most cases water or steam extraction from a geothermal reservoir causes some decline in reservoir pressure.

The only exception is when production from a reservoir is less than its natural recharge. Consequently, the pressure decline manifests itself in further changes, such as temperature conditions (cooling), phase conditions (increased boiling), chemical composition, surface manifestations and land elevation (subsidence).

The energy production potential of a geothermal system is not only dependent on the available energy in the ground, but is predominantly determined by this pressure decline. The pressure decline is determined by the rate of production, on the one hand, and the nature and properties of the system, on the other.

Comprehensive and efficient management is an essential part of successful geothermal resource utilization. Such management implies controlling the energy extraction from the geothermal system so as to maximise the resulting benefits, without over-exploiting the resource.

Geothermal resource management involves deciding between different courses of action, and the operators must have some idea of the possible outcome of the different alternatives. Geothermal resource management is a field where co-operation between the US and Iceland has the potential to be very fruitful because geothermal fields have common characteristics and the experience of utilizing one field may be of benefit to operators of other fields.

Modelling the nature of a geothermal system is one of the most powerful tools available for resource management in order to understand and predict its behaviour. Reservoir models are also helpful in estimating the outcome of different management actions. The field of numerical geothermal modelling has evolved greatly during the last two decades. A lot of the relevant development of methods and tools has taken place at the Lawrence Berkeley Laboratory in California. A significant contribution to this effort has come from co-operation with Icelandic scientists and the modelling of Icelandic geothermal systems.

Reinjection is an integral part of any sustainable and environmentally-friendly geothermal utilization, both as a method of waste-water disposal and to counteract pressure draw-down by providing artificial water recharge (Stefánsson, 1998, 2005). Reinjection is essential for sustainable utilization of geothermal systems that have limited natural recharge. However, one of the dangers associated with reinjection is the cooling of production wells, but this can be minimised through careful testing and research. Tracer testing, combined with comprehensive interpretation, is probably the most important tool for this purpose. Some significant advances in tracer testing techniques have come about through US-Icelandic co-operation, and these need to be developed further.

Sustainable geothermal utilization involves energy production at a rate which may be maintained for a very long time, such as 100-300 years (Axelsson et al., 2004). This requires efficient management in order to avoid overexploitation, which mostly occurs because of lack of knowledge and poor understanding, and also in situations when many users draw on the same resource without common management. An example of the latter is at the Geysers Geothermal Field in California.

Geothermal resources of highly variable nature may be managed in a sustainable manner. Good examples are the vast geothermal resources in sedimentary basins in different parts of the world (Axelsson et al., 2004). Further cooperation between US and Icelandic geothermal engineers in the area of resource management would be mutually beneficial.

7.6 Business aspects and financing of projects

One field where Icelandic companies have scored greater success than their counterparts elsewhere is that instead of the renewable energy companies being heavily subsidised by taxpayers' money, they generate substantial revenue for their owners. This means that the resources are well managed from the financial point of view.

Recently, Icelandic financial institutions have decided to put emphasis on financing and investing in geothermal projects world-wide. One of Iceland's largest banks, Glitnir Bank, has stated that sustainable energy will be one of the three main fields of expertise on which it focuses globally. The bank took part in establishing an investment company, called Geysir Green Energy, which has been actively looking for opportunities in the United States. Iceland-America Energy is a geothermal company with projects under way in California and elsewhere. Its mother company, Enex, has also been active in many countries.

Reykjavik Energy is probably the best known Icelandic geothermal company. It has grown into becoming Iceland's largest power company, overtaking the National Power Company last year, which mainly is involved in hydropower. Reykjavik Energy has founded an investment company, Reykjavik Energy Invest, which has ambitious plans in the sphere of developing geothermal resources in the world and is participating in projects in the Philippines, Indonesia, Djibouti and elsewhere.

Icelandic geothermal energy companies are open to partnerships with leading financial institutions and developing companies for their overseas operations, and this could become an interesting area in the cooperation between Iceland and the United States.

7.7 CO_2 capture and sequestration—zero-emission power plants

According to data from Kagel et al. (2005) the average emission of CO_2 from fossil-fuelled electric power plants in the USA is about 620 kg/MWh, whereas the average emission of CO_2 from a flashed steam geothermal plant is only 27 kg/MWh. Nonetheless, one environmental impact of geothermal production is the emission of some undesirable gases to the atmosphere, and the major geothermal gas is CO_2. Therefore, reduction in its emission is a desirable goal in geothermal utilization.

Wells already drilled for reinjection of liquid have been made available by Reykjavík Energy for mineral sequestration studies in an attempt to devise a new way of disposing of the CO_2. At the same time, studies are under way as regards the disposal of H_2S, the other troublesome gas emitted by geothermal plants, and there is a good chance that both these studies may lead to the establishment of a "zero-emission power plant." The studies are being done in collaboration with US scientists from Columbia University, among others.

A possible means of storing CO_2 underground is to use chemical bonding of injected CO_2 in a mineral phase. Igneous rocks such as basalt provide the necessary base cations to effect the precipitation of carbonate minerals from injected CO_2-saturated fluids (See, e.g., Matter et al., 2007). Upon injection into basalt aquifers, CO_2 will acidify the groundwater and the acid will be neutralized by water-rock reactions, where, for example, the Mg^{+2} and Ca^{+2} released supply cations that react with the dissolved CO_2 to form carbonates.

Even though the physical and hydrological conditions in the geothermal reservoirs are not the most favourable conditions for CO_2 mineral sequestration, results of determination of calcite in high temperature geothermal boreholes can nevertheless provide critical background information for the planning of field-scale CO_2 mineral sequestration experiments. Such determinations have been carried out in some geothermal areas in Iceland and suggest that a significant portion of CO_2 is captured, and that experiments under more favourable conditions should be worthwhile (Armannsson et al. 2007).

Planned studies of sequestration at Hellisheioi in Iceland will be done under more favourable conditions than in previous studies already carried out, i.e. at lower temperatures, and will be designed so as to obtain as much information as possible. The results of this experiment will not only be of use in geothermal studies but also to any emitter of CO_2 that can use the results to devise a possible means of disposal of CO_2 by sequestration in basalts. This is another area where US-Icelandic cooperation would be desirable.

8. NEW TECHNOLOGY DEVELOPMENTS—THE NEXT PHASE OF SCIENTIFIC EXPERTISE

8.1 Deep Drilling

Studies indicate that it would be possible to increase the output of high-temperature geothermal fields ten times, without increasing their area, by producing supercritical geothermal fluids, at higher temperatures and pressures and from much deeper wells than are currently used. Thus, the Iceland Deep Drilling Project (IDDP) is investigating the technical and economic feasibility of producing energy from such supercritical geothermal systems on land in Iceland, similar to those responsible for black smokers associated with mid-ocean ridge hydrothermal systems.

In Iceland this will require drilling to depths of 4 to 5 km in order to reach temperatures of 400-600°C. It is estimated that wells producing supercritical fluid would have an energy output ten times greater than conventional shallower geothermal wells.

This project is being funded by a consortium of three Icelandic energy companies, the US aluminium company Alcoa, and the Government of Iceland. If this project proves successful, it could lead to a major step forward in the economics of developing high-temperature geothermal resources by developing DUGRs worldwide.

The IDDP has engendered considerable international interest. The International Continental Scientific Drilling Program (ICDP) and the US National Science Foundation (NSF) are contributing funds to this program. There could be a role for an interagency group of US organizations (NSF/DOE/USGS) to play in the IDDP. Similarly, Icelandic scientists and engineers could collaborate with these agencies in the investigation of DUGRs in high-temperature geothermal fields in the USA, for example at the Geysers Geothermal Field in California and in many other high-temperature systems in the USA.

Drilling to produce a supercritical fluid of an unknown chemical composition presents a dilemma. The fluid need to be sampled and chemically analyzed before proper material with respect to scaling or corrosion can be selected for heat-exchangers or power generators. The choice of technology to be applied for power generation cannot be decided until the physical and chemical properties of the fluid have been determined. Nonetheless, it appears likely that the fluid will be used indirectly, in a heat-exchange circuit of some kind. In such a process the fluid from the well would be cooled and condensed in a heat-exchanger and then injected back into the field. This heat-exchanger would act as an evaporator in a conventional closed power-generating cycle. There are numerous opportunities for US agencies to participate in this advanced engineering project.

8.2 Hot Dry Rocks—Enhanced or Engineered Geothermal Systems

During the last two decades or so, several projects have been aimed at heat mining by injecting cold fluid into hot rocks. Considerable work has been done on inducing steam production in declining operational geothermal fields by injecting cold water into deep boreholes, e.g. in the Geysers Geothermal Field in California. These heat-mining projects have operated under different names, such as "Hot Dry Rocks (HDR)", "Hot Wet Rocks (HWR)", "Hot Fractured Rock (HFR)", "Enhanced Geothermal Systems (EGS)" or "Engineered Geothermal Systems (EGS)", and have been tested to various extents in the USA, Europe and Japan. Heat mining by injecting cold fluid into hot rocks is common to all these projects. In Europe the hot rock temperatures tested at 4-5 km depths ranged from 200-300°C; in the USA they were from 300-400°C and above 500°C in Japan.

Recently, the IDDP added the acronym DUGR [for Deep Unconventional Geothermal Resources] to the list of acronyms above, in an attempt to distinguish geothermal reservoirs at supercritical conditions from HDR, HWR, HFR or EGS. DUGRs have temperatures in the 400-600°C range, and can produce supercritical fluids, if permeable zones are intersected by drilling.

The greatest unknowns in the DUGR systems are uncertainty about fluid composition and the permeability properties. We do not know how permeable fracture systems respond to production at semi-brittle temperatures, i.e. at 500-700°C in basaltic rocks and at 400-600°C in volcanic rocks of rhyolitic to intermediate chemical composition. If drilling a DUGR intersects a supercritical system of marginal permeability, then the possibility of using the EGS approach should be considered.

Injection of cold water to induce fracture permeability (hydro-fracturing) might be a more productive way of utilizing a DUGR system than simply attempting to flow the supercritical reservoir fluid directly. Given the much higher enthalpy of the DUGR systems, the power output available would be much higher than that produced by any EGS existing to date. The experience gained in investigating DUGRs in Iceland will be directly transferable to the USA.

8.3 Ocean floor drilling—Advanced technology

Considerable advances have been made in drilling technology within the oil and gas industry by developing the technology in drilling what has been called multilateral completion of wells (branched or fingered wells). This technology has been developed in order to harness relatively thin oil-yielding zones, e.g. in permeable sandstone beds of only a few metres' thickness, at great depths beneath the sea floor.

A similar approach, using the technology of multilateral wells, could open new dimensions in harnessing geothermal resources, e.g. in environmental sensitive fields, and should be considered closer by geothermal prospectors.

The opportunity exists for a very comprehensive scientific programme, investigating the anatomy of a mid-ocean rift system by combining land-based and ocean-based deep borehole studies with complementary geological and geophysical and seismic imaging studies and putting the drilling activities into a broader regional geological context.

8.4 Technology projects—What is in the pipeline?

There are numerous areas of research and development by the geothermal industry in the USA and Iceland where collaboration would be highly desirable. For example, deep drilling to produce high-temperature and high-pressure hydrous fluid requires advanced drilling technology—special casing materials and advanced cementing techniques. Conventional and proven technology needs be improved.

The most sensitive parts in a drillhole, with respect to its performance and lifetime for production, are the steel casings and cementing integrity. Improper casing selection and handlings, poor cementing jobs, or too frequent thermal cycling, may all lead to well failure. The casing in DUGR wells need be stressed to the limits of material tolerance due to the extremely high pressures and temperatures involved.

Steam turbines for high-temperature and high-pressure supercritical steam require heat-exchangers for electricity production. Depending on the fluid geochemistry, advanced corrosion and scaling studies may be required before power can be produced economically from the DUGR systems. Cooperative research projects and pilot studies would not only be beneficial to US-Icelandic collaborators, but to the geothermal industry at large.

Development and deployment of advanced downhole logging and fluid sampling tools for use at high fluid pressures and temperatures is needed to deal with the DUGR systems. Discussions about collaboration between Sandia National Laboratory (through the DOE) and the IDDP on this topic have been in progress since 2002. Unfortunately, this collaboration has not been realized yet due to lack of funding from the US side.

However, a less ambitious collaboration for downhole tool development and testing has been established between Iceland and several European countries, funded by the European Commission. Some of the tool components to be used have been developed and tested by Sandia.

At the moment, only a few of the available downhole tools so far developed can withstand the range of temperatures that will be encountered in the DUGR systems. Advances in high-temperature tool development and monitoring technique are badly needed.

In addition to investigations and sampling of fluids at supercritical conditions, the IDDP will permit scientific studies of a broad range of important geological issues, such as investigation of the development of a large igneous province, and the nature of magma-hydrothermal fluid circulation on the landward extension of the Mid-Atlantic Ridge in Iceland.

Furthermore, the IDDP will require use of techniques for high-temperature drilling, well completion, logging, and sampling, techniques that will have a potential for widespread applications in drilling into oceanic and continental high-temperature hydrothermal systems.

The addition of a scientific program to the industry-driven IDDP drilling venture has obvious mutual advantages. The IDDP provides opportunities for scientists to become involved in an ambitious project that has a budget larger than can be funded by the usual agencies that fund scientific drilling on land. In turn, the industrial partners will benefit from strong scientific contributions that will expand opportunities for innovation and provide a perspective that can be of critical importance in the context of poorly understood natural systems such as supercritical geothermal reservoirs. Clearly, improved collaboration between the USA and Iceland in these diverse scientific and technical areas will be mutually beneficial.

CONCLUSION

I hope that in this testimony I have managed to demonstrate how geothermal resources can significantly contribute to the emerging clean energy economy of the United States and thus strengthen the security of the country.

In order to achieve this goal in the coming years, cooperation between Iceland and the United States can play an important role. I have outlined a number of areas where such cooperation on technical, scientific and business projects is either already taking place or could be speeded up and enhanced with the creation of a supporting network. The result would be to enhance tremendously the utilization of geothermal power in the United States.

In this process the US Senate and the House of Representatives could, and must, play an important role.

I hope that my testimony and our willingness in Iceland to provide further information and to engage in the necessary cooperation will help the Congress in its important deliberations.

This new energy cooperation between Iceland and the United States would be a great homage to our long-standing alliance and friendship.

ATTACHMENT 1.—PERMANENT CO_2 SEQUESTRATION INTO BASALT AT THE HELLISHEIDI GEOTHERMAL PLANT IN ICELAND

The reduction of anthropogenic CO_2 emissions is considered one of the main challenges of this century. By capturing CO_2 from variable sources and injecting it into suitable deep rock formations, the carbon released is returned back where it was extracted instead of freeing it to the atmosphere. This technology might help to mitigate climate change.

Injecting CO_2 at carefully selected geological sites with large potential storage capacity can be a long lasting and environmentally benign storage solution. To date CO_2 is stored as gas in association with major gas production facilities such as Sleipner in the North Sea operated by Statoil and In Salah in Algeria operated by Sonatrack, BP and Statoil.

The CO_2 fixation project at Hellisheidi Iceland will on the other hand take place in a different geological media; the CO_2 will be stored as solid calcium carbonate mineral in basaltic rock.

Why basalt and why Iceland?

Basaltic rocks are one of the most reactive rock types of the Earth s crust. Basaltic rocks contain reactive minerals and glasses with high potential for CO_2 sequestration. Basaltic rocks are common on the Earth s surface, for example the continental flood basalts of Siberia, Deccan plateau of western India, Columbia River basalt in north-western United States, volcanic islands like Hawaii and Iceland and the oceanic ridges. More than 90% of Iceland is made of basalt.

Natural processes

The process, where CO_2 is released from solidifying magma, reacts with calcium from the basalt and forms calcite, occurs naturally and the mineral is stable for thousands of years in geothermal systems (Figure 1*). Chemical weathering of basalts at the surface of the Earth is another example of carbon fixation in nature. The proposed experiment will aim at accelerating these natural processes.

The project at Hellisheidi

A mixture of water and steam is harnessed from 2000 m deep wells at Hellisheidi geothermal power plant. The steam contains geothermal gases, i.e. CO_2. It is planned to dissolve the CO_2 from the plant in water at elevated pressure and then inject it through wells down to 400-800 m, just outside the boundary of the geothermal system (Figure 2).

Zero emission

It shall be kept in mind that the amount of pores in the basaltic rock is limited. Therefore, the results from the Hellisheidi experiment will not safe the world s climate. However, the experiment might demonstrate that a zero emission geothermal power plant is a possibility and even the option to store the main part of Iceland s CO_2 emission in a safe way. This technology, if proved successful, can then be exported to other basaltic terrains of the Earth.

Project consortium

The University of Iceland, Reykjavik Energy, University Paul Sabatier in Toulouse, Columbia University in N.Y., the Icelandic GeoSurvey and Lawrence Berkeley Laboratories in California have established a research group. Reykjavik Energy, one of the world s leading companies in harnessing geothermal energy, will provide the infrastructure of its geothermal fields at Hellisheidi, and create a natural laboratory for the research. The area has been extensively studied.

The research will be a combined program consisting of field scale injection of CO_2 at Hellisheidi, laboratory based experiments, large scale plug-flow experiments, study of natural CO_2 waters as natural analogue and state of the art geochemical modelling.

Knowledge for the future

The bulk of the research will be performed by PhD students at the University of Iceland, thereby generating the human capital and expertise to apply the advances made in the project in the future.

ATTACHMENT 2.—TENTATIVE BUDGET FOR US—ICELAND COOPERATION IN THE IDDP

- Desired action: launch a US-Iceland collaboration immediately.
- Funds needed—for the next 5 years—25 million USD (approximately 5 million a year).
- US—Iceland cooperation by the DOE and ISOR, with involvement of SANDIA and other laboratories, institutes and universities cooperating to support the technology of the IDDP.
- Specific areas of collaboration:
  - —Develop and deploy advanced in high-temperature down hole logging tools and techniques and downhole fluid samplers.
  - —Develop high-temperature measurement while drilling tools (MWD) to monitor well conditions during drilling.
  - —Improve drilling at high-temperatures, select and test Drill Bits—e.g. PCD bits, and other drilling methods under development, e.g. thermal spallation. Improve continuous coring methods, e.g. with respect to penetration rate and cooling efficiency.
  - —Fluid Handling and Evaluation—harnessing natural supercritical fluids for power production and extraction of valuable minerals and/or metals.
  - —Reinjection-sustainable harnessing of geothermal resources—develop reinjection schemes in deep seated reservoirs. Develop evaluation methods.
  - —Material sciences—casings and wellheads, cements, heat exchangers, turbines.

As relevant, items 1 to 5 can be described in more detail, the scope of the research defined, potential partners specified, and the details of budget required for each task estimated. Part of the research and tool testing can be deployed in the first IDDP well in FY2009. The well will be drilled in 2008 (August-December), flow tested in 2009 (after heating up), and a pilot plant engineered and tested from 2009 to 2015. IDDP wells 2 and 3 will be drilled in 2009 and 2010, flow tested and studied for energy and chemical production as relevant. The IDDP mission could be completed

* Figures 1–2 have been retained in committee files.

in 2015. The range of fluid compositions that will be produced will range from dilute modified meteoric waters to modified seawater.

If the first well yields promising results the US-Iceland collaboration could begin planning attempting the same approach in the USA in FY 2011.

The CHAIRMAN. Thank you very much, President Grímsson. Thank you for your oral testimony, and also the excellent written testimony you've provided. It is very extensive and in-depth.

Let me also thank you publicly for your leadership in focusing our attention on this subject. As you know, Congress is pulled in many directions, and I think that the tendency in Washington is not to maintain a focus on any one subject very long. I think what you've been able to do in Iceland is keep a focus on this issue of developing renewable energy resources, and particularly geothermal resources over a substantial period, and obviously it's paid off very handsomely for your country.

Let me ask if you could give us any more information about the potential areas of cooperation that you mentioned, between our two countries, which are very good. To what extent is there an international consortium in existence, either formally, de facto, or in connection with geothermal research and development? Are there substantial efforts going on in other parts—in parts of Europe, in Australia, you mentioned China—perhaps you could give us a little insight into that?

Mr. GRÍMSSON. Thank you very much, Mr. Chairman. Let me say that, perhaps the benefit that we in Iceland have derived from other countries not having taken sufficient interest in this power and energy resource over the past half a century or so, was that it enabled us to develop a technological lead in this area, which we have now, in recent years, used as a base to create partnerships with many different countries in the world.

I mentioned this fascinating project in China—it has been enormously successful. It creates a potential for transforming the heating system in most of the major Chinese cities from coal and oil, over to clean energy, geothermal power, and thereby more or less cleaning up a large cause of the pollution in the Chinese cities.

The third-largest energy company in China, Sinopec, has had a number of dedications to my country. Next Tuesday, I will meet with President Hu of China, to discuss how this corporation should be taken further.

It's absolutely clear that China has now woken up to the great potential that the country has in the field of geothermal power, and the Chinese leadership is determined to utilize that potential.

In addition, we have started such a corporation in Germany. Many people wouldn't have thought that Germany could be a potential country from geothermal energy contribution, but that is definitely the case. Similarly, man Central and Eastern European countries, as well as countries in Central America, Russia, as well as India.

In fact, there is now almost endless traffic of Energy Ministers, and experts and business leaders to my country to try to get access to our limited manpower, because we are a small country and there's a limited manpower that we have in this area.

But the most recent addition is the entry of major banks and investors and corporate players into this area, because they have finally realized that geothermal, although expensive in the beginning can, in the long run over more than a century or so from the same portholes or so, if they are managed correctly, provide an extremely profitable long-term energy operation which is safe and secure and cost-effective. The reason why they want to do it, is that the banks and the investment companies have come to the conclusion that geothermal power is over 30 percent more profitable than any other form of clean energy today.

I think the strong interest from the business and the financial community is, perhaps, the best evidence of the extraordinary profit-making capability of this resource, if it is done in the right way. Part of the reason why electricity here in the United States from geothermal power plants is so much more expensive than the electricity from geothermal power plants in Iceland—in Iceland it's about 2 or 3 cents per kilowatt, whereas I believe it's about 7 or 8 here, in the United States, on the average—is that the Icelandic power companies use the geothermal source for many other business ventures. So, the electricity profits they get from that single resource, is just a part of their entire profit portfolio. That is why they can offer the electricity at a lower price.

So, I have now seen, in the last few years, an emergence of a strong international interest in this. I would even say that there is already a race on to get access to the scientific manpower, the technological capabilities, that are available in this area.

Because you need scientific manpower in order to be able to harness this resource, there is a limit provided by the availability of the scientific cooperation in this area.

Therefore, support for universities, research institutions, and long-term technical programs are an essential part of this success. We established in Iceland, in cooperation with the United Nations, almost—more than 25 years ago, the United Nations Geothermal Program. It wasn't intended for developing countries—not European countries or the United States, but we have trained almost 400 technical experts from many different parts of the world.

That network is now a key contributor to the success of the Icelandic cooperation with these countries. We want to do the same, from a little bit different perspective, with the United States in the coming years.

That's why I have issued, in addition to people in the Senate, a number of key American universities and technological institutions. That's why the Department of Energy sent a delegation to Iceland a few months ago, and we welcomed them with a warm heart and a strong interest. I believe there is a great scope for cooperation between the Department of Energy and the United States, between different State governments and city governments all over the United States, and also between business corporations, as well as universities and research institutions.

The CHAIRMAN. Thank you, thank you very much.

Senator Murkowski.

Senator MURKOWSKI. Thank you, President Grímsson. Just listening to your testimony, again, makes me energized—excuse the pun—about what the potential is for geothermal. It makes me frustrated that we have not done more in this country to advance it.

To have your leadership on this issue, I think is absolutely imperative.

You've given us some figures here this morning that ought to wake everybody up. If we're concerned about the initial high cost, the up-front cost, to invest in geothermal, your statement that geothermal ends up being 30 percent more profitable than any other energy source out there, ought to get the attention of those in the investment community.

As you know, in Alaska, that's been one of our struggles, our issues—we've got a lot of potential, we haven't been able to match up those with the investment and the capital side of it with the potential out there.

You mentioned the aspect of cooperation, and how Iceland is in a position to provide levels of assistance, and I appreciate how you have detailed all of those. I am very encouraged that you will be up in my State in just a couple of weeks here, along with Secretary Karsner, looking at some of the issues of energy in the Arctic, and how we can further advance, and I'd like to continue our conversation at that time.

I do want to point out, I guess, to the group that's here and those that are paying attention to this issue—in many ways, Iceland and Alaska are very similar, being Arctic areas, small populations, reliant on fossil fuels to power us from the beginning. But also recognizing that many things have been put off limits, because our population is small in number, and our expenses are so incredibly high.

But your point, to me, that other nations are looking to Iceland as a place to do their business, not because you have a great deal of manpower, or a labor source, but because you have a reliable, affordable source of energy. So that, whether you're a high-tech company that can basically do business all over the globe, instead of choosing a country that has a great deal of human resource, these businesses are now choosing to locate in place where the energy resource is there.

In several of my communities, I've got a grouping of about 17 communities out in Western Alaska, we're looking at a project there. They're currently paying, on average, about 30 cents a kilowatt hour for their energy costs. If we can put together a project that works for these 17 communities and network them, and bring them to a point where energy is now affordable, there's a level of sustainability out in villages that has never existed before.

So, I get energized, and I forget to ask my question. Let me ask you, you mentioned the concept of dry, hot rock development, and how one of the things that we might seek to do in terms of cooperation is further research in this area. Do you see this as economical in the future, as a power source, this dry rock? Dry, hot rock development? Or, is that still one of those that we need to spend a little more focus on, in developing that technology?

Mr. GRÍMSSON. Let me first, Senator, pay tribute to our cooperation and your friendship, toward me and to Iceland in this area ever since we first met in Alaska some years ago. As you know, I have, for a long time, been a strong believer that geothermal could be extraordinarily important for Alaska.

Perhaps, also, because it can feed the smaller communities in many different ways, and it can solve the energy problems, and help those communities to move away from oil, over to a cleaner, much cheaper energy base, and thereby strengthen—not only the community, but the economic potential of those.

We will be very happy—and I know the energy companies and the investors from Iceland are quite interested in exploring such cooperation with Alaska. You have been so kind—as well as my friends in Alaska—to invite me to come to the Arctic Energy Conference that you were hosting in Alaska next month. That might give us opportunities to explore this potential for Alaska, in a systematic way.

Let me also add that, here in Washington, one tends to forget that the United States is a Northern, and Arctic country. I can understand that, given the heat and the climate, and the humidity.

But one of the effects of President Putin putting that metal flag on the bottom of the Arctic sea bed was to wake everybody up to the enormous energy resource and the energy potential of the Arctic on the Northern regions. It's estimated—and I have been saying that, said it up in Alaska about 5 years ago, but nobody wanted to listen until now—but about a quarter of the unused energy resources in the world are in the Arctic, on the Northern territories.

That is also an area where, I believe, my country or the United States—both being Arctic and Northern countries—could have extensive cooperation.

In addition, and I think that's also an encouragement for Alaska—what has happened in the last year or two is that companies of many different types, industrial companies, software companies, internet companies, now want to gain access to clean energy resources on a long-term basis. We tried for 25 years, in Iceland, to get the second aluminum company to come to our country, and there were no takers.

But now, we are faced with what I call a queue of foreign companies and corporations, not only in the aluminum sector, but also in the internet, and the information technology sectors. Companies like Microsoft, Intel, Cisco, Google and others. They are looking forward to looking to exploring the potential of a long-term access to clean energy resources.

That has made me conclude that those regions, or States within the United States or countries in the world that can offer long-term access to clean energy resources of this kind, will be almost magnets for corporate investments in the years and the decades to come. That is a very important addition to the energy consideration. That it will strengthen the competitive position of the respective cities, regions and states that are fortunate to be blessed with this resource.

So, there is a completely new business environment out there. It's important for my country, and for the Senate, and for the U.S. Government to take that into consideration. Everyone wants to combine clean energy usage with the business opportunities of this new century.

Let me make it clear, Senator, that what I said before that was a geothermal power is—according to some banks and investors—more than 30 percent more profitable than any other form of clean energy—not, perhaps, of the entire energy field, but of clean energy.

With respect to your question of dry, hot rock, it is indeed one of the fascinating key areas of scientific and research estimation. In many different parts of the world, people are looking at that possibility, and then what I've sometimes said, simply harnessing the fire inside. We tend to forget that we sit on top of a huge fireball. That is probably the greatest energy resource that the planet is blessed with. Our task is to find the technology to harness that fire, which is inside the planet. We have made enormous progress in the last 30 or 40 years, but we are still in that process of technological innovation. The dry, hot rock area is one such exploratory phase which I believe offers a lot of possibilities.

I also mention another one which I have not mentioned this morning, and that is geothermal drilling on the seabed. There are, of course, geothermal resources on the bottom of the ocean floor. With the technology derived from the oil and the gas industry in recent decades, getting oil and gas up from the seabed, we have now, a much stronger technological possibility to harness the geothermal resources under the seabed.

That could be another area where cooperation between the United States and Iceland and other countries could, indeed, be very profitable, in addition to the deep drilling project, which I mentioned before. Consists of going as far down as 5 kilometers to an area where there are between 400 to 600 degrees heat. To examine the combination of pressure and heat—how that can be utilized.

So, there are fascinating opportunities out there, and I believe strongly that if we play it right, the support from the Senate and the Department of Energy and Russian, and Iceland and some other countries as well, we could see an extraordinary technological progress in the next 5 to 10 years in this area.

The CHAIRMAN. Before we continue with the questions, Senator Domenici, did you wish to make an opening statement? If so, please go right ahead.

Senator DOMENICI. Senator, I'll wait for my turn, and to vote.

The CHAIRMAN. OK, fine.

Senator Akaka.

Senator AKAKA. Thank you very much, Mr. Chairman.

President Olafur, again, it's great to have you here, and I want you to know that I'm very interested to hear more about the partnership, partnership of the public and private sectors in Iceland—during the early days of research and development and also during the days of exploring the potential of geothermal in Iceland, that's one of two questions. I understand the high potential of geothermal is risk-heavy and it requires much money, involves initial investments. Iceland overcame those risks, I understand, and challenges, and have shown the world that this has paid off. This is why I'm interested in hearing about your partnership of public and private sectors.

The other question is—which is important to us—at what point did funding shift predominantly to the private sector in these partnerships? So that, first there's the partnership, and the other is a funding shift predominantly to the private sector.

Mr. GRÍMSSON. Thank you very much, Senator. Let me first address what you said about the great risk involved in this area.

Maybe 20, 30, 40 years ago there was considerable risk involved. But now with the advance in the scientific knowledge of geologists and other scientific expertise in this area, if there is a sufficient scientific preparation for the drilling projects, the risk has been reduced considerably.

So, the combination of sound, preparatory science, before you start the costly drilling can reduce the risk to such an extent of now our energy companies very seldom come out with a zero result from their drilling. This was not the case 30 or 40 years ago. So, it's important to realize that the risk has been reduced considerably. Although the initial cost in the drilling is considerable, that is offset by—once you built the station, there is very little you have to do to it, for decades.

So, that is why the municipalities in Iceland that built the geothermal power plants are very reluctant to sell them. Because it enabled the municipalities to lower the taxes on the citizens, because they get so much profit from the geothermal.

In my country, the development of the geothermal was locally based. These were initiatives taken by local counselors in small towns, in fishing communities who simply wanted hot water for their houses. The famous Blue Lagoon, close to the fishing town of Keflavik to Vik, is a by-product of seven local counselors—fisherman and workers deciding in the local council 30 years ago, so they wanted hot water for their houses.

So, there is a series of locally owned municipal geothermal companies, that have grown up in different parts of the country, whereas the hydro-sector has been more driven by the State. But, it's more local initiatives that have driven the geothermal sector.

Of course, the State has played a role that is primarily through the drilling. But that company has now been privatized. So, the Iceland Drilling Company is now one of the largest local drilling companies in the world for the purpose of geothermal and it's a completely private enterprise, doing this solely on a profit-making basis, without subsidies to the company itself.

There has been some difficulties for the municipally owned geothermal energy companies to find ways, how do they allow themselves to partner up with banks and investors in order to create private entity enterprises, both in Iceland and elsewhere. But that's just now been primarily sold.

This year, we have established two major investment instruments in this area that intend to operate globally, on a business basis. One is Geysir Green Energy, and last month—no, sorry, this month—Goldman Sachs became one of the shareholders in the Geysir Green Energy Company which is jointly owned by the local geothermal company in Southwestern Iceland, the Icelandic investors and one of the Icelandic banks.

The other is Reykjavik Energy Invest, which was recently founded by the Reykjavik Energy Company in cooperation with some Icelandic investors and financial authorities with the purpose of inviting both American and other investors to join in.

So, out of what begun as a municipal-driven activity 40 or 50 years ago, have now developed major financial instruments that intend to become major players on a business basis, solely in the United States, in China, in Russia, in Indonesia, in Western Europe, as well as Central and Eastern Europe. I have come as far as to say that if we get it right, we will get more profit and greater revenues for my country through foreign activity outside of Iceland in this area, than we will probably get from any other sector in our economy. I know it's a strong statement, but I believe in the light of the energy requirements of the world, this is probably the most exciting and the strongest profit-oriented business endeavor that we can enter in to.

So, when I hear people here in the United States say, "Geothermal is costly, it's difficult, it's risky," and so on and so forth, I advise you to take a look at how we here in Iceland have turned this into an extraordinarily profitable business and intend to stay in it for a long while. You might doubt my words, but talk to the investors and the banks who are risking their money in this field. They wouldn't be doing it, unless they thought they would get great profit out of it.

The CHAIRMAN. Thank you.

Senator Domenici.

STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Senator DOMENICI. Mr. Chairman, I have a very brief opening statement, and I would ask that it be made part of the record as if read.

The CHAIRMAN. We will include it in the record.

Senator DOMENICI. Thank you very much.

Mr. President, let me thank you, again, for coming to testify. Your information will be very useful to the committee as it works to address our geothermal opportunities.

I think you know that both the Chairman and I come from New Mexico. There has been a great deal of money that has been spent at Los Alamos National Laboratory, where they went to very deep places under the surface to seek geothermal and to try to bring it up. They went through hot rocks, and put substance in to see if they could generate sufficient heat to the surface, so that it would become viable. My understanding, and I guess we will hear that from a witness that follows, Mr. Chairman, is that program didn't work for Los Alamos—at least from what I understand. We'll be glad to see what they did, or didn't do, that would change the situation.

In your testimony, you spoke about making loans to companies for exploration and drilling. Should the drilling fail to yield the expected results, the loans convert to grants—is that right, so far?

Mr. GRÍMSSON. Mm-hm.

Senator DOMENICI. On the surface it would appear that you are providing a grant program for those who fail. Perhaps you could give us a little bit more information to clarify exactly how this program works. Is that how it works, or did I get it wrong?

Mr. GRÍMSSON. In my country now, the new geothermal activity is entirely driven by the energy companies themselves. This is done within the auspices of the energy companies alone, they don't need any grants or support for it.

What we have, however, done is to establish the so- called Iceland Deep Drilling Project, which is a public/private partnership with some money from the Icelandic State, some money from the Reykjavik Municipal Energy Company, but also some private funding from, like, Alcoa, the aluminum company and other private resources, with the purpose of exploring the potential—as I said before—of harnessing an area of, between 400 to 600 hot, degrees hot geothermal resources.

That would be an entirely new phase, if that is successful, of the whole geothermal potential—not only in Iceland, but in the United States and all over the world.

So, I think, Senator, we have to distinguish between energy projects that are based on the ongoing technology, and what we already know now.

Although incentives might be given, for example, in this country here to different parts of the United States that are, perhaps, hesitant to start exploring this possibility, or even take the small communities in Alaska, the villages and so on—on the basis that if it is successful, then they will repay the whole thing back.

So, I believe, in the long run, you don't have to look at this as a State-subsidized kind of business. There might be areas of scientific and technological exploration, or even some drilling explorations tat are part of a research storage program, in the same way as you can say that Los Alamos Laboratory were in the beginning, used for producing the bomb, and so on, but have moved from that area over to geothermal and other contribution from a scientific point of view.

But, in this respect, I have to emphasize, however, that the greatest problem we have found in cooperation with other countries and partners is to let them realize that the more that you make a successful geothermal business, it is as important to manage the resource for decades after the drilling and the establishment of the turbines, and so on.

The reason why some of these energy projects, geothermal, have failed in the United States—have been closed down—was that there was not enough attention paid to the management of the resource, it was over-utilized over a short period, because the owners didn't realize that you have to have a level of sustainability in order to maximize your profit.

The biggest problem we had with the Chinese in explaining to them the nature of the geothermal business, was to let them realize this managerial aspect of the resource. Because they only looked at this as engineering corporation, in terms of the drilling and the turbines.

So, it is the comprehensive view, the entire business perspective of the long-term operation of it, which is important. Even if there are some subsidies and grants in the early stages, they should not be a hindrance for the overall long-term development of the resource.

Senator DOMENICI. Mr. President, let me say to you, once again, we appreciate your bringing this information to us, and the exchange of expertise between your experts and ours—the few that we have—will certainly be something we will look forward to as a result of this bill.

Mr. GRÍMSSON. If I can just say, Senator, some years ago, risk insurance either through tax incentive or other supporting mechanism was, perhaps, an important element in the development of this resource, but I don't think it is any more. I think now the companies, the investors are sufficiently advanced that they don't need any risk insurance in order to enter this in a big way.

Senator DOMENICI. That's good. Thank you very much.

[The prepared statement of Senator Domenici follows:]

PREPARED STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

Good morning. I want to add my welcome to President Grimsson of Iceland. You've traveled far, and you come with decades of experience in the development and use of geothermal resources.

I also want to welcome our other witnesses who've come to help us assess S. 1543, the National Geothermal Initiative Act of 2007.

Rather than take a lot of time for a lengthy opening statement, I will just note two things:

1. Geothermal energy is an important component of our quest to develop every conceivable domestic source of energy; and
2. That said, some, including myself, have a number of concerns about the specifics of this particular bill. The Administration is going to testify "the goal may be technically unattainable given the timeframes specified" and I hope we can work together to address this and other issues.

However, I look forward to working with you, Chairman Bingaman, to address those concerns as we work towards a mark-up of this legislation.

I know that time is short and we have a large number of witnesses with several lengthy statements to be made. I will likely submit most of my questions for the record to help keep this hearing on time.

Thank you Chairman Bingaman.

The CHAIRMAN. Thank you very much.

Senator Tester.

Senator TESTER. Thank you, Mr. Chairman.

I want to echo Senator Murkowski's remarks that your testimony is exciting, it gives us hope, and you're well on the way to having 70 percent of your energy from renewable resources, you're well on the way to zero emissions, and you've done it. I mean, that kind of shoots holes in any arguments that we can't do it, if you've done it, we can. So, I want to thank you on that.

Many of my questions have been answered, but I do have a couple. That is, you come from a different perspective, you've developed some partnerships with the United States. Have you noticed any regulatory or business barriers in this country to developing geothermal energy?

Mr. GRÍMSSON. There might be some. Although I know a lot about this business, there are some areas where my knowledge is limited. Maybe you could, perhaps, talk to representatives within the United States about this regulatory framework.

But, in order to proceed in a successful way, what I think we require is legislative support from the Congress. We need support from the Department of Energy. But, above all, we need strong interest from respective States, or cities or regions within the United States, because it has to be regionally and locally driven. That is the nature of this resource. If the interest is there, from the State governments and the city governments, I don't think there is a regulatory problem.

We are, for example, now engaged in three geothermal projects in California. They are not big, but they are the first geothermal that the Icelanders entered into in California, including providing a geothermal re-heating system for the ski resort of Mammoth. So, maybe Senator, you can come skiing to California and relax in the hot water provided by those resorts in the future.

Senator TESTER. The latter rather than the former would be better, yes.

Mr. GRÍMSSON. But the second is geothermal energy project within a National Park in California. I think that bears witness to the environmental element of this geothermal resource that California has allowed, such a power plant to be built within a National Park.

So, there might be some fine-tuning of the regulatory framework or the legislative framework and so on, but by and large, I think we need a strong support from the institutions, and then let the business sector run with the ball.

Senator TESTER. You had also spoke of, in your testimony—I think there were seven points—one of them was cooperation for higher ed and research institutions with Iceland and the United States, as well as banking. It makes sense. I was just curious—is there that kind of partnership now, and how extensive is it?

Mr. GRÍMSSON. Let me also pay tribute to what we have learned from the United States in this area. Many of our most foremost experts have been trained, and educated here, within the United States. I think it's important for you to realize that the reason that the United States—you have enormous resources of knowledge and experience in this area, it's just a question of putting it together in a different way, and giving it a different priority. Icelandic scientists have, for a long time, cooperated with research institutes and universities and other bodies within the United States Some of our most foremost people have also stayed within the United States for a long time.

We have cooperation with U.S. scientists and official bodies in the Icelandic Deep Drilling Project, we have cooperation with the Lawrence Livermore Laboratory. There was a tester who led the very distinguished MIT report in this area has, in the recent months, established cooperative links with one of our major universities in this area.

So, there is already a network in place. But, it has not been given the sense of priority, either from Congress or, with all due respect, perhaps until now, recently, from the Department of Energy. Also, different State governments, or city councils within the United States could do more.

But, if you succeed in harnessing the great rush of all the knowledge you already have in the United States, in cooperation with us in Iceland and others, I think you can have enormous progress in this area, in the coming years.

We have discussed with Under Secretary Karsner the possibility of, perhaps, doing a formal agreements between Iceland and the United States, modeled on the framework which has already been made between Sweden and the United States in this area.

As I said in my opening statement, there's a very strong interest in my country, of the scientific community, from the authorities, from the business community to strengthen our cooperation with the United States and we see that as a fascinating continuation of our alliance and strong friendship for more than half a century.

Senator TESTER. Thank you President Grímsson for your leadership and your vision. I very much appreciate it.

The CHAIRMAN. Senator Barrasso.

Senator BARRASSO. Thank you very much, Mr. Chairman.

Mr. President, I was curious, you talked about CO_2 capture, and a new way of disposing of the carbon dioxide, I think you said into rock, mineral sequestration, underground storage, and I noticed you had a couple of pages in the report, one toward the end and one at the very end. Could you give us a progress report, if you could? You talked—there's mention of planning of a full-scale CO_2 mineral sequestration experiment, and how that's developing and how you see this going down along the line?

Mr. GRÍMSSON. Thank you very much for mentioning that, because I have taken a strong personal interest in this project. It was, the beginning of it was a scientific partnership that I helped to create between prominent scientists from Columbia University, and the leaders of the Icelandic scientific community in this area.

The American leaders on this project have been Professor Klaus Lackner, and Professor Wally Broker of Columbia University who partners up with professors and scientists of the University of Iceland.

Then the Reykjavik Energy Company agreed to make the portholes available for this experiment. According to these prominent scientists—and I have to take their word for it, because it's not my expertise. The experiment is based on taking CO_2 from the geothermal emission in the beginning, pump it down into the portholes where it will mix with the basalt layers, and through chemical processes, turn into solid rock. I have a brief description here on this one piece of paper on this project which I might leave with you afterwards.

Another element of this project is the technology being developed in Arizona to pump CO_2 from the atmosphere and turn it into such a substance that it can also be pumped down into the ground.

There is, furthermore, the third dimension in this project is to take the exhaustion from aluminum smelters and other such industrial plants, and let them also mix up with the basalt layers, and turn into solid rock.

I think I'm correct in saying that all other carbon sequestration projects in the world run the risk of the CO_2 escaping sooner or later into the atmosphere. This is, perhaps, the only extensive scientific project based on the experiment of turning it into a solid substance, where it will exist down there, perhaps, for thousands of millions of years. Will it work? I don't know. But we'll know in 4 to 5 year's time.

My answer has been that, I doubt if these world- class scientists would be spending their effort or risking their reputation on this project, because it's—as you can hear, a high-profile, exciting project. If they can believe there is a reasonable chance of succeeding, this—the technological machine to take the CO_2 from the atmosphere has already been developed in Arizona. Now we have been discussing to bring it to Iceland to test it in different weather conditions than in Arizona. Since the basalt layers exist in Russia and the United States, India, as well as in Iceland, you have to be sure that the machinery will work in many different weather conditions.

But I have said so, and I will repeat it today, that if it succeeds, it's probably the most revolutionary contribution to the CO_2 problem from a single technological innovation that we could have. But, it is also an excellent example of what a cooperation between the United States and my small country could contribute of global relevance, by putting our best scientists and the best American scientists with strong corporate and financial support from the business community, and make them work together.

I will be happy to share with you that information, and provide you and others on the committee with more extensive information about this.

Senator BARRASSO. Thank you very much, Mr. President.

Thank you, Mr. Chairman.

The CHAIRMAN. Again, Mr. President, thank you very much for being so generous with your time, and expertise on this important issue and you've done a good job on focusing our attention on the subject, and we hope we can make serious progress and follow through with some of your recommendations.

Unless any other member has another question, why don't we thank you and then go to our second, and then our third panel after that.

Mr. GRÍMSSON. Just let me thank you, Senator, and the committee for the honor you have given me and my country for asking me to come here. I think it is testimony to what has been achieved in my country by scientists and the researchers in municipalities and local councilors, as well as governmental leaders over the last 50 years. So, by coming here today, I am bearing a witness to a long history of many people who have combined to make this a successful effort.

If I may conclude by inviting the committee to visit my country and take a closer look, and find out that what I have really told you makes sense on location, in Iceland. We are proud to host the astronauts who went to the moon for the training session before the space program was successful, we will be happy to host the committee in the same spirit for this new, fascinating journey for clean energy in the United States.

The CHAIRMAN. Thank you for that very generous invitation. We will try to take you up on it. Thank you.

Mr. GRÍMSSON. Thank you very much.

The CHAIRMAN. Our second panel is the Honorable Alexander Karsner, who is the Assistant Secretary for Energy, and Dr. Mark Myers, who is Director of the Department of Interior Geological Survey.

All right, Thank you both for being here. We will start with you, Secretary Karsner, and we appreciate your willingness to testify on this important subject, you're a frequent visitor to our committee, and we're always glad to see you, so go right ahead.

STATEMENT OF ALEXANDER KARSNER, ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. KARSNER. Thank you, sir.

Mr. Chairman, members of the committee, thank you for the opportunity to appear before the committee today to provide the Department of Energy's views on S. 1543, the National Geothermal Initiative Act of 2007. It's always an honor to appear before this committee, but let me say, it's particularly a pleasure today to be testifying after President Grímsson who has been instrumental in shaping much of my thinking on the subject of geothermal.

You all know that I was an Air Force brat for most of my youth, so I grew up in Kirtland, and Lowry and Carswell and places like this, but was very familiar with Kiler in Iceland, and the security legacy relationship we've had there. A new era of energy security can be born out of this alliance with Iceland and so I'm very enthusiastic and honored to be testifying after the President.

Turning now to the bill before the committee today, S. 1543. It establishes a national goal of achieving 20 percent of total electric energy production in the United States from geothermal resources, not later than 2030.

Additionally, the legislation directs the Secretary to establish a geothermal research, development, demonstration, commercialization, outreach, and education program in support of this 20 percent national goal.

While the Department shares the committee's interest in rapidly accelerating market penetration of all renewable energy technologies, including geothermal—this particular goal may, in fact, be technically unattainable within the timeframe specified.

Generating 20 percent of our Nation's electricity from geothermal resources would require in excess of 165 gigawatts of geothermal power plant capacity by 2030, based on the Energy Information Administration's (EIA) reference case, Electricity Demand Forecast.

In 1978, USGS National Geothermal Resource Assessment estimated 23 gigawatts of estimated conventional geothermal, also called hydrothermal technology, that can be developed for electricity. The difference of more than 142 gigawatts would have to come from new discoveries, conventional resources that were not viable at the time of the 1978 assessment, and unconventional means, such as enhanced geothermal systems (EGS), co-produced fluid from oil and gas wells, and geopressured, geothermal resources, as well as the avoided electricity use from heat, and heat pump applications. With the exception of one small co-production generator, none of these unconventional resources are currently being used to generate commercial power in the United States.

A recent report by the Massachusetts Institute of Technology, "The Future of Geothermal Energy," estimates that 100 gigawatts of electricity could be, in fact, installed by 2050 using EGS technology.

Again, while the Department supports the intent of the legislation, there are significant concerns with the feasibility of the national goal set out in S. 1543. The Department looks forward to working with this committee to resolve these and other technical concerns with S. 1543.

Since the founding of the Department of Energy, the agency has supported geothermal research and development. Over that period, a number of key accomplishments have contributed to increase commercial development of hydrothermal resources, to a point where today it has, in fact, reached market maturity. Favorable provisions of the Energy Policy Act of 2005, and other Federal and local incentives encourage energy to develop hydrothermal resources. These include an updated resource assessment, a Programmatic Environmental Impact Statement for major geothermal areas in the Western United States, a streamlined permitting and royalty structure, loan guarantees, and an extension of the production tax credit.

Looking at the future, the Department is currently considering the findings of the MIT study it funded, using funding in Fiscal Year 2007's operating plan.

DOE is holding discussions with industry and academic experts, further defining technical barriers and gaps, and determining technical and commercial actions that can help industry overcome the barriers, and to bridge those gaps. We expect to release this evaluation no later than the end of 2007.

Mr. Chairman, the Department anticipates that geothermal resources will continue to play an important and growing role in our Nation's energy portfolio, as we look to rapidly expand the availability of this clean, secure, reliable domestic source of energy.

The Department looks forward to working with this committee to resolve concerns related to S. 1543 and to continue our national commitment to clean, renewable energy production.

Mr. Chairman, this concludes my prepared remarks, and I'd be happy to answer any questions the committee members may have.

[The prepared statement of Mr. Karsner follows:]

PREPARED STATEMENT OF ALEXANDER KARSNER, ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before the Committee today to provide the Department of Energy's views on S. 1543, the National Geothermal Initiative Act of 2007, and to update the Committee on the Department of Energy's (DOE) Geothermal Program.

S. 1543 establishes a national goal of achieving "20 percent of total electrical energy production in the United States from geothermal resources by not later than 2030." To accomplish that goal, the legislation requires the Department of Energy and the Department of the Interior to characterize the complete U.S. geothermal resource base by 2010; develop policies and programs to sustain an annual growth rate in geothermal power, heat, and heat pump applications of at least 10 percent, and to achieve new power or commercial heat production from geothermal resources in at least 25 States; demonstrate state-of-the-art geothermal energy production; and develop tools and techniques to construct an engineered geothermal system power plant. Additionally, the legislation directs the Secretary to establish a geothermal research, development, demonstration, commercialization, outreach and education program in support of the 20 percent national goal.

The Department has significant concerns with the feasibility of the national goal established in this legislation. Generating 20 percent of our nation's electricity from geothermal resources would require more than 165,000 megawatts of geothermal power plant capacity by 2030, in Energy Information Administration's (EIA) reference case electricity demand forecast.[1] The 1978 USGS National Geothermal Re-

[1] The Energy Information Administration projects Total Electric Power Sector Capacity in 2030 to be 1159 GW. This projection is based on an assumption that geothermal power plant has a capacity factor of 80-85 percent. While the Department shares the Committee's interest in rapidly accelerating market penetration of all renewable energy technologies, including geo-

Continued

source Assessment estimated 23,000 megawatts of identified conventional geothermal resources, also called hydrothermal technology, that can be developed for electricity. The difference, more than 142,000 megawatts, would have to come from new discoveries, conventional resources that were not viable at the time of the 1978 assessment, and unconventional means such as Enhanced Geothermal Systems (EGS), co-produced fluid from oil and gas wells, and geopressured-geothermal resources, as well as and avoided electricity use from heat, and heat pump applications. With the exception of one small co-production generator, none of these unconventional resources are being used currently to generate commercial power. A recent report by the Massachusetts Institute of Technology (MIT), The Future of Geothermal Energy, estimates that 100,000 megawatts of electricity could be installed by 2050 using EGS technology. The MIT projection assumes a 15-year technology development program is conducted by the public and private sector prior to widescale installations.

Since the founding of the Department of Energy, the agency has supported geothermal research and development. Over that period, a number of key accomplishments have contributed to increased commercial development of hydrothermal resources—to a point where it has reached market maturity. The Department's investment contributed to the identification of those resources, accurate characterization and modeling of hydrothermal reservoirs, improved drilling techniques, and advanced means of converting the energy for productive uses. The Federal government has realized many successes in hydrothermal technology development, as evidenced by winning eight R&D 100 Awards in the past ten years. I would like to share with the Committee the Department's current assessment of the geothermal industry, and discuss briefly the future potential for geothermal development as a part of a diversified, domestic clean energy portfolio.

GEOTHERMAL INDUSTRY

Geothermal energy is the heat from deep inside the earth, coming in large part from the decay of radioactive elements. Geothermal heat is considered a base load renewable energy source, and can be used for electricity generation and direct use (space heating, district heating, snow melting, aquaculture, etc.). While geothermal energy is available at some depth everywhere, in the U.S., it is most accessible in western states such as California, Nevada, Utah, and Hawaii, where it is found at shallow depths as hydrothermal resources. This is where the bulk of conventional, commercial geothermal development is taking place, but a number of other states, notably Idaho, Oregon, Arizona and New Mexico, could see new power projects coming online in the very near future.

Geothermal resources can be subdivided into four categories: 1. hydrothermal; 2. deep geothermal (Enhanced Geothermal Systems or EGS); 3. geopressured; and 4. fluid co-produced with oil and gas. Of these, hydrothermal resources, which are characterized by ample heat, fluid, and permeability, have been developed commercially around the world. The other resource categories have not reached commercial maturity and are less accessible through conventional geothermal processes. The United States has been and continues to be the world leader in online capacity of hydrothermal resources for electric power generation.

Currently, the U.S. has approximately 2850MW_e of installed capacity and about 2,900 MW_e of new geothermal power plants under development in 74 projects in the Western U.S., according to industry estimates. In 2006, EIA estimates that geothermal energy generated approximately 14,842 gigawatt-hours (GWh) of electricity. The geothermal industry presently accounts for approximately 5% of renewable energy-based electricity consumption in the U.S. Most of the balance is split between hydropower and biomass, with wind and solar contributing a small portion.

In general, conventional hydrothermal technology is sufficiently mature, based on the following:

- The Western Governors Association geothermal task force recently identified over 140 sites with an estimated 13,000 MWe of power with near-term development potential.
- Hydrothermal reservoirs discovered at shallow depths using existing drilling technology, based upon similar available oil and gas practices used in the industry, are cost-effective.

thermal, this particular goal may be technically unattainable within the timeframe specified. The Department looks forward to working with the Committee to resolve these and other technical concerns with S. 1543.

- Power plant technology is based on standard cycles and can be bought off-the-shelf. Major development of binary-cycle power plant technology has enabled the development of increasingly lower temperature hydrothermal resources.
- Hydrothermal-generated electricity is cost competitive in certain regions of the country, where the resource can be maximized.

Favorable provisions of the Energy Policy Act of 2005 (EPACT 2005) and other federal and local incentives encourage industry to develop hydrothermal resources. EPACT 2005 contains significant provisions to promote the installation of geothermal power plants and geothermal heat pumps. These include:

- Resource Assessment.—USGS has been directed to update its 1978 assessment of geothermal resources (Circular 790). EPACT 2005 mandates that USGS complete the Resource Assessment report by September 2008. To date, the Department of Energy has contributed over $1 million in financial support as well as technical support through its national laboratories and the Department's Geothermal Resources Exploration and Definitions activity.
- Programmatic Environmental Impact Statement (PEIS).—A PEIS is being developed for the major geothermal areas in the Western U.S. by the Bureau of Land Management (BLM), in partnership with the U.S. Forest Service. DOE is a cooperating agency for the PEIS and the Department anticipates that completion of the PEIS will encourage geothermal production.
- Streamlined Permitting and Royalty Structure.—EPACT changed the royalty structure for leasing on Federal land from a 50/50 State/Federal split to a 50/25/25 split for State/Federal/local, providing an incentive for local governments to attract geothermal resource developers. EPAct also streamlined leasing requirements, which lowers costs for potential developers.
- Federal Purchases of Renewable Energy.—EPAct 2005 requires that the Secretary of Energy seek to ensure that federal consumption of electric energy during any fiscal year should include the following amounts of renewable energy; 1) not less than 3 percent in fiscal years 2007 through 2009, 2) not less than 5% in fiscal years 2010 through 2012 and 3) not less than 7.5% in fiscal year 2013 and each fiscal year thereafter.
- Loan Guarantees.—EPACT 2005 authorizes the Department to issue loan guarantees to eligible projects that "avoid, reduce, or sequester air pollutants or anthropogenic emissions of greenhouse gases" and "employ new or significantly improved technologies as compared to technologies in service in the United States at the time the guarantee is issued". On May 16, 2007, the Department issued a Notice of Proposed Rulemaking to establish the loan guarantee program. The comment period for that rulemaking has closed, and the Department anticipates finalizing the rule shortly. In addition, on August 3, 2007, the Department named David G. Frantz as the Director of the Loan Guarantee Office, reporting directly to the Department's Chief Financial Officer. By providing the full faith and credit of the Unites States government, loan guarantees will enable the Department to share some of the financial risks of projects that employ new or significantly improved technologies. DOE is currently authorized to provide $4 billion in loan guarantees, and the 2008 President's Budget requested $9 billion in loan volume limitation.

In addition, the Tax Relief and Health Care Act of 2006 extended the production tax credit for geothermal and other renewables that are put into service through December 31, 2008. This provision has had a significant impact on encouraging new installations of conventional geothermal power facilities; as I mentioned previously, over 2,900 MW_e are now under development in the U.S. An investment tax credit of 10 percent is also available to the industry, but cannot be combined with the production tax credit. Because conventional geothermal is a mature technology and favorable policy changes have clearly resulted in the growth of the industry, the FY 2008 Budget Request terminates the current Geothermal Technology program.

ENHANCED GEOTHERMAL SYSTEMS (EGS)

Enhanced Geothermal Systems (EGS) involves technology that enables geothermal resources that lack sufficient water or permeability (compared to conventional hydrothermal resources) to be developed. The ultimate intent is to tap energy from hot impermeable rocks that are at a depth of between 3 and 10 kilometers in the earth's crust. Such rock formations require engineered enhancements to enable productive reservoirs.

DOE funded MIT to conduct a study of EGS potential in the U.S. MIT made the following key findings:

- EGS has the potential to produce up to approximately 100,000 MW of new electric power by 2050 based in part on an abundance of available geothermal resources.
- Elements of the technology to capture EGS are in place.
- Multiple reservoir experiments are required.
- Successful R&D could provide performance verification at a commercial scale within a 15-year period nationwide.

The Department is currently considering the findings of the MIT study. DOE is holding discussions with industry and academic experts, further defining technical barriers and gaps, and determining the technical and commercial actions that can help industry overcome the barriers and to bridge the gaps. Input has come from oil and gas companies, service companies, academia, the geothermal industry, international experts, government agencies, and the national laboratories. We expect to release this evaluation by the end of 2007.

CONCLUSION

In conclusion, Mr. Chairman, the Department anticipates that geothermal resources will continue to play an important and potentially growing role in our nation's energy portfolio, as we look to rapidly expand the availability of clean, secure, reliable domestic energy. The industry currently benefits from tax incentives and regulatory streamlining in EPACT 2005, and future industry investments in enhanced geothermal have the potential to significantly expand domestic geothermal energy production. The Department looks forward to working with this Committee to resolve concerns related to S. 1543, and to continue our national commitment to clean, renewable energy production. Mr. Chairman, this concludes my prepared remarks, and I would be happy to answer any questions the Committee Members may have.

The CHAIRMAN. Thank you very much.

Dr. Myers, go right ahead.

STATEMENT OF MARK D. MYERS, DIRECTOR, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Mr. MYERS. Great, thank you, Mr. Chairman and committee members for the opportunity to testify today, and to provide the Department of Interior's views on S. 1543.

The Department of Interior supports the goal of increasing the percentage of electrical production that comes from renewable resources, which could have many positive effects to the environment and the economy. Expanded national geothermal resource assessment effort will contribute to the goal of providing the information needed to assess the potential contribution of geothermal energy to the Nation's domestic energy mix.

Geothermal resources have the potential to provide significant amounts of clean, renewable, reliable energy to the United States. Based on current projections, the United States will need to increase its electrical generating capacity by 40 percent over the next 20 years. The critical question is, to what extent can geothermal resources contribute to the increasing demand for electricity?

Geothermal energy is one of the Nation's largest resources of renewable power. In the 1978 U.S.G.S. National Geothermal Resource Assessment estimated 23,000 megawatts of identified conventional geothermal resources, however currently installed capacities estimated to be approximately 2,850 megawatts, or about 12 percent of that potential.

Under the Energy Policy Act of 2005, the U.S.G.S. is conducting a new assessment of conventional moderate to high-temperature geothermal resources, and will report on the results of that assessment in the Fall of 2008.

The new assessment will provide the detailed estimate of the geothermal electrical power generation potential from identified and undiscovered resources that could be used to evaluate major technical challenges, or increase geothermal development.

Approximately 250 identified geothermal systems will be included in the current assessment effort, which will result in an improved understanding of thermal, chemical and mechanical mechanisms that lead to the formation of productive geothermal systems.

I'd like to say, in order to have a successful geothermal project, you need certain technical properties to the rock—you need a hot source of rock, you need a way to transfer that heat energy through, which is through a fluid. You need the rock to have enough properties of conductivity or permeability, in order to actually be able to move the fluid through the rock in a sufficiency to extract the heat, and you need a cap rock source over the type. These issues are not unlike what you need for an oil and gas deposit, but those elements need to be present.

So, when you look at characterizing and assessing conventional geothermal resources, the assessment will include a provision to look at Enhanced Geothermal Systems, or EGS. EGS are geothermal resources that required some sorts of engineering to develop that permeability, that interconnectability in the rock, necessary for the circulation of the hot water or steam, and the recovery of the heat for the electrical power generation.

These types of reservoirs can range from sub-commercial geothermal resources that need modest permeability enhancement, or fracturing of the rock, to entirely impermeable hot, dry rock that either lacks the connect conductivity between the rock zones, or the fluid you need to transfer the heat.

EGS, this enhances the focus of rapidly evolving scientific and technical study in both the United States and abroad. With an additional study, the characterization that would be authorized under S. 1543, the U.S.G.S. can provide a more comprehensive understanding of how these potential resources can contribute to the domestic energy mix.

Several other unconventional geothermal resources have the potential for electrical generation. These include, geopressure geothermal resources, and co-produced geothermal and oil and gas. Geopressure geothermal resources are found in deep, high-temperature permeable formations and sedimentary basins that have water at significantly elevated pressures. The hot, high-pressure water, saturated with methane and the resources consist of a combination of thermal, mechanical, and chemical energy. Most of the geopressure geothermal resources are located in the Northern Gulf of Mexico Basin.

Coal-produced geothermal and oil and gas is a relatively new concept, where geothermal resources rely on dedicated wells for producing—from primarily water-bearing formations under high pressure—a coal-produced system is one in which the geothermal heat extraction process coordinated with new or existing oil and gas wells. This requires geothermal electrical power technology to lower fluid production rates, typical of most oil and gas wells.

The U.S.G.S. has geothermal and related expertise, as well as an ongoing effort in geothermal research and characterization. S. 1543 will require the U.S.G.S to expand its current assessment effort. We believe the best approach to a comprehensive national geothermal assessment is to develop the geologically based methodologies for evaluating unconventional geothermal resources capable of providing electricity. Additionally, our understanding conventional reservoirs would be improved by enhanced characterization that would be done in conjunction with the evaluation of unconventional resources.

At present, most identified geothermal systems in the United States are incompletely developed, or inadequately characterized. The Department shares the committee's desire to increase the use of renewable energy, including geothermal resources, to ensure that we are able to promote renewables in the most cost-effective ways available, and to maintain appropriate flexibility in the budget management, the Administration recommends the bill be amended to authorize, rather than require, the assessments within the statutorily provided timeframe. This would ensure that the activities authorized under the bill would compete in the normal prioritization, budget and funding process.

Thank you, Mr. Chairman, and I'd be happy to answer any questions that you might have.

[The prepared statement of Mr. Myers follows:]

PREPARED STATEMENT OF MARK D. MYERS, DIRECTOR, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Mr. Chairman and Members of the Committee, thank you for the opportunity to provide the Department of the Interior views on S. 1543, "National Geothermal Initiative Act of 2007."

The Department of the Interior supports the goal of increasing the percentage of electricity production that comes from renewable sources, which could have many positive effects on the environment and economy. An expanded national geothermal resource assessment effort could contribute to this goal by providing State and Federal government policy makers, other Federal agencies, the energy industry, and the environmental community with the information needed to estimate the potential contribution of geothermal energy to the Nation's energy mix. However, the Department has several concerns with S. 1543, including the availability of funding for the work proposed in the context of overall funding for the Administration's priorities. We share the Committee's desire to increase the use of renewable energy, including geothermal resources. That said, to ensure that we are able to promote renewables through the most cost effective ways available, and to maintain appropriate flexibility in budgetary management, the Administration recommends that this bill be amended to authorize rather than require the assessment within a statutorily prescribed timeframe. This would ensure that the activities authorized under this bill would compete under the normal prioritization, budgetary, and funding process. We would like to work with the committee to revise the bill to address these issues.

GEOTHERMAL ENERGY—EXISTING STUDIES AND REMAINING QUESTIONS

Domestic geothermal resources have the potential to provide significant amounts of clean, renewable, and reliable energy to the United States. Based on current projections, the United States will need to increase its electrical power generating capacity by 40 percent over the next 20 years. A critical question is to what extent can geothermal resources contribute to this increasing demand for electricity? Geothermal energy already constitutes one of the Nation's largest sources of renewable electrical power, yet the installed capacity of approximately 2850 megawatts falls short of current geothermal resource estimates.

Under § 226 of the Energy Policy Act of 2005 (EPAct), the U.S. Geological Survey (USGS) is currently conducting a new assessment of conventional moderate-temperature and high-temperature geothermal resources and will report on the results of that assessment in the fall of 2008. The new assessment will provide a detailed estimate of the geothermal electric power generation potential from identified and undiscovered resources and include an evaluation of major technical challenges for increased geothermal development. Approximately 250 identified geothermal systems will be included in the current assessment effort, which is resulting in improved understandings of the thermal, chemical, and mechanical processes that lead to the formation of productive geothermal systems.

In addition to characterizing and assessing conventional geothermal reservoirs, under the EPAct authorization, the USGS is examining one type of unconventional geothermal resource—Enhanced Geothermal Systems (EGS). EGS are geothermal resources that require some form of engineering to develop the permeability necessary for the circulation of hot water or steam and the recovery of heat for electrical power generation. These types of reservoirs can range from subcommercial geothermal reservoirs that need some modest permeability enhancement to entirely impermeable "hot dry rock" that not only requires permeability but also sufficient quantities of water. A provisional examination of the onshore U.S. EGS resources will be included with the new USGS national assessment efforts. However, EGS is the focus of rapidly evolving scientific and technical study both in the United States and abroad. With additional study and characterization that would be authorized in S. 1543, the USGS could provide a more comprehensive understanding of how this potential resource can contribute to the domestic energy mix.

Besides EGS, there are several unconventional geothermal resources that have potential for electrical generation. These include Geopressured Geothermal resources and Co-Produced Geothermal and Oil & Gas. Geopressured Geothermal resources are found in deep, high temperature, permeable formations in sedimentary basins that have water at significantly elevated pressures. This hot, high-pressure water is saturated with methane, and the resource consists of a combination of thermal, mechanical and chemical energy. Most of the geopressured geothermal resources are located in the northern Gulf of Mexico Basin. Co-produced geothermal and oil and gas is a relatively new concept. Where geopressured geothermal resources rely on dedicated wells producing from primarily water-bearing formations under high pressure, a co-produced system is one in which the geothermal heat extraction process is coordinated with new or existing oil wells. This requires adapting geothermal electric power generation technology to the lower fluid production rates typical of most oil wells.

Under S. 1543, USGS contemplates carrying out a national geothermal resource assessment that would build on current USGS efforts by including unconventional geothermal resources, as well as an enhanced characterization and understanding of the domestic, conventional geothermal resources.

In carrying out such a comprehensive assessment, USGS would coordinate and cooperate with the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), other Department of the Interior bureaus, State geological surveys, and other relevant entities that have geothermal expertise and responsibilities. USGS and DOE are already cooperating on the current national resource assessment mandated by EPAct through shared technical expertise and DOE's provision of supplemental funding to USGS.

REQUIREMENTS OF S. 1543

S. 1543 requires the Secretary of the Interior, acting through the Director of the U.S. Geological Survey (USGS), to conduct and complete a comprehensive nationwide geothermal resource assessment that examines the full range of geothermal resources in the United States; submit to the appropriate committees of Congress a report describing the results of the assessment; and in planning and leasing, consider the national goal established under this Act.

The USGS has geothermal and related expertise as well as an ongoing effort in geothermal research and characterization. This bill would require USGS to expand on the current assessment effort, and we believe the best approach to a comprehensive national geothermal assessment is to develop geologically based methodologies for evaluating unconventional geothermal resources capable of producing electricity. Additionally, our understanding of conventional reservoirs would be improved by the enhanced characterization that could be done in conjunction with evaluation of unconventional resources. At present, most of the identified geothermal systems are incompletely developed and inadequately characterized. The current USGS effort will help alleviate some of this challenge, but more work can be done.

CONCERNS WITH S. 1543

S. 1543 requires that a national assessment be completed by 2010. The Department does not believe that this timeframe adequately recognizes other important budgetary priorities and believes that the activities authorized under this bill should compete under the normal prioritization, budgetary, and funding processes.

In order to substantively undertake an evaluation of the unconventional geothermal resources, a methodology for assessing these resources must first be developed, peer reviewed, and published. Even with full funding at the levels contemplated in this bill, methodology development would take approximately one year. Once that methodology is developed and peer reviewed, more time would be needed to conduct the national assessment of the unconventional resources and a more robust evaluation of the conventional geothermal resources. We are concerned about the statutory timeframes for accomplishing the assessment laid down in this bill. We would like to work with the committee to ensure that the timeframe used by the Federal government for its assessment of unconventional resources is prudent and consistent with the national goal identified in S. 1543.

With recent interest in offshore areas for geothermal development, we would appreciate clarification as to whether unconventional resources should include areas offshore such as the outer continental shelf (OCS). If the national assessment includes the OCS, USGS would work in cooperation with the Minerals Management Service which would have the lead for the OCS portion of the effort. However, inclusion of the OCS would increase the cost and time needed to complete this assessment.

Many geothermal resources are located on onshore Federal lands. The availability of leases of geothermal resources to electricity producers is important to the national goal identified in this act of increasing the percentage of electrical energy production from geothermal resources. It should therefore be noted that onshore geothermal resources on the Federal lands are leased by the Bureau of Land Management (BLM) under regulations developed pursuant to EPAct. The BLM and Forest Service (FS) are already considering geothermal development in their land use planning. BLM and FS are jointly preparing a Geothermal Programmatic Environmental Impact Statement (PEIS) to plan for and support future geothermal leasing. This PEIS will evaluate pending geothermal lease applications and areas with high potential for geothermal development, and in this sense support the goal identified in S. 1543.

CONCLUSION

In conclusion, the Department of the Interior believes that it is important to consider all available options that may contribute to the goal of a comprehensive national assessment of geothermal energy. Such an assessment would provide a variety of organizations the information needed to determine the viability of geothermal energy to contribute to the Nation's domestic energy mix. However, we have concerns relating to the bill's timeframe, clarity and scope. Significant changes are needed to address the full range of the Administration's concerns before we could support this legislation.

Thank you, Mr. Chairman, for the opportunity to present this testimony. I will be pleased to answer questions you and other Members of the Committee might have.

The CHAIRMAN. Thank you both very much.

Secretary Karsner, let me ask you, first of all, obviously a major purpose that we have in putting forth this proposed legislation is to get a focus area of energy development over a significant period of time. So, I think we've got an unfortunate history in this country of funding something for a year, and not funding it for a year, and then back again, and then cutting the funding in half. This is one of those areas, as I understand it, there is no funding in the current year budget for geothermal—am I right about that?

Mr. KARSNER. You are correct about that.

The CHAIRMAN. That is a change from some previous years. I mean, maybe you could give us a little bit of the history in the last several years as to what we've done in this area, as you understand it?

Mr. KARSNER. Yes, sir, I will.

Of course, the Department's reaching its 30th anniversary in coming weeks, and over those 30 years, it has traditionally funded geothermal for 28 of them. So, this wasn't the first year it was zeroed out, in fact, the year prior was.

Cumulatively, the Department has invested about $1.3 billion over that period, predominantly—and almost exclusively—aimed at hydrothermal shallow reservoirs. So, a lot of good progress was made through the taxpayers' investment over that amount of time, over more than a quarter of a century. Even as recently as the last several years, the geothermal program has earned up to 8 R&D 100 awards for excellence and breakthroughs in its technology.

Interestingly, though, with the passage of the Energy Policy Act—some of the policy that had, in fact, been lacking, some of the efforts by the Federal Government to fund commercialization aspects that were not in effect prior to the EPAct 2005—came in effect and had a very substantial impact on the rise of the sector.

So, there's not a direct correlation, one-to-one, with the amount of R&D investment to the prosperity and the proliferation of the technology into our economy. So, in fact, the correlations are the opposite—as the technology R&D funding has gone down, and tax credits and other incentives, streamlined permitting royalties go up—more deployment occurs, and more private sector capital is stimulated.

We'd like to understand, better, what the findings were of the MIT report that has been so consequential in terms of establishing some equilibrium with an eye toward the future of going beyond just conventional hydro-thermal investments, and getting into accessing what is possibly an immeasurable resource underneath the whole of the country, but accessing it in new ways that, previously, we had not.

The CHAIRMAN. Let me just say, I hope you will work with the committee and those of us who are supporting this legislation—to get it in a form so that it would lay out something of a blueprint that the Administration could be supportive of going forward, so that we don't have a constant push and pull between the Administration and the Congress, the Congress wanting one thing, the Administration committed to something different.

I hope that we can work that out this fall, and then I hope that we can see that reflected in budget requests coming from the Administration in future years.

Mr. KARSNER. We'd be pleased to continuously work with the committee on that basis.

The CHAIRMAN. That would be great.

Let me turn to Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman.

I just want to follow up on that, you know, it appears to me that our energy policy is somewhat dictated by who's liking what type of energy. Is wind the end all and be all? With some people it is, and you've got them taking point on it, and you see great things happening. You've got an advocate—certainly, Senator Domenici, Senator Bingaman have been huge, strong advocates in the nuclear, and you see advances there; President Bush decided it was ethanol.

There is this very sporadic focus, and with that focus comes the dollars, and there's that flurry of activity, but when we're talking about sustainable energy into the future, there's got to be leadership and initiative and the funding that comes with it.

So, I appreciate your statements here that you support the intent of where we're going with this legislation, I'm concerned that you point out that right now you don't think it's feasible. I guess I get inspired by President Grímsson, I'll say so, and I think we need to figure out how to get to yes on some of this stuff, instead of saying, "Well, we can't meet the 20 percent goal, so we're just not going to start there."

Let me ask you about the low-temperature geothermal research. We have been delighted to partner with the Department of Energy in the State of Alaska to work on a project up there that you're very familiar with. We've demonstrated the viability of low-temperature technology, but we know we've got to enhance its performance to improve the efficiency if we're to develop the systems.

What plans does DOE have for pursuing advanced low-temperature geothermal research going forward?

Mr. KARSNER. Thank you, Senator, that's a great question, and I think you're referring to the Chena Hot Springs Project, which is one of those R&D 100 awards——

Senator MURKOWSKI. Right.

Mr. KARSNER [continuing]. That I just alluded to, based on using record low temperatures, in fact, to convert geothermal to an energy resource at site.

That project is an example of how we have matured something, and the question, then, becomes how should we proliferate it? So, that's a new model.

Fundamentally, most geothermal discussions are about distributed energy. So, it compels an array of other discussions that we haven't looked at in our very narrow focus, almost exclusively on the conversion technologies, or resource assessments.

In this case, we have to figure out how we might facilitate a reliability in the manufacturing at scale at 200 KW conversion devices produced here domestically for the purpose of exploiting those widely available resources. We can't really do these things on an on again/off again basis. That is to say, suppliers have to know there is a real and continuous market.

So, I'd say, with respect to low temperature, we need to do a lot more market cultivation, as we have done in other programs.

I take your point, and in fact, take it very seriously, when you talk about the propensity that government has had through a legacy of managing this portfolio in prioritizing one technology over the other. I hope that we are being successful, and that we will have a future of moving beyond technology preference and selection, and moving toward preference for attributes—that is to say, the priorities of our mission are that energy ought to be clean, it ought to be affordable, it ought to be reliable, it ought to be secure, and really, it ought to be domestic, to the extent that we maximize it with the Department of Energy. That, that definition ought to be cross-cutting and holistic to a balanced portfolio approach to technologies.

So, I know that is what Secretary Bodman has emphasized and that we have emphasized. But it is a necessary thing that you have put to us, that we move beyond that, and not fluctuate in the way that we invest in these technologies.

Having said that, proportionality and perspective of what each can contribute, and the positive and negative characteristics of each technology—and almost every technology possesses both positive and negative characteristics—have to be taken into account. So, I take the view that we will need all of these technologies, and we will need them to meet those criteria. Of course, geothermal is one that, one could say, meets it in spades, in terms of its reliability, its security, its cleanliness, et cetera.

Senator MURKOWSKI. I appreciate that.

Mr. KARSNER. So, proliferation of the 200 KW is going to require more commercialization focus.

Senator MURKOWSKI. Appreciate that, and I couldn't agree with you more.

Dr. Myers, just very quickly, as you talk about the new assessment, I would certainly like to see the U.S.G.S. do this new assessment as soon as possible, do you have plans for an examination of the low-temperature resources, in addition to the traditional resources, then, as part of the national assessment?

Mr. MYERS. Senator Murkowski, a national assessment will focus on high and moderate temperature, again, we plan on completing that by 2008——

Senator MURKOWSKI. What is moderate? How do you define moderate temperatures?

Mr. MYERS. Ninety degree C.

Senator MURKOWSKI. OK.

Mr. MYERS. Ultimately, the enhanced assessment to look at EGS would look more dominantly and provide a methodology for assessing many of the SGA or low-temperature.

Senator MURKOWSKI. But that enhanced assessment isn't this assessment that will be going forward first?

Mr. MYERS. That's correct.

Senator MURKOWSKI. So, you don't see that happening for awhile?

Mr. MYERS. I see, under the current funding scenarios, us being able to successfully complete the assessment that we're doing on the 250 sites by 2008. But, the enhanced—looking at, particularly looking as ESG—won't happen unless we devote more resources to the assessment, in the outgoing years beyond that.

Senator MURKOWSKI. But, in any case, it wouldn't be until a couple of years from now, provided that funding is there?

Mr. MYERS. That is correct.

Senator MURKOWSKI. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Tester.

Senator TESTER. Yes, Mr. Chairman.

I'd like to thank the panelists for being here today.

I may have asked this question before, so you'll have to refresh my memory—is the DOE concerned with carbon release and global warming, in general?

Mr. KARSNER. I think you have asked the question before, and the answer remains, yes. We're very concerned, and we're very assertive on the subject matter, as would be indicated by our participation this week and the President's convening the major economies on this subject.

Senator TESTER. As I look at some of the work that the DOE's done—and I don't want to be critical, but I will—a lot of it has been around coal, which is big in the State of Montana, so I can't be negative against that, and petroleum, which is big around the State of Montana, and nuclear power. With the exception of potentially nukes, global warming is a huge issue with those energy sources, but yet when I go through your testimony, very little is being done with things like geothermal, which seems to be a slam dunk.

I'm a little bit embarrassed by the fact that Iceland has moved forward on this very rapidly—we've got tremendous resources in this country, and literally, nothing has been done. As I look back, you're quoting studies from 1978—that's nearly 30 years ago.

When I was in high school and debated, if I had taken a 30-year source for my substantiation for evidence, I'd have lost every damn debate—and I lost most of them anyway—but I'd have lost every damn debate I was in. I mean how can you go back 30 years for substantiation of saying that 20 percent by 2030 is not achievable?

Mr. KARSNER. Two separate things there—in terms of the ultimate capacity that may be achievable, there are a great deal more factors than the U.S. Geological Survey study—I'll let my colleague from the U.S.G.S. speak to the study itself—but as a power plant developer, what I can tell you is, the studies are fine, they're interesting at a given scale to have a government background study. By way of example, if I were using wind study and statistics from the NOAA, as wind developers frequently do—that is useful as a baseline, but it is not at all useful in terms of commercially financing and deploying the technology.

Senator TESTER. Yes, but——

Mr. KARSNER. So, the study being 30 years old, has no correlation to the fact that the sector is booming now, as never before. So, we want an updated study, I think that's a good piece of the legislation, I think, very thoughtful, but it is not what is the indispensable factor in the growth.

Senator TESTER. But, one of the first statements you made in your testimony—and correct me if I'm wrong—is that a 1978 study said that 23 KW would be available. So, the 20 percent was unrealistic by those standards. Of course it would be unrealistic by those standards. When was the last time an assessment was done on geothermal availability in this country?

Mr. KARSNER. I don't have the answer as to the last time it's been done—I believe in 1978—you're correctly quoting. But, whatever the margin of error may be in the modernization of the study, I can assure you, Senator, by magnitudes and orders of multiples of three or four times, it will be an extreme delta between 20 percent and 165 KW by 2030, whether 23 moves to 30, or 35 or 40. We have nothing in the body of science, from MIT or elsewhere, that would allow us to say that's feasible.

Senator TESTER. I can just tell you, from my perspective, as a dirt farmer from North Central-Montana, if I don't think it can be done, it won't be done. Period. It won't happen. If I go into it and say, "Yes, we're going to use the resources that we have, and we're going to demand more resources for an assessment that take into all counts of geothermal," then it will happen. I think, I honestly think that 165 KW is entirely achievable. Even with a miniscule 23 in a 1978 study.

But, the truth is, I don't think there's enough focus on geothermal and I think that's the problem. I don't mean to be critical with the study here, because I think that you have to come forth with what the Administration wants you to come forth with, so you've got no choice, you're between a rock and a hard place, but to overlook the geothermal opportunities and to go in saying that we can't achieve 20 percent by 23 years from now, I think is selling this country short, and quite frankly selling the Department of Energy short on their ability to look into the future with a vision. That's all I have to say.

We need to have an assessment done, and would I hope that that assessment is a realistic assessment, and not an assessment that we go in and say, you know, "We don't have the resources, so we might as well forget it." I hope it's complete, it doesn't sound like it's going to take into account a lot of things it should be looking into, it'll take into moderate and high resources—correct, Dr. Myers?—when I think there's even more availability out there, in some of the stuff below 90 degrees.

But, I want to thank you for your testimony and thank you for coming, I appreciate it.

The CHAIRMAN. All right, thank you very much, Thank you both for your testifying.

I think I'll go ahead with the third panel, here, so please come forward at this point.

On the third panel is Susan Petty with AltaRock Energy in Seattle, Washington, David Wunsch, who is a Ph.D., from the New Hampshire Geological Survey, Lisa Shevenell, who is a Ph.D. with the Mackay School of Earth Sciences and Engineering at the University of Nevada in Reno, and Kenneth Williamson who is a geothermal consultant and Ph.D. from Santa Rosa, California.

Thank you all very much for being here.

Let me just ask if each of you could take about 5 minutes and summarize your testimony. We will include your full testimony in the record, but we would appreciate you telling us the main points that you think we need to focus on.

Ms. Petty, Thank you for being here, I understand you were one of the co-authors of the MIT study that's been referred to here several times, and we congratulate you on that, and go right ahead.

STATEMENT OF SUSAN PETTY, PRESIDENT, ALTAROCK ENERGY, INC., SEATTLE, WA

Ms. PETTY. Thank you, Mr. Chairman and members of the committee. I'm honored to have the opportunity to speak to you today regarding S. 1543.

One of the goals of the MIT study was to look at what the future of geothermal energy might be. Our 18-panel member study looked first at assessing what the magnitude of the resource was, and we found that this geothermal resource is truly vast. It extends across the entire continent and it's available to us using technologies to recover it, that we are not now using.

We found that, while you can use the heat through circulation of fluids through natural fractures and permeability, we can access much more of this resource by creating or enhancing fractures in hot rock. These are the enhanced, or engineered geothermal systems, or EGS.

EGS power is technically feasible today. The first project, a commercial and public venture in Germany—will go online in the next few months at the—in the town of Guntherhocking. Potentially—the study found that—potentially 100,000 megawatts could be online by 2050 with modest Federal investment over an 8 to 10-year period of only $368 million.

The best resources of this kind are economic, now. These best sites where high temperatures are found at shallow depths, are actually, have been studied in the past, and could be used to develop this type of resource, with this technology with today's—with today's economic power crisis.

However, the study also found with incremental technology improvement, the cost of power from these types of resources, from EGS resources could be cut in half, or more. These technology improvements are built upon the technology we use today to generate power from conventional or hydro-thermal resources, and rely on drilling technology, conversion technology, and fracturing technology that we use now. So, while this is technically feasible in many areas, it's not economic across the whole United States.

However, with combing learning by doing, and innovative technology improvement, we could make a really large amount of energy both technically and economically feasible.

The fracturing technology that we use comes out of the oil and gas industry, but has been demonstrated and improved at sites in Europe, and is now being tested in sites in Australia. There are 8 companies in Europe developing more than 50 projects using this type of technology, this has happened due to price incentives and technology and research investment from European Union.

Twenty companies in Australia are now working to commercialize EGS power development, and here in the United States we have one company focused on developing power from EGS technology. As a result of the findings of the MIT study, I founded AltaRock Energy in this past year, and we plan to use the technology that has been developed in the past, both by the Department of Energy's research program in geothermal and also through research that has been conducted in Europe and is being conducted in Australia.

S. 1543 provides for funding for geothermal energy research, as well as increasing geothermal energy use by 10 percent per year, to ultimately reach a 20 percent goal of our Nation's energy use. However, we're not asking to make this investment with no return. If only half of the energy that would meet this goal of 20 percent were generated from Federal lands, over $1 billion of royalties would be generated from this energy production.

This royalty would go 50 percent to the Federal Government, and the other 50 percent would go to the States and counties in which these energy developments took place. This seems to me to be a very excellent return on a very modest investment.

So, in both—while getting this investment, while making this investment not only ensures this return, it also provides our country with a source of clean, renewable, and an indigenous energy. Thank you.

[The prepared statement of Ms. Petty follows:]

PREPARED STATEMENT OF SUSAN PETTY, PRESIDENT, ALTAROCK ENERGY, INC., SEATTLE, WA

Mr. Chairman and Members of the Committee, I am honored to have the opportunity to speak to you regarding Senate Bill 1543, the "National Geothermal Initiative Act of 2007," which was introduced to the Senate on June 5, 2007, by Senator Bingaman to encourage increased production of energy from geothermal resources.

One of the goals of S. 1543 is to achieve 20% of electric power generation from geothermal energy by 2050. You may be asking yourself if this a realistic goal? In the fall of 2004, I was included in a 12 member panel led by Dr. Jefferson Tester of the Massachusetts Institute of Technology that looked at the Future of Geothermal Energy. Our group consisted of members from both industry and academia. While some of us started the study convinced that it was possible to engineer or enhance geothermal systems (EGS) with today's technology, many of us, including myself, were skeptical. As we reviewed data, and listened to experts who were actively researching new methods, testing them in the field, and starting commercial enterprises to develop power projects from geothermal energy using this emerging technology, I believe all of us became convinced that a way had been found to tap into the vast geothermal resource under our feet.

Everywhere on Earth, the deeper you go, the hotter it gets. In some places, high temperatures are closer to the surface than others. We have all heard of the "Ring of Fire, " characterized by volcanoes, hot springs and fumaroles around the rim of the Pacific Ocean, including the Cascades, the Aleutian Islands, Japan, the Philippines and Indonesia. We know that along the tectonic rifts such as the Mid-Atlantic Ridge including Iceland and the Azores, the East African Rift Valley, the East Pacific Rise, the Rio Grande Rift running up through New Mexico and Colorado and the Juan de Fuca Ridge the earth's heat is right at the surface. But other geologic settings allow high temperatures to occur at shallow depths, such as the faulted mountains and valleys of the Basin and Range, the deep faults in the Rocky Mountains and the Colorado Plateau. In addition, the sedimentary basins that insulate granites heated by radioactive decay along the Gulf Coast, in the Midwest, along the Chesapeake Bay and just west of the Appalachians can not only provide oil and gas, but hot water as well. (See Figure 1).*

The heat contained in this vast resource is so large that it is really difficult to contemplate. Even with very conservative calculations, the MIT study panel found that the amount of heat that could be realistically recovered in the US from rocks at depths of 3 km to 10 km (about 2 miles to 6 miles) is almost 3,000 times the current energy consumption of the country. (See Figure 2). Listening to the experience of those developing the Soultz project in France, the Rosemanowes project in the UK and the Cooper Basin project in Australia, the panel members began to understand that the technology to recover this heat was here today. We can drill wells into high temperature rocks at depths greater than 3 km. We can fracture large volumes of hot rock. We can target wells into these man-made fractures and intersect them. We can circulate water through these created fractures, picking up heat and produce it at the other side heated to the temperature of reservoir rocks. We can produce what we inject without having to add more water. Long term tests have been conducted at fairly modest flow rates on these created reservoirs without change in temperature over time. No power plants have yet been built, but several are in progress in Europe.

Does this mean that we can build economic geothermal power plants based on EGS technology right now? At the best sites, where high temperatures occur at shallow depths in large rock masses with similar properties, geothermal power production from EGS technology is economic today. But to bring on line the huge resource stretching across the country from coast to coast, we need to do some work.

I'd like to talk about the economics of geothermal power production so you can better understand what needs to happen to enable widespread development of power projects using EGS.

At some places in the Earth's crust, faults and fractures allow water to circulate in contact with hot rock naturally. These are hydrothermal systems where natural

* Figures 1–5 have been retained in committee files.

fractures and high permeability allow high production rates. Even low temperature systems can be economic if the flow rates produced are high enough. The capital cost for the wells and wellfield-related equipment generally is between 25%—50% of the total capital cost of the power project. The capital cost for hydrothermal projects can range from around $2,500/installed kW to over $5,000/kW, largely depending on the flow rate per well and the depth of the wells. The levelized break-even cost of energy for commercially viable hydrothermal projects currently ranges from $35/MWh to over $80/MWh. Of this, about $15-25/MWh is operating cost. The rest is the cost to amortize the power generation equipment and the wellfield.

Hydrothermal power is a good deal: Clean, small foot print, cost-effective. So why isn't more power from hydrothermal sources on line? The issue for hydrothermal power is risk. Because the risk related to finding the resource and successfully drilling and completing wells into the resource is high, development by utilities is unlikely. In order to accept this risk, independent power producers need a long-term contract at a guaranteed price and a high return on their investment. Utilities are loath to give a long-term contract because the payments to the generator will be treated as debt in determining their debt-to-equity ratio for credit and bond ratings.

Hydrothermal projects also tend to be small in size. While some of the potential future hydrothermal projects might be large, many of these are associated with scenic volcanic features protected as national parks or revered by Native Americans. A large scale project might mitigate the risk by spreading it over a much larger number of MW. In addition, there is a true economy of scale for geothermal power projects. For instance, the same number of people are needed to operate a 10 MW geothermal project as operate a 120 MW, or even a 250 MW, project.

Most of the really good (i.e. economic) hydrothermal systems are in the arid West. Not only is cooling water—which improves project economics by improving plant efficiency—an issue in this part of the country, but also the wide open spaces mean high-potential sites are often far from transmission, operators, supplies and large population centers with a high demand for power. Little potential for producing power from conventional geothermal, i.e. hydrothermal, sources exists in the Midwest, Southeast or East Coast.

Still, hydrothermal power has the potential to supply the country with more than 20,000 MW, or about 2% of our current installed capacity. However, the very high reliability of geothermal power means that this would be about 4% of our current annual generation. And this power is baseload or power that is available night and day.

Over the years, the cost of generating electricity from hydrothermal sources has dropped from around $130/MWh to less than $50/MWh. This was facilitated by incentives provided both by the market during the mid-1980s oil crisis, and by the government in the form of tax subsidies encourage the construction of over 2,000 MW of geothermal power that went on line from 1986-1995. Some of this drop in cost is due to research conducted by the US Department of Energy (DOE). For instance, in 1980 the DOE completed the first demonstration binary power plant at Raft River. This plant enabled the use of fluids at temperatures much lower than had been developed in the past. Industry commercialized this technology, and now most of the new geothermal power plants being built today are binary plants. DOE research, together with industry, developed high-temperature tools that are now essential to the evaluation of geothermal wells. A combination of DOE-supported research and industry effort as improved binary power plant efficiency by almost 50% from the earliest commercial plants in the 1980s, and flash power-plant efficiency by almost 35% over the same time period. This translates directly into reduction in overall project cost and power prices because fewer wells and less equipment is needed to generate the same amount of energy.

The MIT study started with the current state of the geothermal industry. The first task we realized we needed to undertake was a realistic look at the size and potential cost of developing geothermal power across the continent. It has long been realized by scientists that a vast geothermal resource exists everywhere as long as technology allows us to drill deep enough, develop a reservoir by creating fractures or enhancing natural fractures, and connect wells to circulate fluid through that reservoir. The US Geological Survey has been tasked with a detailed evaluation of the US geothermal resource, but this could not be finished in time for our study. The MIT panel, therefore, undertook a preliminary assessment of the geothermal resource in the US.

Using data collected over the years with DOE support, maps of the temperature at depth were developed by Dr. David Blackwell's group at SMU. Temperature at the midpoint of 1 km thick slices was projected at 1 km intervals starting at a depth of 3 km and extending down to 10 km, a reasonable limit for drilling using today's technology. The heat resource contained in each cubic kilometer of rock at these temperatures at each depth was then calculated. The amount of energy stored in this volume of rock is so enormous that it is really impossible to comprehend. (See Figure 1) We then looked at the studies that had estimated what fraction of this heat might be recovered, and at what efficiency this recovered heat might be turned into electric power. Studies showed that for economic systems, 40% or more of the total heat stored in the rock is recoverable. We also considered the more conservative recoverable estimates of 2% and 20%. Even at 2%, the amount of energy that could be realistically recovered, leaving economics and cost considerations aside, is more than 3,000 times the current total energy consumption of the US, including transportation uses.

In order to understand the technology needed to recover this energy, we turned to the published literature on the experiments done in the past at Fenton Hill, Rosemanowes, Hijiori, Ogachi and Soultz. We also brought in experts who are currently working on the Soultz project and on commercial engineered and enhanced geothermal projects in Europe and in Australia to tell us about the status of their work and their future efforts and needs. By the end of the study, we had concluded that EGS technology is technically feasible today. We can:

- Drill wells deep enough and successfully using standard geothermal and oil-and-gas drilling technology with existing infrastructure to tap the geothermal resource across the US, including areas in the Midwest, East and Southeast.
- Consistently fracture large rock volumes of rock.
- Monitor and map these created or enhanced fractures.
- Drill production wells into the fractured rock.
- Circulate cold water into the injection well and produce heated water from the production wells.
- Operate the system without having to add significant amounts of water over time.
- Operate the circulation system over extended test periods without measurable drop in temperature.
- Generate power from the circulating water at Fenton Hill and Ogachi.

In addition, EGS power projects are scalable. Once the first demonstration unit has been tested at a site, the potential exists to develop a really large scale project of 250 to 1000 MW. Combined with the fact that good EGS sites where large bodies of hot rock with fairly uniform properties can be found across the US, that the sites are so many that they can be selected to avoid places with no transmission capacity or those located near areas of scenic beauty or environmental sensitivity, generating power from EGS technology looks like a winning proposition.

The real question then becomes, not is it realistic to anticipate generating 20% of our nation's electric power from geothermal energy, but can we make it cost effective?

The MIT panel included members from industry and research who are experts in the economics of power generation. The panel developed a list of key technologies that could help reduce the cost of generating power from EGS. They considered the changes in the cost of power generation from hydrothermal systems over the last 20 years, and the current state of EGS technology. They also considered research currently underway, not only that sponsored by DOE through universities and the national laboratories, but that being done by industry. Using models developed by both DOE and MIT, the cost of power and the impact on that cost of these possible technology improvements was examined. In addition, the panel looked at the impact of "learning by doing" on the cost of power.

We concluded that at the best sites, those with very high temperatures at depths of around 3-4 km in areas with low permeability natural fractures, EGS is economic today. Figure 3 shows the relative cost of power from a 300°C site at a depth of 3 km. With current technology power from this site could be generated for a levelized cost of power of about $74/MWh. This isn't the price that power could be sold for, since it doesn't include profit. It does, however, include financing charges at higher than utility rates, operating costs and the cost of amortizing the capital investment in the welfield and power plant. At deeper depths and lower temperatures, the cost of generating power using EGS technology is much higher, about $192/MWh. (Figure 4).

With incremental technology improvement, the cost of power could be cut in half or more, particularly for the deeper high temperature systems. These incremental technology improvements include things like improving conversion cycle efficiency, being able to isolate the part of the wellbore that has been treated so that untreated parts can be fractured, redesigning wells to reduce the number of casing strings and improved understanding of rock/fluid interaction to prevent or repair short circuiting through the reservoir. None of these technology improvements require game changing strategies, just the kind of advancement that comes from persisting in extending our knowledge to the next level. Looking at the high temperature example in Figure 3, the levelized cost of power could be cut to $54/MWh or about 27% with these technology improvements implemented. The moderate temperature site could see a much larger reduction of over 60% to $74/MWh.

Figure 5 shows a supply curve for EGS based geothermal power for the entire US. This curve shows the amount of power available at a certain cost. However, this is cost of power not price. In other words, this is not the price that an independent power producer would charge a utility for this power if they were selling it to them. However, it does give an idea of what could be economic in the future. The two sets of dots are calculated using current technology and the projected cost using future incrementally improved technology. Once the cost of power increases to around $100/MWh, it is clear that more than 400,000 MW would be available or development. This means that the amount of power we could develop is not limited by the resource available, but by the cost. And the cost is limited by the technology and the fact that we aren't doing this here in the US.

We concluded that at the best sites, those with very high temperatures at depths of around 3-4 km in areas with low-permeability natural fractures, EGS is economic today. With incremental technology improvement, the cost of power could be cut in half or more, particularly for the deeper high temperature systems. These incremental technology improvements include things such as improving conversion cycle efficiency, being able to isolate the part of the wellbore that has been treated so that untreated parts can be fractured, redesigning wells to reduce the number of casing strings and improved understanding of rock/fluid interaction to prevent or repair short circuiting through the reservoir. None of these technology improvements require game-changing or revolutionary strategies, just the kind of advancement that comes from persisting in extending our knowledge to the next level.

The cost of this type of technology improvement is not high. The panel felt that an investment of ~$368,000,000 over a period of about 8-10 years combined with industry involvement could result in 100,000 MW on line by 2030. This would be 10% of the current installed capacity and over 20% of the current electric generation of the country. Combined with the hydrothermal resource, it is a very realistic goal to have geothermal energy provide 20% of the nation's electricity by 2030. However, the effort would require federal support, university, laboratory and industry research, and development and a real commitment to renewable energy use.

Currently more than eight companies are developing EGS power projects in Europe and more than 20 companies are working to get power on line using this technology in Australia. AltaRock Energy Inc. is the only company focused on commercializing power generation from EGS technology in the US. In Europe, price subsidies and European Union-sponsored research are helping to start more than 50 EGS projects. In Australia, government grants, help with transmission access, research, and legislation requiring generation from renewable energy sources are driving EGS technology to commercialization. Other countries with fewer economic geothermal resources are planning to include geothermal energy in their generation portfolio. The US needs to commit to this clean, baseload, renewable power source for our own energy future.

SUMMARY

- The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century
  —http://geothermal.inel.gov/publications/future—of—geothermal—energy.pdf
  —12 member panel lead by Dr. Jefferson Tester through MIT
- Conclusions
  —EGS power is technically feasible today
  —Potentially 100,000 MW can be on line by 2030 with federal investment of ~$350,000,000
  —Resource extends across US
  —Best resources economic today at high temperature, shallow sites
  —With incremental technology improvement, cost can be cut in half
  —With learning by doing and innovative technology improvement cost can be reduced for deep resources to ¼ cost with current technology
- Hydrothermal Systems
  —Natural permeability
  —High flow rates
  —Few big systems
  —Located in Western US
  —Exploration drilling is needed and remains risky

—Economic now even for low temperatures
—>2800 MW on line growing by about 300 MW/yr
—Potential for as much as 20,000 MW at economic costs over next 40 yrs
—>95% average availability
—Technology improvement reduced cost (not price)—13¢ per kWh in 1986 to about 5¢ per kWh in 2006

- Enhanced Geothermal Systems (EGS)

—Resource is vast
—Distributed across the US, but best sites in West
—Low or no natural permeability
—Reservoir must be engineered to
  —Obtain high flow rates
  —Develop good heat exchange area
—Exploration risk reduced
  —Temperature only needed
  —Drill deeper to get greater temperature
—Large systems can be developed
—Uses proven state-of-the-art drilling technology
—Fracturing technology developing
—MIT study identified key areas of technology improvement needed to reduce cost
—Potential for CO_2 sequestration
—8 companies in Europe; ~20 companies in Australia working to commercialize
—AltaRock Energy—first US company focused on EGS technology development

STATEMENT OF LISA SHEVENELL, PH.D., DIRECTOR, GREAT BASIN CENTER FOR GEOTHERMAL ENERGY, UNIVERSITY OF NEVADA, RENO, NV

Ms. SHEVENELL. OK, thank you Mr. Chairman for the opportunity to participate in this discussion about funding a more aggressive geothermal initiative. I am the Director of the Great Basin Center for geothermal energy, and have 24 years experience in geothermal research. The Center that I lead was created in 2000, and receives funding from a variety of public and private sources.

It is estimated that approximately 9,000 megawatts could be brought online by 2015, based on the results of a 2005 Western Governor's Association workshop. A 2006 Western Governor's Association report also states that a strong, over-arching theme is the need for stable long-term policies at both the Federal and State levels, to address U.S. energy needs.

The Nation needs sustained longer-term energy policies, yet this has not yet occurred. Funding cycles remain irregular and uncertain, S. 1543 would help remedy the ongoing situation of these uncertain funding cycles.

Volatility in funding persists in threatening the success of the national geothermal program, as stated previously by members. The proposed elimination of the DOE geothermal program would be very damaging to research efforts, and has been damaging numerous research institutions that are losing key personnel to other interests.

A sustained, expanded, and dependable funding source is needed to supply the necessary research programs that will help to increase utilization of geothermal resources. Without continued funding, the Nation's geothermal research program can not continue to contribute to this important and growing industry. Key researchers at several leading geothermal research institutes have been lost due to volatility in funding.

These institutions include: Idaho National Lab, Oregon Institute of Technology, Southern Methodist University, Stanford University, University of Nevada, Reno, and the University of Utah.

A reduction in research staff corresponds to a reduction in the ability to train students with real-life, applied research experience in collaboration with industry.

We are in a time of growing needs for expertise in geothermal at the exact time that we have been losing expertise due to unstable funding cycles.

As the industry is poised for rapid expansion, many in the industry are aging, and too few students are graduating to fill the increasing work force needs. Our Center's collaboration with industry and research, outreach and training and resource development is important to the future health of the industry. Educational activities must be accelerated at a number of institutions to meet the growing demand for a trained work force in geothermal energy.

In summary, recent downturns in funding are disturbing. Without continued, consistent, stable funding, our universities and other research institutions will face continued loss of faculty with expertise in geothermal resources research, and a contribution of educational programs nationwide to this growing industry will be reduced accordingly.

Federal investment in geothermal research and education needed by industry and government alike, are appropriate and necessary components of a national energy policy, and the increased funding suggested by S. 1543 will go far in assisting the industry in their research and education needs. Now is the time to aggressively pursue secure, clean, reliable geothermal energy.

We, therefore, request that the U.S. Senate pass S. 1543, so that the use of geothermal energy in the United States can be accelerated. Thank you.

[The prepared statement of Ms. Shevenell follows:]

PREPARED STATEMENT OF LISA SHEVENELL, PH.D., DIRECTOR, GREAT BASIN CENTER FOR GEOTHERMAL ENERGY, UNIVERSITY OF NEVADA, RENO, NV

Mr. Chairman and distinguished members of the committee, thank you for the opportunity to appear before you and participate in this discussion about funding a more aggressive geothermal initiative in the U.S. through Senate Bill 1543.

INTRODUCTION

I am the director of the Great Basin Center for Geothermal Energy at the University of Nevada in Reno and I have experience leading and conducting applied research in geothermal energy in collaboration with industry for the past 24 years. The Center was created by the University in 2000, receives funding from the University and various federal, state and tribal agencies and the private sector, and through the leadership of Senator Reid, has received congressionally directed appropriations since 2002. The mission of the Center is to work in partnership with U.S. industry via research, outreach and education to establish geothermal energy as a sustainable, environmentally sound, economically competitive contributor to energy supply in the United States. We are conducting several timely research projects to assist industry in identifying and characterizing geothermal resources. We have conducted numerous workshops for geothermal stakeholders of all kinds, and have published extensive data sets, maps, presentations, and publications on our web site (www.unr.edu/geothermal). We are working with and graduating students to enter the workforce to participate in the geothermal industry, an activity that must be accelerated to meet the growing demand for a trained workforce in geothermal energy. The industry is expanding rapidly, and employees are not available at the rate needed.

BACKGROUND

In the President's 2006 State of the Union Address, he noted again that we needed to secure America's energy future, and provide access to reliable domestic energy supplies. Geothermal is a reliable baseload power source available 24/7. It is estimated that approximately 9000 megawatts (MW) could be brought on-line within the next decade based on the results of a Western Governor's Association workshop held in Reno in 2005. However, this was not a scientifically based estimate, and our knowledge at this point is not sufficient to give a full estimate of the total accessible resource base. Federal programs to conduct this assessment are needed as industry does not have the staffing or infrastructure available to conduct a proper assessment.

A National Research Council report (Renewable Power Pathways, 2002) indicated that geothermal has an enormous potential resource base, and that geothermal research by the U. S. DOE should be increased, particularly into technologies that can reduce risk, reduce costs, or expand the accessible resource base. In the Western Governors' Association's Clean and Diversified Energy Advisory Committee report of 2006 (http://www.westgov.org/wga/initiatives/cdeac/) they state that "A strong, overarching theme . . . is the need for stable, long-term policies at both the federal and state levels. . . ." to address U.S. energy needs. The nation needs sustained longer-term energy policies, and this has not yet occurred. Funding cycles remain irregular and uncertain, as evidenced by the elimination of the DOE geothermal program in spite of authorization of increased funding for research by the DOE in the Energy Policy Act of 2005. Senate Bill 1543 would help remedy the ongoing situation of these uncertain funding cycles. Exploration and early testing are very expensive and highly risky.

Exploration technologies available today require confirmation of the resource by drilling, which is expensive, with costs ranging from a few million to 10 million dollars per production well. Because the cost and risk of exploration are higher than for oil and gas and other competing energy sources, the ability to obtain financing is more difficult.

Nevertheless, increases in geothermal power production are clearly forecast for the future. Less growth is anticipated in direct use applications, although greater focus should be placed on those uses also given that increased direct use of geothermal resources would displace fossil fuels. In its May 2007 survey, the Geothermal Energy Association found that there were 69 power projects in the U.S under various stages of development, totaling approximately 2500 MW. In Nevada alone, 195 drilling permits have been issued in the past 3.5 years. In contrast, no projects were completed in Nevada from 1993 until the end of 2005. In August 2007, the U.S. Bureau of Land Management held their first geothermal lease sale in two years in Reno. Almost 123,000 acres were leased in Nevada alone at a sale price of $11.7 million. It is anticipated that 1500 new MW will be on-line in Nevada by 2015, with 240 MW currently permitted. Clearly there has been a large increase in interest in developing geothermal resources in Nevada, requiring greater staffing and investment across all sectors.

The last geothermal resource assessment in the U.S. was conducted by the USGS in the 1970s from which they estimated a hydrothermal resource base of between 95,000 and 150,000 MW. Our understanding of geology is far different today than it was in the 1970s, which is shortly after the time that plate tectonics began gaining acceptance as a standard model for the Earth. In the last 30 years there have been huge advances in structural geology and characterization technology. Significantly, the oil industry has developed major new 3-dimensional seismic imaging technology and directional drilling. These are primarily responsible for a revolution in petroleum reservoir prospecting and management, but have not been applied as yet in the geothermal industry. It was not until the 1980s that binary system power conversion became economical in geothermal plants. With a binary system, the heat from geothermal fluids is transferred to another fluid with a lower boiling (flash) temperature. This lower flash point fluid is then used in the generator to produce electricity. The binary cycle allows electricity to be generated from a lower temperature reservoir. Thus, what was not a significant reservoir in the 1970s may well be significant today. The survey published in the 1970s is out of date. Clearly, a modern resource assessment must be conducted if geothermal energy is to reach its potential.

THE IMPORTANCE OF GEOTHERMAL TO THE NATION

Increasing our use of geothermal and other renewable energy resources helps diversify our power supply. Increasing the use of geothermal energy also helps us move away from our dependence on carbon dioxide-producing fossil fuels as the main components of our energy supply. Geothermal power production is also a more reliable and consistent power supply than other renewable resources because the plants operate 24 hours per day and are not subject to daily variations in weather as are solar and wind power generation. It is not subject to price volatility as are oil and natural gas, and it boosts energy security because it is a domestic energy supply. Distributed, smaller electrical power plants such as geothermal plants increase our national security because many more spatially distributed targets would need to be destroyed to cause large-scale power disruptions than would be the case with existing large coal-fired and nuclear power plants. Decisions made by this committee impact U.S. energy security. As part of a comprehensive energy plan, geothermal energy must be utilized to help decrease our dependence on fossil fuels. Additionally, geothermal energy can be used to produce alternative, clean transportation fuels such as hydrogen.

SUCCESSES FROM PREVIOUS DOE INVESTMENT

Previous dollars going to research from the DOE geothermal program have led to many successes in the past years, and I will outline a few examples based on the recent work at our Center. Our research results are directly contributing to the DOI goals of characterization of the complete geothermal resource base by 2010 and much of our data for the Great Basin has been transferred to the US Geological Survey for their assessment efforts. Some of the new areas identified in Nevada by DOE funded research efforts were recently bid upon and leased at the August 14 BLM lease sale (e.g., McGinness Hills, Desert Queen). We have identified previously unknown geologically favorable areas for productive geothermal resources, which should help in future exploration efforts. We have developed new exploration techniques (such as shallow temperature surveys and remote sensing techniques) and are actively sharing data and techniques with the geothermal industry. Research conducted has benefited industry by locating new resources, ranking known resources and helping to characterize them to increase drilling success. Through efforts such as a meeting held with industry and DOE in late 2006 in Reno, we also work closely with industry to identify research needs.

However, volatile funding cycles persist in threatening the success of the national geothermal program. The proposed elimination of the DOE Geothermal program would be very damaging to our research efforts, and has been damaging to the efforts of other research institutions that are losing key researchers to other industries. Without renewed geothermal funding soon, we would be forced to close the Great Basin Center for Geothermal Energy. As Senate Bill 1543 states: "federal policies and programs are critical to achieving the potential" of geothermal resources. A sustained, expanded and dependable funding source is needed to support the necessary research programs that will help to increase production of geothermal energy and reduce up-front risk of geothermal exploration and development. Bill 1543 also states that funding should be prioritized for discovery and characterization of geothermal resources, currently the major function of the Great Basin Center for Geothermal Energy. Further, the Bill states that a national center should support the development and application of new exploration and development technologies and disseminate geological and geophysical data to support geothermal exploration activities; these are functions that our current work supports for the Great Basin, which includes Nevada and parts of California, Idaho, Oregon and Utah.

RESEARCH INVESTMENT

DOE research should focus its funding in four key areas: (1) improving the accuracy of exploration technology to reduce risk; (2) improving drilling technology to reduce risk and cost; (3) improving identification and characterizations of geothermal resource to enhance development; and (4) increasing industry cost-sharing of exploration drilling in previously undeveloped areas.

Without continued funding, our research projects and the Great Basin Center for Geothermal Energy will cease to contribute to this important and growing industry. Key researchers at several leading geothermal research institutes have already been lost due to uncertain and irregular funding cycles through DOE. These institutions include Idaho National Laboratory, Oregon Institute of Technology, Southern Methodist University, Stanford University, University of Nevada, Reno, and University of Utah. A reduction in research staff corresponds to a reduction in the ability to train students with real-life applied research experience in collaboration with industry. Funding for geothermal must increase and stabilize, otherwise these research institutions will be forced to seek other resources, abandoning their geothermal work, resulting in a huge loss to the geothermal community. We are in a time of growing needs for expertise in geothermal at the exact time that we have been losing expertise due to unstable funding cycles. Consistent federal policies and funding over longer periods of time are needed to develop our untapped geothermal resources, both for power generation and direct use applications. Increased, consistent funding for the GeoHeat Center (Oregon) would also go far in advancing direct use applications, in addition to electrical generation. This Center is the only U.S. institute focusing on direct use applications, and they similarly have just lost an expert in this field due to unstable and uncertain funding cycles.

EDUCATIONAL INVESTMENT

We must increase our investment in geothermal research and education at this critical juncture. As the industry is poised for a rapid expansion, many in the industry are aging, and insufficient students are graduating to fill the need for the increasing workforce needed. The Federal government also faces a shortage of engineers and geoscientists needed in land-management and regulatory roles. Our Center's collaboration with industry in research, outreach, training and workforce development is important to the future health of the industry. Currently, individuals are in very high demand due to the booming mining and petroleum industries that seek many of the same talents as are needed in the geothermal industry. This educational activity must be accelerated to meet the growing demand for a trained workforce in geothermal energy. The industry is expanding rapidly, and employees are not available at the rate needed. I have been approached frequently this year by industry seeking employees of nearly any type, be it part time, full time, temporary, interns, or graduate students—whoever is trained and available. Skilled workers are at a premium and resources need to be allocated to rapidly develop a trained workforce at both the graduate and undergraduate level, as well as at the community college level for technicians, and programs and curricula are currently under development.

SUMMATION

In summary, recent downturns in funding are disturbing. Without continued, consistent, stable funding, our research projects and projects at other research institutions will cease to contribute to this important and growing industry and our institutions will face the continued loss of faculty with expertise in geothermal.

Historically, the DOE geothermal program has contributed much to the industry with modest agency investments to applied research and cost shared programs, and the increased funding suggested by Bill 1543 will go far to assist the industry in their research and education needs.

We therefore request that the US Senate pass Bill 1543 such that the use of geothermal energy in the US will be accelerated. I believe that stabilization and expansion of the investment in geothermal energy research and cost-shared programs is critical to future power generation of the U.S. Federal investments in geothermal research and in education of the workforce needed by industry and government are appropriate and necessary components of a National energy policy. Now is the time to aggressively pursue secure, clean, reliable geothermal power. Thank you.

The CHAIRMAN. Thank you very much.

Dr. Wunsch—is that the correct pronunciation?

Mr. WUNSCH. Yes, it is, Mr. Chairman.

The CHAIRMAN. Thank you for being here, and please, go right ahead.

STATEMENT OF DAVID R. WUNSCH, PH.D., GEOLOGIST AND DIRECTOR, NEW HAMPSHIRE GEOLOGICAL SURVEY, AND VICE-PRESIDENT, ASSOCIATION OF AMERICAN STATE GEOLOGISTS, CONCORD, NH

Mr. WUNSCH. Mr. Chairman, thank you very much, and members of the committee for allowing me the chance to participate in this panel and testify in favor of S. 1543. I am currently the Vice President of the Association of American State Geologists, and represent the Chief Executives of the Geologic Bureaus of the 50 States, as well as the Commonwealth of Puerto Rico.

AASG support S. 1543, and believes that geothermal energy is vastly under-utilized as a resource that could contribute to the Nation's energy independence, economic growth, and the quest for low-emissions, sustainable energy resources.

S. 1543 is also a big step in integrating the resources of the Federal Government, agencies, national labs, academia and State agencies, such as the State surveyors.

In the eyes of the public, geothermal energy is generally equated to the areas of high hydrothermal resource development out West, Yellowstone National Park is probably one example they may have seen.

Now, on the opposite end of the spectrum of low-temperature geothermal, something that's become ubiquitous is the use of geothermal heat pumps that are—can be used pretty much around the country.

What I'd to speak to a little bit is about the things that occur in that temperature range in between, which includes the use of hot dry rock technologies and binary systems where other chemicals can be used that boil at temperatures less than the boiling temperature of water, and can convert that heat energy into mechanical for electrical production.

As was mentioned by previous panel members, the oil and gas production and geo-pressurized fluids that come out of there also has a unique potential for producing energy as a by-product of oil and gas production. Another one that is vastly underused, is direct heat, just simply the hot water that can be utilized for heating large buildings, factories, and for such uses as greenhouses, food processing, curing cement products, and many others.

Mr. Chairman, from your home State of New Mexico I've borrowed a bulletin from the New Mexico Bureau of Geology and Mineral Resources. It is an excellent summary of some of the different uses of geothermal energy. On the second page of that they have a great graphic that shows a range of temperatures and things that the water can be used for, including lumber drying, building greenhouses, et cetera.

In my State of New Hampshire, the Northern part of the State, which is very forested, has taken a real economic downturn because of the loss of the lumber and wood products industries. Now, if there was direct heating, perhaps, to heat some of these large factories, imagine the economic boom that could be encountered by providing some of the cheaper energy costs which might make these more competitive in the economic world markets. That would not only help New Hampshire, but many of the Northern States that are heavily forested.

In reference to specific programs mentioned in S. 1543, the State Geologists believe that it is time to do this new enhanced assessment that we've been talking about. There are some maps that have been made by various sources, but some of the data is not consistent, or they are presented at broad national scales, and there is a need for a comprehensive data set presented at a detailed scale.

Since the last one that was done by the U.S.G.S. in 1979, there's been huge advances in geophysical exploration, including 3–D imaging. In addition, the State Geological Surveys have been involved in carbon sequestration studies, so that there's been enhancements in the amount of data that's been collected in the sub-surface, which can be used concomitantly for characterizing geothermal resources.

In addition, State Geological Surveys often have information about local geothermal resources that could be captured in this national assessment. For example, the Alaska State Geological Survey performed an assessment in the early–1980s as a primary source of analysis for current prospecting of that State.

In my State of New Hampshire, we have legislation that's been introduce, H.B.415 that would charge the State Geological Surveys with conducting a geothermal assessment. Having technical support, and perhaps, cooperative funding from this Federal program would enhance our efforts, tremendously.

Therefore, AASG believes it's imperative that any national assessment should be performed in cooperation with the State Geological Surveys, regional volcano observatories and other agencies, and academic institutions.

With respect to the U.S.G.S. timeline for the enhanced study of 2010, this may be a little bit short, considering all of the resources that would have to be combined, especially if State assessments were brought in, but perhaps 2012 might be a more appropriate date.

Currently, less than 1 percent of the energy the Nation consumes is from geothermal resources, so the goal of 20 percent of our electrical production by 2030 could be a bit ambitious. For example, Australia which has a smaller population and total demand, but is farther along in hot dry rock technology, has limited their power expectations to 6.8 percent of its baseload by 2030. However, if we include the energy efficiencies that could be gained by broad-scale low-temperature geothermal as well as geo-exchange heat pumps, maybe the 2030 goal of 20 percent is, indeed, workable, and it's something I believe we should strive for.

In summary, AASG fully support S. 1543, we believe for Congress, it's the time now to act to support research, development and to sponsor demonstration geothermal energy projects to meet our needs, and to make us less dependent on foreign energy sources and ensure our national security. AASG members and the State Geological Surveys they direct are willing and able partners to partner with the U.S.G.S., Department of Energy and other Federal entities that would be charged with developing and assessing the Nation's geothermal resources.

Thank you, and I'll be glad to answer questions after the panel concludes.

[The prepared statement of Mr. Wunsch follows:]

PREPARED STATEMENT OF DAVID R. WUNSCH, PH.D., GEOLOGIST AND DIRECTOR, NEW HAMPSHIRE GEOLOGICAL SURVEY, AND VICE-PRESIDENT, ASSOCIATION OF AMERICAN STATE GEOLOGISTS, CONCORD, NH

INTRODUCTION

Mr. Chairman and members of the Committee, thank you for the opportunity to present testimony in full support of S.1543. I am the vice-president of the Association of American State Geologists (AASG), which represents the chief executives of the geologic agencies of the fifty states and the commonwealth of Puerto Rico. The state geologists, and the geological surveys they direct, collect geologic information, conduct research, and disseminate this information by way of scientific reports, maps, and other means. Collectively the state surveys represent one of the largest centers of geological information in the United States, and whose participation will be critical in assessing and exploring geothermal resources for the nation.

S.1543 fills an important gap in the research and development of geothermal resources in the United States, and would serve to remedy the lack of programmatic support for the DOE geothermal program as defined in the Energy Policy Act of 2005. Geothermal Energy is an untapped and underutilized resource that could contribute immensely to our nation's energy independence, economic growth, and quest for low-emission, sustainable energy resources. Recently an interdisciplinary panel affiliated with the Massachusetts Institute of Technology (MIT) concluded that both conventional and engineered geothermal systems could produce 100 gigawatts of electric energy for the United States in the next 50 years. Their report (The Future or Geothermal Energy, MIT) recommends that the time to enlist a comprehensive plan to develop the nation's geothermal resources is now. S.1543 is a big step toward integrating the resources of federal government agencies, national labs, academia, and state agencies in performing a national assessment to evaluate our nation's geothermal resources.

THE RANGE OF GEOTHERMAL ENERGY OPPORTUNITIES

In the eyes of the public, geothermal energy is generally equated with areas of concentrated hydrothermal activity in the western United States, such as Yellowstone National Park. Large-scale geothermal systems exploit high-temperature water sources, capitalizing on the supercritical water and stream generated at relatively shallow depths, and use its heat energy to turn turbines and generators that produce electricity. In the past decade a more ubiquitous, low-temperature form of geothermal energy has been commercially successful that utilizes the constant temperature of the earth at very shallow depths. These low-temperature geothermal heat pump systems, sometimes referred to as geoexchange systems, are very efficient at heating and cooling, and are regularly being used in large commercial buildings, military installations, public buildings such as schools, and private homes. Geoexchange systems can be installed literally anywhere, and offer widespread access to geothermal resources.

Direct hydrothermal power generation, and geoexchange systems described above represent the high and low-temperature end members of the geothermal energy spectrum, respectively. However, there are several applications of geothermal energy that exist between these temperature regimes, and offer a tremendous opportunity for the development of cost effective, low-impact energy sources that are viable in geologic settings that are more geographically diverse. For example, in tectonically stable regions of the nation, most geothermal resources are non-hydrothermal and are more difficult to exploit using existing technologies. Yet the potential for this type of "dry" geothermal energy is enormous because its use is not restricted to hydrothermal activity normally associated with tectonically active regions. Technology is being developed to exploit non-hydrothermal geothermal energy reserves, known as hot dry rock (HDR) reservoirs. These energy extraction technologies work by tapping heat with deep boreholes drilled into a HRD reservoir. Once boreholes are installed, water is injected into the HDR reservoir to induce fracturing and increase the heat exchange capacity of the reservoir. This artificial generation of fractures creates more pore space and surface area for water cycled into the HDR reservoir to absorb geothermal heat. Water heated by contact with the rock is then extracted from the fracture system through a neighboring extraction well and used to generate power in steam turbines. In typical HDR designs the water is circulated on a closed loop and injected back into the fracture reservoir once it has passed through the power plant. Hence, HDR geothermal systems are nearly 100% emission free, introducing no wastes into the environment. Some designs, such as binary systems, incorporate a secondary organic fluid that is circulated in a closed loop system to create the mechanical energy necessary to generate electric power at temperatures below the boiling point of water (212°F).

Several countries, including Japan, Switzerland, Sweden, Germany, are actively advancing HDR technology by research and development, or operating demonstration power-generating systems using HDR technology. The European Union currently has sponsored a demonstration site near Soultz, France that has shown promising results. In Australia, private enterprise is leading the way in actively developing the technologies for constructing engineered HDR systems. And the U.S., through a HDR project at Los Alamos National Lab, has also worked with this technology. There are many areas of the country that may be viable for exploiting these enhanced or engineered geothermal systems at depths that are within the drilling range of current technology, including much of the western United States.

Geopressurized geothermal resources consist of gas-saturated brines contained in oil and gas reservoirs under anomalously higher temperatures and pressures than would ordinarily be expected. There are many producing regions in the U.S. that have geological formations that exhibit these conditions. The U.S. Department of Energy conducted a geopressurized-geothermal research program from 1975 to 1992. The resulting work showed that wells with high brine flow rates could produce natural gas as well geothermal heat energy as a byproduct that could be used to produce electricity using a Hybrid Power System (HPS), similar to the binary system described above. The brine could safely be reinjected into the formation to enhance recovery efforts. To date, geothermal resources related to oil and gas production remain largely underutilized. The further development of the resource would benefit from enhanced reservoir characterization, improved high-temperature and high-pressure drilling, construction, and completion technologies, and the development of high efficiency binary-cycle power systems. S.1543, in Section 5, addresses these and other constraints that preclude the active development of these geopressurized-geothermal resources, and would promote research, development, demonstration, outreach and education, and commercial application.

The use of direct heat applications of geothermal waters is a vastly underutilized resource. Water need not be heated to boiling or supercritical temperatures to produce economic benefit. Water temperatures in the 100°F range can be used for aquaculture and enhancing biogas production. Geothermal fluids in the 150°F range can be used for direct heating green houses, buildings and homes, food processing, curing fabricated cement, and other purposes. Direct heating applications can also be co-generated from power plants that utilize hydrothermal fluids. The New Mexico Bureau of Geology and Mineral Resources has compiled an excellent description and examples of the wide uses and range of applications based on ambient temperature of the fluids. The publication (Geothermal Energy in New Mexico, 2006) is attached to this testimony.* Data compiled by the Southern Methodist University estimates that much of the West, and select areas of the eastern half of the country may have temperatures in the range to accommodate the direct uses described above within 10 kilometers of the surface, which is a depth currently attainable utilizing present drilling and engineering technologies adapted form large-scale oil and gas production.

COMMENTS SPECIFIC TO SENATE BILL

The Association of American State Geologists strongly supports the initiatives that would be authorized in S.1543 if it became law. The Bill would charge the USGS, in cooperation with DOE, to conduct a nationwide assessment of geothermal resources within the United States. This assessment is overdue. The last comprehensive characterization of geothermal resources was conducted by the USGS in 1978 (USGS Circular 790). Since then there have been clear advances in geophysical exploration, including three-dimensional (3-D) imaging, and other methods for enhanced subsurface characterization. Moreover, maps created by different sources that show favorable areas for geothermal resources are often not consistent, or they are presented at broad, national scales. Thus, there is a need for a uniform, comprehensive national dataset presented at a detailed scale.

Many state geologic surveys maintain the well record libraries for the states, and conduct the majority of basic geologic mapping activities that are being performed in their states with funding through the USGS Cooperative Mapping Program. In addition, several state surveys are either independently or through consortia investigating a variety of geologic repositories for carbon sequestration. The geologic data being compiled from these efforts could concomitantly provide valuable information for characterizing geothermal resources. These basic data are critical to identifying and characterizing the nature and extent of low permeability formations in basins or basement, or low-grade hydrothermal resources that could be candidates for engineered geothermal systems.

For example, state geologic surveys often have a significant amount of information on local geothermal resources that should be captured in the national assessment. The Alaska State Geological Survey performed an assessment in the early 1980's that is the primary source for analysis and current prospecting. Therefore, the AASG believes it is imperative that any nationwide assessment of geothermal resources should be performed in cooperation with the state geological surveys, regional volcano observatories, and other local agencies that have knowledge and data within and among the states. The development of cooperative efforts and programs should be clearly reflected in Bill 1543. In my own state of New Hampshire, there

*Publication has been retained in committee files.

is currently a bill being evaluated by our state legislature (HB 415-FN) which would charge the New Hampshire Geological Survey with conducting a geothermal assessment of the state. This would include compiling available geophysical data that have become available since a cooperative Department of Energy pilot well project was completed in the 1970's. For our new assessment, we would also collect new data and expand the database of bottomhole temperature measurements. This statewide assessment could benefit from cooperative efforts, technical support, and additional funding from federal agencies, and would ultimately provide new and more comprehensive data, including geochemical and radiometric analysis of granite, which is one assumed source of higher heat-flow areas within the state. The statewide assessment for potentially expanding geothermal energy use is consistent with New Hampshire's goal of having 25% or its energy needs supplied from renewable sources by 2025. Many states have their own agendas for developing renewable or green energy supplies, so the time is appropriate for establishing a cooperative federal program would assist state efforts to compile scientific data that collectively will be a critical component of any national assessment.

S.1543 assigns the USGS a deadline of 2010 for completing the geothermal assessment, which may not afford enough time to coordinate the resources available between federal and state agencies, or synthesize the assessments that states may be conducting independently. This is especially true if engineered geothermal systems are considered. Perhaps 2012 would be a more appropriate date, which would allow adequate time to complete the assessment. It is important that the national assessment be comprehensive and robust, because the nation would depend upon the findings of this report to develop the full extent of its geothermal resources. Just as important, a realistic and accurate assessment will be critical in meeting the stated goal of having 20 percent of the total US electrical energy production from geothermal resources by 2030.

Currently less than 1 percent of the energy the nation consumes is created from geothermal sources, so the proposed goal of achieving 20 percent of total electrical production by 2030 from geothermal resources is ambitious, especially if this number refers strictly to electrical energy production, and does not consider improvements to efficiency. The EIA reports that total energy demand is increasing in the United States, and is expected to grow by 41 percent by 2030 (EIA website, http://www.eia.doe.gov/oiaf/aeo/pdf/trend—3.pdf). By comparison, Australia has a smaller population than the US, and is farther along in the development of HDR power. Private companies have applied for permits for 116 areas, and can be expected to invest $A 524 M ($US 435 M) in their projects in the next six years. But Australia has limited their geothermal power expectations to 6.8% of its base load power needs by 2030.

In the case of the US power portfolio, the 20 percent goal may be a more achievable if energy efficiency is included. For example, geothermal heat pumps are the most energy efficient and environmentally friendly method of heating and cooling homes. They are 48% more efficient than gas furnaces and 75% more efficient than oil furnaces, and the increased efficiency means reduction in greenhouse gas emissions. Installing a heat pump system in a typical home is equal to planting an acre of trees in terms of greenhouse gas reduction. For every 100,000 homes with geothermal heat pump systems, foreign oil consumption is reduced by 2.15 million barrels annually, and electricity consumption is reduced by 799 million kilowatt hours annually. The more than 900,000 geothermal heat pumps installed in the U.S. currently yield an energy savings equivalent to taking 1,165,000 cars off the road, planting more than 346 million trees, or reducing crude oil imports by 19.3 million barrels. If geothermal heat pumps were installed in commercial, industrial, and private residences nationwide, we could save several billion dollars in annual energy costs, and significantly reduce demand for electricity.

SUMMATION

The Association of American State Geologists fully supports the initiatives and programmatic efforts being proposed in S.1543. Geothermal Energy is an untapped and underutilized resource that could contribute immensely to our nation's energy independence. The nation's energy needs are expected to grow in the coming decades, and the Congress should act now to support research, development, and demonstration of geothermal energy resources and projects to meet the nations energy needs, reduce our dependence on foreign energy sources, and to ensure national security. New technologies, and advances in the scientific understanding of the earth's subsurface make a variety of geothermal applications viable for meeting part of the nation's energy needs. The members of the Association direct the activities of the state geologic surveys, who are willing and able partners that can assist the US Geological Survey and the Department of Energy with assessing and developing the nation's geothermal resources as defined in S. 1543. Thank you.

The CHAIRMAN. Thank you very much.
Dr. Williamson, go right ahead.

STATEMENT OF KENNETH H. WILLIAMSON, PH.D., GEOTHERMAL CONSULTANT, SANTA ROSA, CA

Mr. WILLIAMSON. Chairman Bingaman, members of the committee, thank you for inviting me here today. I'm not representing any company or industry group, these are my personal views today.

My experience is 5 years of government geothermal research in the U.K., and the rest of my experience has been in private industry, where I worked for a U.S. company that developed a quarter of the world's geothermal resources.

I'd also like to say that the leading geothermal company worldwide, at this time, is an American company—Chevron is the largest producer of geothermal energy worldwide. The geothermal assets, I also should say, are not in the United States.

The CHAIRMAN. You're saying Chevron's geothermal assets are not in the United States? Is that your point?

Mr. WILLIAMSON. Chevron's geothermal assets are in Southeast Asia, but it is currently the largest producer of geothermal energy worldwide.

The CHAIRMAN. All right.

Mr. WILLIAMSON. I believe the national goal proposed in S. 1543 is of great importance to our country, that's why I'm here today. It will enable us to reduce greenhouse gas emissions, and improve energy security. But, it will be very challenging for both industry and for government—it implies an 18 percent per year growth rate.

Hundreds of billions of dollars of private investment are required, about half a trillion dollars, by my estimate. Tens of thousands of geothermal wells have to be drilled, millions of acres of land have to be leased, and permits approved, so I think the focus of S. 1543 has to be to motivate industry to take up these challenges.

I see four roles that government can adopt to help motivate industry. The first is to provide incentives. I see engineered geothermal systems, or Enhanced Geothermal Systems as the key to large-scale development. It will be—it's the only way that I can see that we could reach that 20 percent goal. The fastest way to get that moving is to provide incentives to private industry.

Governments in Germany and Australia have already done so, and private industry responded quickly in both countries. For example, a subsidized power price for the first few hundred megawatts of EGS installed might be the most effective, and it should be spread over a range of geological environments, if that's how we chose to do it.

The second role I see if for research. There are two key areas of research to making EGS work, in my opinion. The first is, we need to improve EGS productivity. We need to do experiments on how to improve the flow of water through these cracks that we make in the rocks, and be able to predict what will happen with computer models.

Second, sometimes cold water leaks through from one well to the other, and that can be very damaging. We need to be able to devise a system to repair these short circuits. So, these are the two areas of focus I would like to see on EGS research.

Another area of research that would be productive, I believe, is what I call "heaven systems." The currently developed geothermal systems in the United States, almost all have associated hot springs, but I believe there are many geothermal systems that have no surface expression, and we lack rapid reconnaissance tools to find these systems. We need better geophysical tools to target wells and both areas would benefit from basic research that the government could sponsor.

The third government role I see as being critical is in education. Many U.S. geothermal experts started their careers in the 1970s, as I did. We urgently need a new crop of engineers and geologists in this industry. We need geothermal courses to be taught in universities across the United States.

The fourth role is in leasing and permitting. Millions of acres of government land will need to be leased to develop this 20 percent goal. The BLM will need the resources to do this, and the permitting process will need to be streamlined.

I have to say, the first project I worked on in the United States when I arrived in 1981 was successfully discovered in Northern California, and it is still awaiting permits to be developed.

The CHAIRMAN. It's awaiting permits from one of the Federal Departments, the Department of Interior? Or who?

Mr. WILLIAMSON. I believe it's currently held up in the District Court, there's been a challenge to the permit that was issued.

The CHAIRMAN. OK.

Mr. WILLIAMSON. In conclusion, then, I believe that geothermal can play a major role in cutting greenhouse gas emissions, and establishing energy security for this country. I believe that past technology will not get us to the 20 percent goal. I believe that EGS is the key, and I believe that continued research is required.

Private industry must be motivated to move quickly on EGS, and the government must find a way to do this, with financial incentives and streamlined approvals.

Thank you for your attention.

[The prepared statement of Mr. Williamson follows:]

PREPARED STATEMENT OF KENNETH H. WILLIAMSON, PH.D., GEOTHERMAL CONSULTANT, SANTA ROSA, CA

Chairman Bingaman, members of the committee, thank you for inviting me to testify today. I had 24 years experience exploring and developing geothermal resources with Unocal Corporation, an American company that developed a quarter of the world's geothermal capacity. I worked in geothermal research and exploration for 5 years with the British Geological Survey. My doctorate thesis involved a study of heat flow from the earth in East Africa. I am now a geothermal consultant, and for the past several months I have been working with Chevron Corporation, the largest producer of geothermal energy in the world. I am not representing any company or industry group today. This testimony reflects my personal views.

S.1543 seeks to establish a national goal: 20 percent of total electrical production in the United States from geothermal resources by 2030. Achieving this would be a major step towards reducing greenhouse gas emissions, and creating energy security for our country. It would demonstrate to the rest of the world that clean, base load electricity can be generated on a large scale with minimal carbon dioxide emissions, and without the risks of nuclear power.

What will it take to get there? With the current geothermal installed capacity in the U.S. at less than 3,000 MW, we need to grow at 18 percent per year based on EIA predictions.[1] It will take hundreds of billions of dollars of capital, tens of thousands of geothermal wells, and millions of acres of land. We should look to private industry to invest dollars and drill wells, but government also has a critical role.

The 20 percent goal will not be achieved using the technology of the past. Traditional geothermal resources are hard to find, but easy to produce. Once a hole is drilled in the right place, usually more than a mile deep, geothermal brine or steam flows up the well and can be used to generate power. However natural geothermal reservoirs require very special geological conditions—not only must the rock underground be hot, it must also be naturally fractured so that water can flow through it.

In the past, we have found these reservoirs in the same way that the early oil industry found oil—by searching for seeps on the surface. Hot springs on the surface are the best place to start drilling for geothermal reservoirs deep below. But many of the promising sites with hot springs have already been drilled.

We need new technologies that can find "hidden geothermal reservoirs" deep in the earth, where no hot springs are leaking to the surface. The oil industry developed ways to find oil when there were no oil seeps at the surface. The geothermal industry needs reconnaissance tools that can detect deeply buried geothermal reservoirs with no associated hot springs, and more precise methods to target wells.

However, to achieve the 20% goal we must develop a new kind of geothermal resource, called EGS. We know it is possible to create reservoirs artificially in rocks that are already hot, but not permeable. In this case a well deep enough to penetrate hot rocks will not produce geothermal fluid when it is first drilled. Instead it will have to be stimulated with high pressure fluids, in a way that creates a substantial network of cracks extending out from the well into the surrounding hot rock. This process has come to be known as Enhanced Geothermal Systems, or EGS.[2] Making EGS work economically has been an elusive goal, and governments in the US, Europe and Japan have spent hundreds of millions of dollars trying over the past 30 years. But now EGS technology is within reach. A European Union project in France made significant progress, and government and industry are working together in Australia on an ambitious venture to demonstrate EGS on a large scale. In Germany, a new geothermal industry has responded aggressively to the high prices offered for renewable energy.

How can the U.S. government facilitate geothermal growth, and motivate the private sector?

Incentives.—My view is that incentives that offer higher returns for EGS power projects during the early years of development are likely to be more effective than cost sharing, since they are directly linked to the goal of increasing electricity generation.

Research.—We need basic research to support the development of tools which will enable us to:

1) Explore for hidden geothermal systems: We need rapid reconnaissance tools to identify prospects and more precise targeting tools to increase the success rate of exploration wells.

2) Improve the productivity of Enhanced Geothermal Systems: This will require a better understanding of how cracks form and propagate in different stress regimes and rock types. New tools need to be developed that allow specific zones in a hot borehole to be isolated for both fracture creation and short-circuit repair. This will allow multiple fracture zones to be created from a single borehole, enhance the water circulation rate, and reduce the cost of development.

Geothermal research involves a wide range of disciplines that benefit strongly from interaction with other industries. Research funding should not be concentrated in one or two institutions, but strategically distributed to take advantage of synergies in other industries and disciplines.

Education.—Many geothermal experts in the US began their careers in the 1970's, as I did. There is an urgent need to train and recruit a new crop of geoscientists and engineers. Geothermal courses need to be taught in universities, and the basic concepts introduced in schools.

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[1] Energy Information Administration(2007). Annual Energy Outlook 2007 with projections to 2030.

[2] Tester, J., Anderson, B., Batchelor, A., Blackwell, D., DiPippo, R., Drake, E., et al. (2006). The Future of Geothermal Energy. Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century. Massachusetts Institute of Technology.

Leasing and Permitting.—Once the economic feasibility of EGS has been demonstrated, there will be another critical role for government. To develop enough sites to achieve the national goal, the process for leasing land and permitting projects will have to be streamlined, and the BLM will need adequate resources.

In summary, the goal to generate 20 percent of our electricity from geothermal resources by 2030 is very aggressive relative to our previous experience. But large scale geothermal development will be essential if we are to reduce greenhouse gas emissions, and help to ensure energy security. The good news is that the technology to make Enhanced Geothermal Systems work economically is within reach. If government provides incentives for initial development of EGS, funds basic research to improve technology, educates new engineers and geoscientists in geothermal disciplines, and streamlines the leasing and approval process, EGS will become a compelling sector for private investment.

The CHAIRMAN. Thank you very much.

Thank all of you for your excellent testimony.

I have some written questions that I will submit and will ask you to respond to if you could in the next week or two, but I did not have any oral questions right now.

Let me defer to Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman, I will be brief in my questions, as well.

I note, Dr. Shevenell and Dr. Williamson, you both speak to the need to make sure that we have those individuals—whether they're in the universities or the programs that are focused on the technology that we'll be able to advance this. We heard Under Secretary Karsner suggest that the goals that we have set out are not feasible. They will not be feasible if we don't have the individuals that are educated, working on it, trained, focusing on this. So, it could be a self-fulfilling prophecy if we don't put the funding where we need the funding to make sure that we are moving in that direction. So, I appreciate that focus, just in terms of making sure that we have the individuals in these areas.

Dr. Williamson and Ms. Petty—you both mentioned the incentives, certainly recognize there are some who say, "Well, this is a mature technology, we don't need incentives, we don't need financial assistance, we don't need anymore more than the existing production tax credits." I'm assuming that both of you would agree that, in fact, some form of financial assistance, or some form of financial incentive continues to be necessary in the area of geothermal, is that correct from both of you?

Ms. PETTY. Financial incentives that have worked in the past include the Standard Offer No. 4 that was part of the California Utility Position back in the early 1980s when the price of oil was so high last time. This stimulated a great deal of the expansion of geothermal that happened during that next 5 years, and a lot of the power that we have online now, which is generating at much, much lower prices than were originally paid for that power back when it went on line in the 1980s, it came as a result of those Standard Offers.

The loan guarantees that the Department of Energy made for geothermal developers, while it—I think—expanded our knowledge of systems and improved our understanding, did not develop a lot of power. The tax incentives that we have are useful for geothermal, but perhaps not as useful as they have been for wind energy. The only happen after production is online, they're a production tax credit.

As we've said, and many of us have said, there's a great deal of time between the first discovery of a resource, or the first effort to develop it, and the actual generation of power. If that time period could be shortened, then these production tax credits might be more useful, but because of permitting delays, and because of the difficulty of obtaining the geothermal rights to land, the delays have made these tax incentives, perhaps, less valuable.

In Germany and Australia, they actually use price incentives, and that's getting a lot of power online.

Senator MURKOWSKI. Let me ask you one question, Dr. Williamson, you mentioned as one of your four proposals here, we need to look to additional basic research, and doing what we can to help identify where our geothermal prospects are. In Alaska, we've got a project that we are looking at out on the Aleutian Chain, and we've got a company who is looking to use Unmanned Aerial Vehicles, drones, to attempt to improve the detection efforts to more precisely identify where the hot spots are. Is this something where, in your opinion, this kind of research could be helpful in reducing the costs? Or, give me your sense on that.

Mr. WILLIAMSON. Senator, can I address your previous question first?

Senator MURKOWSKI. Certainly, go ahead.

Mr. WILLIAMSON. The reason I think incentives are important is, I believe strongly that we have to address the issue of greenhouse gases. If you look at the growth required in geothermal additions per year, in order to achieve the 20 percent goal, it is so aggressive that the only way I can see that it an be met is by private industry, as I have seen in my career—private industry responding to incentives in the early years—only in the early years, and for the first phases of development.

So, that's the reason—if there was no sense of urgency, I would not advocate that. But there's a strong sense of urgency here, there is a technology issue to be solved before EGS can be, in my opinion, is going to be economic. So, that's the reason I advocate it.

Senator MURKOWSKI. I appreciate that.

Mr. WILLIAMSON. Your question about using drones for geothermal reconnaissance—I am not familiar with this specific example. My focus in my testimony has been not on research focused on conventional resources, and I think we can—we have developed, as the President of Iceland said, developed the ability to explore and understand them very well, there's always room for improvement—but my focus is on EGS and on hidden systems. If there's no surface expression, then drones that detect thermal effects might also not be so effective.

So, it's hard to predict what areas of research will benefit. This is such an aggressive goal, I'm reluctant to be negative on any area of research, to be honest.

Senator MURKOWSKI. I appreciate it. We don't want the negativity.

Mr. Chairman, thank you , and to all of those who have given us great testimony today, we greatly appreciate your comments.

The CHAIRMAN. Thank you all for being here, and I think this was a useful hearing. We had a lot of good testimony and I appreciate the good work that you folks put into preparing your testimony.

Thank you, that will end our hearing.

[Whereupon, at 12:03 p.m., the hearing was adjourned.]

APPENDIXES

Appendix I

Responses to Additional Questions

Responses of Susan Petty to Questions From Senator Bingaman

Question 1. What level of funding would be needed to generate one full-scale EGS project today?

Answer. a. Commercial Development.—Right now, commercial EGS development is both technically and economically feasible at sites in the US with very high temperatures, >250°C (480°F) at shallow depths of less than 3 km (~10,000 ft). A project would likely start with a demonstration plant of about 10 MW that would include an injector and one or two producers and a small scale demonstration size steam turbine or binary unit. This would cost between $36 million and $42 million depending on the flow that could be achieved per well. The next phase would expand the project by adding two to three additional wells and two more modules of 10 MW each. This would cost an additional $76 million-$83 million. The next phase would expand the project by adding 100 MW of capacity. This added 100 MW would cost around $355 million. The first phase of development would take about 3—4 years depending on permitting issues. The second phase could be added a year later. The third phase build out could be completed the following year. It is feasible that in this way, the project area could be expanded to as much as 500 MW or even more depending on the land area available and the behavior of the first phases of development. As data is collected from operating these early EGS developments, the ability of developers to expand and put more power on line would increase as the cost decreased due to "learning by doing".

Figure 1* below shows the total investment, the federal investment, the private investment and the potential annual royalty revenues possible if geothermal electric power production were to reach 20% of the total US capacity. The federal investment assumes that three EGS demonstration sites would be used to research techniques and equipment that would bring the cost of EGS power down with an emphasis on gaining insight in new areas outside the western US. The federal annual royalty revenues are based on the current regulations requiring 1.75% of gross revenues rising to 3.5% after 10 years operation and the assumption that half of all geothermal projects would be built on federal land. All costs and revenues are escalated to the year shown based on current costs.

b. Commercial investment dominates this development scenario.—There is little hope of successfully developing EGS to the point where geothermal energy supplies 20% or more of the nation's power without commercial development. The private sector has to be involved with guiding the areas for research, with managing projects so that they yield the results desired and with technology transfer from the beginning of each project. Industry needs to ask for the research and assistance it needs so that federal dollars are leveraged to provide the maximum benefit. The federal investment initially increases as the first site is permitted and the research undertaken which will be tested at this site is performed. The highest cost represents the drilling of wells. It is assumed that sites are chosen with as much data and as many wells of opportunity as possible available.

c. Federal Investment.—These early commercial EGS projects would only work at the best sites. To extend EGS across the US requires a great deal of research effort to reduce the cost of power to competitive levels. During the discussions leading up to the report, the MIT panel developed two scenarios for federal funding of research

* Figures 1–6 and Table 1 have been retained in committee files.

and development of an EGS project: 1) Wells of opportunity scenario, and 2) Independent development scenario. The cost for the well of opportunity scenario, where a site with an existing well would be chosen, would be about $87 million spread over at least 3 years and more likely 5 years. This cost includes research into the areas of highest impact for cost reduction. For the independent development scenario, the cost would be about $100 million. The panel felt that this effort should be repeated in at least three geologic conditions that would demonstrate the technology over a large area of the US. This might include 1) a granite below a deep sedimentary basin in the Midwest or one of the basins west of the Appalachians in Pennsylvania or New York; 2) the metamorphic rocks underlying the oil producing sediments in Arkansas, Oklahoma, Louisiana, Mississippi or East Texas; and 3) the Atlantic Coastal Plane in Maryland or South Carolina. Another possible area would be the Cascades in the Pacific Northwest. While most geothermal experts feel there is high potential for EGS in the Cascades, there is little data that defines the resource because there are few deep wells, particularly in the north Cascades. Drilling in British Columbia suggests that the Cascade volcanoes will make excellent EGS targets, but we don't have much information other than that. It is possible that some resource definition drilling with federal funding or cost share would be sufficient to jump-start the development of EGS in the Cascades.

Table 1 shows the EGS panel's estimates of costs for a demonstration project that does not use wells of opportunity. Since this budget was developed as part of the MIT study, the costs are in 2004 $.

Question 2. What is the primary obstacle that keeps geothermal and petroleum companies from exploring and exploiting EGS energy?

Answer. a. Project economics are the primary obstacle.—The economics of producing power using EGS technology are not well defined because the technology is emerging, but clearly the first EGS projects will cost more than conventional hydrothermal geothermal. There is still plenty of hydrothermal power to develop that is cost effective and has already been explored. No projects have been developed yet in the US to demonstrate that this technology is feasible in geologic settings here. Power prices in the western states where the best-cost EGS targets are found are low, so that only the very best sites are economic in these areas. As a result there has been little or no market for this power. Renewable portfolio standards are changing this. Oregon and Washington just enacted renewable portfolio standards. Michigan is considering a law requiring feed-in tariffs similar to those enacted in the European Union for renewable energy that includes a high enough price for geothermal to encourage the development of EGS. Once a few projects get going, there should be significant increase in commercial interest in EGS.

b. Petroleum companies are focused on lucrative oil and gas production.—Geothermal doesn't look very attractive to most oil and gas producers because they are making plenty of money from their core business—oil and gas. Geothermal is a distraction. On the other hand, showing oil and gas producers that they can make some money from a hot dry hole and defer expensive abandonment costs by converting it to geothermal production is gaining some interest.

c. Stimulate geothermal development by requiring oil and gas companies to develop geothermal projects when they lease US oil and gas rights on federal lands.—This has worked well for Indonesia and the Philippines, both countries with a large geothermal resource and little oil and gas.

d. Reduce cost by researching and testing new technology.—The MIT study identified key areas of technology improvement that could reduce the cost of EGS power. While well field cost makes up over 75% of the cost of an EGS project, reducing the cost of drilling is not the only way to reduce this cost. Improved energy conversion efficiency could cut the number of wells needed. Better fracturing methods would not only increase the flow per producer and thus reduce the number of expensive wells needed, but would also reduce the risk of thermal break through or rapid temperature decline that would require new stimulated volume to be created and possibly new wells to be drilled. High temperature pumps for deep installation could allow development of high temperature high flow wells in a wide area across the country. Even when drilling cost is examined, the fastest way to reduce cost may not be the obvious improvement in rate of penetration of the hole. Studies done as part of the MIT panel study showed that as much as a 20% reduction in well cost for deep wells could be made by improved casing design to eliminate one casing string. New oil and gas technology is now available that could make this possible. These incremental improvements could reduce the cost of power from EGS by as much as half.

Question 3. Would a cooperative international technology exchange program accelerate geothermal research, development and demonstrations?

Answer. a. International cooperation is absolutely necessary.—EGS technology is now being developed and tested in Europe and Australia. If the US is going to catch up with the technology improvements being made internationally, we will need to work out data exchange agreements, send our scientists to international meetings, and invite scientists working in these areas to the US to assist with our technology development.

b. The need for international cooperation is immediate.—Commercial companies are dominating technology development of EGS in Australia. While government is still involved, the commercial sector is driving the boat. Cooperating government-to-government in Australia may not yield the benefits now that could have been realized two or three years ago. In Europe, there is still a strong government supported research program, but industry is very involved and the next steps will likely reduce government sponsored research. If we take the course of strong industry involvement in government-supported research, we could see this happen in the US.

Question 4. Who would the key international participants be?

Answer. a. Government:

—The European Union in Brussels (DG Research: Dr Jeroen Schuppers (Jeroen.Schuppers@cec.eu.int). This will cover the majority of the countries in Europe who deals with EGS and hydrothermal.

—Australian South Australia Government: Hon PAUL HOLLOWAY MLC—Minister for Mineral Resources Development. Starting research institute at University of Adelaide for geothermal research.

—Phone 8303 2500

—Fax 8303 2597

—E-Mail—ministerholloway@saugov.sa.gov.au

—Postal Address: GPO Box 2832, ADELAIDE SA 5001

—or the other organization is International Energy Agency/Geothermal Implementing agreement (IEA/GIA). A lot of international cooperation is being carried out under the umbrella of IEA/GIA. Roy Baria is in charge of one of the EGS tasks.

—Australian Federal Government: Geoscience Australia, the Australian geological survey, has a large scale geothermal assessment study going on to map heat flow and temperature with depth over the whole country. I don't have a good contact, but here is the team's email address: geothermal@ga.gov.au

b. Industry:

—Joerg Baumgaertner (BESTEC GmbH) baumgaertner@bestec-for-nature.com

—Doone Wyborn (Geodynamics) dwyborn@geodynamics.com.au

—Barry Goldstein (South Australian Government) goldstein.barry@saugov.sa.gov.au

—Roy Baria (Mil-Tech UK Ltd) roybaria@onetel.com (Roy is now working with Altarock and will be involved in developing US EGS research policy through our company's cost shared participation should there ever be any funding from DOE for research again.)

RESPONSES OF SUSAN PETTY TO QUESTIONS FROM SENATOR DOMENICI

Right now we have about 3000 MW of geothermal power on line. The USGS estimated in 1978 that there might be a total of 27,000 MW of developable power from identified and explored hydrothermal sources. Recent industry assessments suggest that about 5600 MW of this power has been somewhat explored and could be developed successfully over the next 5 years or so with current power prices (Western Governors' Association Clean and Diversified Energy Initiative: Geothermal Task Force Report, 2006). Beyond that, the WGA Task Force found that another 13,000 MW of potential geothermal power is known and could be developed as either power prices rise or the cost of geothermal power increases.

Question 1. What is your assessment of how tough it will be in terms of the amount of investment it will take (both public and private) to meet the goal?

Answer. a. Hydrothermal geothermal projects are being privately funded now in Nevada, California, Utah and Idaho. More than 400 MW of geothermal power are currently being built using private funding. The capital cost of these projects ranges from ~$3000-$3500/kW, with about 70% of the investment financed through private debt, for a total private investment of more than $1,300,000,000 in the coming year alone. However, in order to reach 20% of our nation's electric power from geothermal, a much larger investment will be needed. Hydrothermal geothermal alone can't achieve this goal and except at the best, most cost effect sites, EGS is no yet economic. Research into improved methods of fracture stimulation, better testing and site assessment methods, improved well design and more efficient geothermal power plants can reduce the cost of power from geothermal projects that use EGS technology. This will make power that uses this technology cost effective in more areas of the US.

b. The MIT study looked at several scenarios for bringing large amounts of geothermal power on line. In order to reduce the price of EGS power sufficiently to allow large scale market penetration that results in over 100,000 MW on line, a research investment of about $400,000,000 is needed over the next 8-10 years. After this point investment would decline. Some of this investment would be from the private sector, either through independent proprietary research , or through cost sharing with the federal government. The remainder of this investment would need to come from federal and state sources.

c. Figure 2 shows the estimated federal and private investment in both research and development, required to achieve 20% of total electric power, or about 123,000 MW, from geothermal sources. While a larger and more rapid investment might accelerate the reduction in EGS cost needed to increase the rate of market penetration of geothermal energy, this would only be possible with a strong investment from the private sector. An increase in power of 10% per year seems doable, however, with a federal investment similar to that calculated for the MIT study. Figure 1 shows the investment as research into four EGS demonstration projects of 10 MW each, cost shared with industry. It is assumed that industry would build and operate the power plants and participate in the project and research design. In this way, technology transfer would be encouraged while new technology is being tested. Test site would be selected based on the geology and the potential for large amounts of power being developed in a similar area.

a. The federal investment initially increases as the first site is permitted and the research undertaken that will be tested at this site is performed. The highest cost represents the drilling of wells. It is assumed that sites are chosen with as much data and as many wells of opportunity as possible available.

b. Another form of investment is the private investment in drilling equipment, service company equipment and manpower needed to drill wells, discover and assess resources, design and engineer both reservoirs and power plants and operate both plant and field. Figure 3 shows the number of wells and drill rigs to bring our total installed geothermal capacity to 20% of the nation's electric power.

c. The rigs and services needed to develop geothermal projects, using either EGS or hydrothermal technology, are the same as those used for oilfield operations. Figure 3 assumes that each of these rigs drills 4 successful wells per year. While geothermal drilling requires generally larger completed well diameters to accommodate the larger flow rates of hot water, land based oil and gas drilling equipment can easily be adapted for use in geothermal operations. Geothermal drilling procedures and well design differ from oil and gas, which means that rig crews need to be trained for geothermal drilling and drilling engineers need to understand the conditions geothermal wells will operate under. However, the materials, tools, people and equipment are for the most part the same. Right now, with oil and gas prices high, rigs and equipment are in high demand in the US. However, there is little potential for new discoveries on land in the US. As old wells are worked over and fields that can be enhanced to achieve more production are maximized, equipment is freeing up and becoming more available. This will mean competition for rigs and equipment will ease and prices should stop rising and may even drop. Rigs, geologists, engineers, equipment and services from the oil patch that might become surplus could be employed in the development of geothermal energy. This might smooth some of the extreme ups and downs that the oil and gas industry in the US has experienced and prevent the loss of skilled workers and know how to other countries with a less depleted oil and gas resource. Currently there are about 7 drill rigs configured for geothermal drilling with geothermal trained crews, operating full time drilling geothermal wells. This total increased from 3 the previous year. There are also several exploratory rigs used almost exclusively for geothermal. Four more rigs are planned for the geothermal arena next year. In addition, a number of oil and gas drilling companies have expressed interest in training their crews in geothermal drilling methods and coming to work in the geothermal industry as the number of jobs in oil and gas decrease.

d. Figure 4 shows the people required to develop geothermal capacity to more than 20% of the nation's total power. There are currently about 5000 people employed full time in the geothermal industry according to recent survey by the Geothermal Energy Association. This graph shows the number of additional people required to meet the 20% target. In addition to the full time technical and non-technical employment, construction employment adds about 3 people per MW during the 18-22 month power plant construction phase. Since these workers are not specialized to geothermal, they are not shown below. It is assumed they would move over from other industrial construction areas to build geothermal plants.

Question 2. In terms of the technologies that will have to be developed or refined, how tough will it be and how long might that take?

Answer. a. The MIT report estimated that with a full research effort including a test site, the initial incremental technology improvements could be developed in about 5 years. However, a three year ramp up period would be needed to acquire and permit a test site and for well drilling if no wells of opportunity could be found. At least two years and possibly as much as four years following testing would be needed to allow technology transfer to move these new methods into general use to realize the benefits in cost reduction.

b. Technology improvement areas include:

- Exploration/Information gathering-Cost of Risk Reduction
  - —50% reduction in cost of risk
  - —Better information—HT borehole televiewer, HT 3 component seismometer
  - —Reduces drilling risk and resource risk as well as cost risk on depth to resource
- Cost of drilling
  - —20% reduction in cost of drilling
  - —Eliminate one casing string—available from oil and gas technology
  - —Improved rate of penetration through better bits—developed by Sandia—can be licensed
- Reservoir Stimulation
  - —Double the flow per well from 40 l/s to 80 l/s without thermal breakthrough
  - —Reduce the stimulation cost by better stimulation design (do it once, do it right)
  - —Chemical stimulation methods
  - —Improved instrumentation HT borehole televiewer, HT 3-component seismometer
  - —Fracture design code
- Power Plant
  - —20% improvement in conversion efficiency
  - —Improved turbine design
  - —Best available binary technology
- Reservoir Management
  - —Modeling software
  - —Prevent or correct thermal breakthrough-chemical stimulation/diversion
  - —Reduce risk of scale or short circuit through rock/water, rock/CO_2 interaction

c. Beyond the incremental technologies, the MIT panel felt that the development of advanced technology would require continuing research at additional geologic settings to ensure the methods are applicable, that the differences in geology can be accommodated and to allow for development and testing of truly innovative breakthrough technology. This research should extend to at least 3 and possibly 4 geologic settings with widely different conditions.

Question 3. Will these new technologies be able to compete economically against the alternatives?

Answer. a. Hydrothermal power prices dropped from over 14¢/kWh during the 1980s to less than 6¢/kWh last year. Prices for EGS power should follow a similar trajectory. With the incremental improvements discussed above, we can see a really large amount of power come into the cost range of about 10¢/kWh as shown in Figure 5. This figure shows that with near-term incremental technology improvements, the cost of over 300,000 MW could be dropped below 10¢/kWh. In addition, learning by doing will mean that as EGS power comes on line, the risks and costs will decrease in relation to the amount of power on line in similar geologic settings, bring costs down further.

b. At present, hydrothermal power sells to utilities for between 6-7¢/kWh. Comparing costs for geothermal power to other renewables, solar thermal is in a similar range of about 7-10¢/kWh, while photovoltaics can cost around 30¢/kWh. Wind power has a lower capital cost and operating cost than geothermal, and much lower than EGS, but because of the fact that wind is intermittent, the capital cost has to be amortized over a much lower number of kilowatt hours. The result is that wind power can cost more per kWh than EGS power from good sites. The cost of coal power depends on the level of clean up of the emissions from the plant. Clean coal (without any carbon emissions considerations) has a capital cost similar to a hydrothermal project of around $3000 to $4000/kW. With fuel cost, this translates to anywhere from 6¢/kWh to over 9¢/kWh. Combined cycle natural gas power costs about 2.5¢/kWh to amortize the capital equipment with the added fuel cost (natural gas price per million BTU divided by 10,000 since it takes about 10,000 BTU/kWh). This is about 8.5-9¢/kWh right now. This means that EGS power is only slightly more costly than power from combined cycle natural gas plants, a little higher than coal power, comparable to solar thermal, much less than photovoltaics and around the cost of wind.

RESPONSES OF SUSAN PETTY TO QUESTIONS FROM SENATOR SALAZAR

Question 1. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. a. Market forces will drive geothermal developers to move to new areas if incentives to encourage development are used. Renewable portfolio standards are definitely a driving force. Because utilities may have a difficult time integrating intermittent renewable like wind and solar into their grid system beyond a certain number of MW, if the RPS requires a large enough fraction of energy from renewables, then geothermal will be considered in the mix. Price incentives are, of course the fastest way to get renewables to market in new areas. Michigan is considering a feed in tariff based on renewable technology with high enough prices for small scale geothermal power projects to encourage developers into the area. The Michigan basin has high potential for EGS power and while costs would be high right now, the geology is well known and risks should be low.

b. Another incentive that could both spur development and reduce dependence on foreign oil imports would be tying federal oil and gas leasing by oil companies to development of a certain amount of geothermal power. This has worked very well in Indonesia and the Philippines. These countries have only a modest amount of oil and gas reserves. They require oil companies who lease new oil and gas concessions to propose to develop geothermal power projects. This wouldn't necessarily include really sensitive areas like the Arctic National Wildlife Refuge. Oil companies are interested in areas offshore from the southeast coast of states like South Carolina, Georgia and Florida. While Florida has a fairly low geothermal potential given current technology and power prices, South Carolina, along with Maryland, Virginia and Georgia have significant potential. Large oil companies have the resources to develop geothermal energy in these areas. Technology improvements and learning by doing would then bring the cost of energy from these Atlantic coastal plane regions down to competitive levels.

Question 2. What percent of our nation's electricity supply do you estimate could come from geothermal sources?

Answer. a. A 20% target is reasonable by 2050.—While it would very likely take longer than the target date of 2030, I feel that 20% of electric power from geothermal sources is not unreasonable. None of the requirements to get this much power online—whether drill rigs, turbines or people—are needed in unreasonable numbers. Once the target of 20% is reached there will be infrastructure, skilled technical support staff and available materials. Demand should reduce the cost of power by shifting the focus of the drilling and construction industry from fossil fuel power plants to geothermal. With all of this expertise and industry focus on getting power on line, the fraction of power from geothermal power could continue to increase more rapidly than demand, replacing fossil fuel power plants. The available resource is so large that this will not limit the development of new projects.

b. Land availability will be one factor limiting the growth of geothermal power.—Only the federal government has the large tracts of land that will be needed to support geothermal development. However, recent changes in the federal leasing laws penalize EGS projects by adding up front capital cost for land acquisition. Because EPAct2005 requires that all geothermal leases on federal land be competitively bid, and because the regulations have established an auction process for the bidding, the recent prices for federal leases have been extremely high. While this may seem good for the federal government, and appear to encourage rapid development to get fast pay back on a developers land investment, it makes things difficult for emerging technology such as EGS. Several areas in the recent round of federal leasing were excellent prospects for EGS development, but not for conventional hydrothermal development. Yet these were leased at high prices per acre by developers of hydrothermal projects. The large upfront capital cost of an EGS project with deeper wells and the technology risk associated with an emerging technology make it very difficult for an EGS developer to compete for land at high prices.

c. Development coordinated with other uses.—While there is an ample amount of federal land in the West, there is less in the east. Eventually, to extend large-scale geothermal power development into the Midwest and East, ways will have to be found to integrate geothermal development with other land uses on private land.

While each geothermal power plant has a relatively small footprint compared with other types of renewables and with fossil fuel plants, the geothermal rights to a large subsurface area are needed to support large scale projects. Figure 6 below shows the Geysers, a 1,000-MW geothermal power project. Large scale EGS projects are likely to look very similar to this area. This image is from an altitude of 10 miles above the earth. Compare this to Figure 7, which shows the coal fired plant at Colstrip, Montana, from the same height above the earth. The land around the Geysers plants is either forested, used for farming or natural. The land around the coal plant and mines at Colstrip is disturbed and barren.

Although the federal government can provide large tracts of land needed for EGS, it also has in place a potential disincentive for developing EGS on them, particularly in the early, formative years. Currently, per-acre bonus bids are required when the geothermal leasing rights on federal land are auctioned. Unlike hydrothermal geothermal development, which relies on finding key parcels to access a geothermal resource, EGS mainly needs sufficient acreage to ensure an economic project. If this bonus is too high, EGS development might be pushed mainly to private land, and the federal government would loose out on the technology's royalty-based payout, which under present law could amount to over $1 billion annually.

d. Water availability is another factor limiting the growth of EGS.—Once the EGS reservoir is filled with water during stimulation, it can be managed so that water losses are very low. However, it can take a really large amount of water to stimulate the reservoir at the start. This water doesn't need to be potable or even of good quality. Treated sewage effluent works well and is being used at the Geysers, while poor quality water is being used at other geothermal areas for recharge. Water for evaporative cooling is also a real benefit to EGS projects since it increases the efficiency of the conversion of heat to power, reducing the need for wells.

Question 3. What percent of our country's heating and cooling supply do you estimate could come from geothermal sources?

Answer. a. Geothermal heat pumps can cut energy use in areas with high need for both heating and cooling in half. While this doesn't actually supply power, it can reduce our demand for power. Energy needs for heating and cooling accounts for about 11% of our nation's total energy consumption. Cutting this in half through the use of geothermal heat pumps could thus account for as much as 5.5% of our energy needs. However, it is really unlikely that all heating and cooling needs could be satisfied using geothermal heat pumps. A more reasonable target would be half the heating and cooling needs of the country supplied by geothermal heat pumps, or about 2.75% of the total energy needs of the US.

b. Direct use of geothermal energy for industry processes, especially in combined heat and power projects, could supply a significant portion of our nation's energy needs. Industrial users consume about 37% of our country's energy. It's possible that half of this could be supplied from direct use of geothermal heat, especially if large scale geothermal development for power also took place. This would therefore account for as much as 18.5% of the energy needs of our country. While this seems like a large target, it certainly would better use the heat extracted from the earth. Adding heating, cooling and industrial uses to EGS power projects would further improve the economics.

RESPONSES OF MARK D. MYERS TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Do you or the USGS think that an enhanced geothermal assessment is needed?

Answer. Since completion of the last national geothermal resource assessment in 1978, there have been significant advances in the understanding of geothermal systems capable of producing electricity and in the technology capable of producing electricity from geothermal sources. The current USGS national geothermal resource assessment, scheduled for completion at the end of 2008, takes into account these advances as they relate to conventional geothermal resources and one type of unconventional geothermal resource, Enhanced Geothermal Systems.

The full potential of unconventional geothermal resources (including Enhanced Geothermal Systems, Geopressured Geothermal., and Geothermal Co-Produced with Oil&Gas) has not been adequately characterized in light of the advances in geothermal science and technology. The resource assessment authorized in S. 1543 would provide for a comprehensive examination of these unconventional geothermal resources, including an evaluation of how unconventional geothermal resources could contribute to the domestic energy mix. In addition, because some of the most promising sites for Enhanced Geothermal Systems development are located along the margins of known conventional geothermal reservoirs, comprehensive geologic examinations of Enhanced Geothermal Systems resources would further build upon the current USGS assessment effort and facilitate a more thorough characterization of domestic, conventional geothermal resources.

Question 2. If so, how might an enhanced assessment affect usage of geothermal energy in the U.S.?

Answer. The current national geothermal resource assessment effort could contribute to the increased usage of electricity production from geothermal resources by providing State and Federal government policy makers, other Federal agencies, the energy industry, the environmental community, and the financing community with information that will aid in estimating the potential contribution of geothermal energy to the Nation's energy mix. Geothermal energy is an underutilized resource in the United States for a variety of reasons, one of which is the lack of basic information on this resource.

Question 3. Is the very modest funding sufficient that the USGS is receiving to conduct this geothermal resources assessment (~$400,000 per year for FY2006-2008) to completely categorize both conventional geothermal resources, as well as unconventional geothermal resources—namely enhanced geothermal systems—without compromising the quality of the assessment?

Answer. Present funding levels for the current assessment effort allow USGS to pursue an assessment of conventional geothermal resources while also conducting limited study of unconventional geothermal resources. For approximately $1.2 million (total), the USGS is characterizing conventional geothermal resources and assessing the potential electrical production from those resources. In addition, USGS is providing a provisional evaluation of the contribution of Enhanced Geothermal Systems (EGS) to the energy mix of the United States. These activities are consistent with those authorized in the Energy Policy Act of 2005.

Question 4. You state that the timeframes specified in the bill may not be adequate for proper resource characterization—excluding the outer continental shelf area. How much time do you believe is necessary to produce a high quality, robust assessment?

Answer. Under the Energy Policy Act of 2005, the USGS is currently conducting a new assessment of conventional moderate-temperature and high-temperature geothermal resources and will report on the results of that assessment in the fall of 2008. To substantively undertake an evaluation of the unconventional resources of the United States, a methodology for assessing these resources must first be developed, peer reviewed, and published, as the USGS does for all of its energy resource assessments. Methodology development will take approximately one year. Once that methodology is developed and peer reviewed, the assessment of the unconventional geothermal resources of the United States would require an additional 2 years.

Responses of Mark D. Myers to Questions From Senator Domenici

Dr. Williamson spoke of this legislation requiring millions of acres of land. As I look at the maps that show the "best" areas for development, I see the current land owner is the federal government. I also know that many of those lands are within reserves that would preclude drilling and surface development and, in many instances, the development of the transmission lines needed to get the electricity to market.

Question 1. Can you comment on Dr. Williamson's statement about needing millions of acres of land and tell me your views on the desirability and feasibility of doing this?

Answer. Our preliminary evaluation of the resource base for Enhanced Geothermal Systems (EGS) indicates that, outside of national parks, wilderness areas, national monuments, wildlife refuges and similarly restricted State lands, approximately 70,000 square miles (45 million acres) of public and private land in the western United States has significant potential for EGS development, with approximately 2000 square miles (1.3 million acres) of the highest potential located in high temperature areas around the margins of known geothermal systems. Although our assessment of the EGS resource is not yet complete, successful development of EGS technology could provide the potential for generating in excess of 100,000 MW on these lands. Realizing this potential depends on balancing many diverse, and often competing, interests with respect to land status, resource use, and energy policy. USGS, as a science agency, provides impartial scientific data and information to land management agencies, agencies with regulatory and policymaking responsibilities and others. We are hopeful that the information provided will help to support appropriate geothermal energy policy.

Question 2. Are we likely going to need to provide sufficiency language to allow the rapid development of this resource on federal lands to meet the stated goal of this bill?

Answer. NEPA compliance will enable Federal agencies to ensure that the environmental impacts are fully understood, and the Department of the Interior does not recommend sufficiency language.

Question 3. Do you believe this country can meet the goal of getting 20% of our electricity from geothermal by 2030?

Answer. Meeting the goal of getting 20 percent of our electricity from geothermal by 2030 depends on many factors, including the resource base, the technology, the land and resource managers, the industry, the financial community, and others. These are complex and interrelated issues and USGS can only speak to the resource base. The geothermal resource base is substantial, but realizing the goals of 20 percent by 2030 will require aggressive development of identified geothermal systems, rapid and successful exploration and development of undiscovered systems, and scientific and technological advances that will enable the large-scale exploitation of unconventional resources like EGS, geopressured geothermal, and geothermal co-produced with oil and gas. Given the scale of these challenges, it may be very difficult to achieve the 20 percent goal by 2030.

One potentially significant contribution from geothermal that is not explicitly addressed by the 20 percent goal is the potential for geothermal heat pump installation to reduce energy demand from commercial and residential buildings. USGS has not studied the geothermal heat pump resource, but, if the resource is as extensive as indicated by the Department of Energy (DOE) and industry studies, reduced demand from widespread geothermal heat pump installations combined with electric power production from aggressive development of conventional and unconventional geothermal resources might have a significant impact on energy demand and help in meeting the 20 percent goal.

Question 4. How difficult will that be to accomplish?

Answer. That depends on a variety of factors, many of which are described above, that are outside the purview of the USGS to answer in any detail.

Question 5. Do you believe that geothermal will compete economically with the available alternatives, or would we need to provide incentives or mandates to force its use?

Answer. The recent resurgence in geothermal exploration and development confirms that a significant number of identified conventional geothermal systems can be developed at costs competitive with other energy sources under the current state of economic conditions and incentives. As to whether incentives or mandates are needed, this issue is not within the purview of the USGS.

Question 6. What is it going to take to complete the called-for assessment in terms of costs, time, and new technology?

Answer. Under the Energy Policy Act of 2005, the USGS is currently conducting a new assessment of conventional moderate-temperature and high-temperature geothermal resources and will report on the results of that assessment in the fall of 2008. To carry out a national geothermal resource assessment that would build on current USGS efforts by including unconventional geothermal resources, as well as an enhanced characterization and understanding of the domestic, conventional geothermal resources, a methodology for assessing unconventional resources would first need to be developed, peer reviewed, and published, as the USGS does for all of its energy resource assessments. Methodology development will take approximately one year. Once that methodology is developed and peer reviewed, the assessment of the unconventional geothermal resources of the United States, and an enhanced characterization of the conventional resources, would take an additional 2 years. Funding of approximately $1.5 million per year would be required for such an effort.

RESPONSES OF MARK D. MYERS TO QUESTIONS FROM SENATOR SALAZAR

Question 1. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. One way to highlight the benefits of geothermal energy is to emphasize the value to the entire country in terms of reducing air pollution, cutting back on greenhouse gas emissions, and fostering national energy independence. In addition, few people recognize that the entire spectrum of geothermal energy use is not limited to the western States. Although conventional hydrothermal resources and the highest grade Enhanced Geothermal Systems (EGS) resources are concentrated in the western United States, much of the unconventional geothermal resource base, including geothermal co-produced with oil and gas, geopressured geothermal, and part of the EGS resource, is in the central and eastern United States. Also, geothermal heat pumps have a significant potential to reduce electric power demand, and this resource can be utilized across the country, with most of the installations to date located in the eastern United States.

Question 2. What percent of our country's electricity supply do you estimate could come from geothermal sources? What percent of our country's heating and cooling needs could come from geothermal resources?

Answer. The current USGS geothermal resource assessment will not be completed until the fall of 2008, but preliminary results indicate that the combined potential from identified and undiscovered conventional geothermal systems as well as EGS exceeds 100,000 MW. This equals approximately 10% of the current US electric power generating capacity. A complete answer to the question of geothermal energy's contribution to the Nation's heating and cooling needs also depends upon the potential contribution from direct use and geothermal heat pumps. The USGS has not investigated the potential for geothermal heat pumps to contribute to the national energy mix, but DOE and industry studies suggest the presence of a significant resource.

RESPONSES OF HON. OLAFUR RAGNAR GRÍMSSON TO QUESTIONS FROM SENATOR SALAZAR

Question 1. The country of Iceland has gone further than any other country in utilizing its vast sources of renewable energy. Why do you think the U.S. has ignored the potential of geothermal energy?

Answer. I have not undertaken any extensive analysis of the US Energy history but perhaps the following aspects of the case of Iceland could be considered in this respect:

- Iceland changed its energy policy following the increase of oil prices created by the Middle East conflicts of the 1970s, the Arab-Israeli War and the Iranian Revolution. This speeded up projects all over Iceland to replace oil by geothermal power. The price of coal and oil when compared to geothermal has been in favour of geothermal projects.
- Icelandic energy companies realised earlier than US companies that geothermal resources can be utilized for many different lines of profitable business. In addition to the energy production; spas, greenhouses, cosmetics, snow melting, etc. Their business model is therefore more comprehensive than the traditional US view of looking at geothermal energy.
- There has been a tendency within many countries, including the US, to concentrate on big solutions and megaprojects whereas the essence of geothermal is that it can be tailormade to fit one household, one village, one city or a whole region. To make a succesful geothermal development a different approach to energy policies is therefore required as the development of Iceland clearly demonstrates.

Question 2. What can the U.S. government do in order to create an infrastructure that better supports the use of geothermal energy?

Answer. In this respect the following ideas could be worthy of consideration:

- create a comprehensive legislative and regulatory framework to further geothermal development in different parts of the United States.
- make geothermal energy an integral part of the energy debate.
- encourage the Department of Energy to strengthen its geothermal operations.
- give encouragement and incentives to cities and states which have geothermal potential.
- provide financial support for scientific and technological research cooperation.
- actively support the ongoing deep drilling projects, for example the Icelandic Deep Drilling project which is based on an Icelandic-US cooperation.
- give temporary tax credits to experimental drilling projects.

RESPONSES OF LISA SHEVENELL TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Your testimony states that research and development funding is critical for workforce training. Is it your opinion that basic R&D funding would take care of the shortage of qualified technical personnel or would a more specific workforce training program be more appropriate for training skilled technical staff?

Answer. Basic R&D funding should take care of the master's level training, although the rate at which students are recruited needs to be accelerated. Universities should also begin to implement geothermal programs in the undergraduate degrees. Similarly, community colleges will need to develop or enhance curricula for technicians to run the power plants.

Question 2. Should we be investing funding in more targeted technical internship programs? What would you suggest?

Answer. These types of programs will be very important. My conversations with several in industry indicate they are interested in such programs as well as in graduate student fellowships. Based on these conversations, it appears that industry will be willing to fund such programs, as they are fully aware of their acute need for a trained workforce. We at UNR are planning a renewable energy minor in collaboration with industry, and one key component of the program is an internship program with the industry partners. However, until the programs are actually implemented, it remains to be seen the degree to which, if any, the federal government should play in funding these programs. Grants to help develop new curricula would be helpful to the process.

Question 3. Has your university been negatively impacted by the elimination of the federal geothermal program?

Answer. Yes, we lost our most productive researcher who was helping to mentor students through his research projects. Fortunately, if stable funding could be demonstrated, he indicated he would consider returning to our university. I can put you into contact with individuals at other Universities who can relay their experiences in losing faculty (and prospective graduate students) if you desire. It is impossible to keep people when we can not assure them they will be paid for at least some reasonable amount of time. There are plenty of other opportunities in the geosciences at this time to pursue alternative employment options.

Question 4. Would a cooperative international technology exchange program accelerate the geothermal research, development, and demonstration?

Answer. Such cooperation is already occurring to a large degree. We are actively working with companies based out of Canada, Israel, and Italy on resource issues. Also international players in developing nations have been actively requesting help from us in the form of workforce training (e.g., Ethiopia, Chile), yet there haven't been the resources to develop training specific to their needs which tend to include short courses. Hence we are investigating incorporating the foreign students into the normal University coursework, and possibly using distance learning, or investigating how we could add to the currently successful training program Iceland has held for individuals from developing nations for many years.

Question 5. Who would the key international participants be?

Answer. Other participants with experience include Iceland, Japan and New Zealand, although Iceland's resource is much different than most of that in the western U.S. Some of the technologies (e.g., drilling) or lessons learned may not be directly applicable to the resources in the U.S., but we could benefit from knowledge gained in the course of development of their international training programs.

RESPONSES OF LISA SHEVENELL TO QUESTIONS FROM SENATOR DOMENICI

I note in your testimony that drilling today costs between a few million dollars to 10 millions dollars per production well. I also gather that a significant number of wells will have to be drilled in order to carry out the assessment work called for in this legislation.

Question 1. Can you give us a range of the number of wells that might be needed to carry out the assessment that is envisioned in this legislation?

Answer. The wells you note here are for production wells, which are larger and more expensive than what is required for exploration and assessment. Expenses for wells drilled for assessment vary depending on depth and difficulties encountered, but are typically $100,000 to $500,000. The USGS assessment study referenced in the bill will likely not have the financial resources to drill many, if any, wells. Primarily, they will be assembling data gathered over the years into Geographic Information System databases (not available during the last assessment), and running more modern models to conduct the nationwide assessment. The data to be acquired will come from previously drilled wells, wells drilled recently by DOE and industry, geologic mapping, geochemical, geophysical and remote sensing studies. The results will likely be regional in nature.

Question 2. I also noted in your statement that you said, "It (geothermal) is not subject to price volatility as are oil and natural gas, and it boosts energy security because it is a domestic energy supply." Are you assuming that geothermal will not see price volatility because we have a lot of it and it will be available to everyone?

Answer. I made the statement mostly because the same water is reused over and over. Other fuels such as coal and natural gas are consumed and continually purchased to operate power plants, and those fuels are subject to price fluctuations as we have repeatedly seen. Essentially, the "fuel" used in geothermal power plants is recirculating hot water which is produced at negligible cost (the cost of pumping the water). Geothermal power plants do not have a continuing need to purchase their fuels as do other types of power plants (oil, gas, coal, nuclear), and also have lower environmental costs (e.g., costs of nuclear disposal are large).

Question 3. To follow up on my last question, didn't the public believe that about nuclear energy back in the 1950s and 1960s, and didn't they also believe the same thing about oil until the 1970s? In short, wouldn't this resource be subject to the same unknown market variables as other energy sources?

Answer. There may be other market variables that come into play such as transmission issues (which will impact other power sources also), but the most expensive part of a geothermal power plant is expended in the beginning during drilling of expensive wells and power plant construction. Operation and maintenance are considerably smaller portions of geothermal energy costs than for other power plants, due to minimal fuel costs. In contrast, other sources of energy (coal, natural gas) have a more modest up-front cost, but continuing costs for their fuels, whose prices fluctuate.

RESPONSES OF LISA SHEVENELL TO QUESTIONS FROM SENATOR SALAZAR

Question 1. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. Ideally, we should be unified in a goal to produce renewable energy nationwide, utilizing the types of renewables that make most sense. Obviously we aren't going to be producing energy via wave action in Nevada, but we in the midcontinent should support research to do so on the coasts. Similarly, geothermal likely won't be economical outside the west for the foreseeable future, but nonetheless remains a very important power source for our country. One of the reasons you have heard so much about EGS (Enhanced Geothermal Systems) is that it has been promoted as a power source that could be used in the entire country. There is indeed a tremendous resource throughout the planet, but realistically, it won't be economical to create a reservoir in places such as New Hampshire, for instance, any time in the foreseeable future due to the deep drilling depths needed and the prohibitive associated costs. The best way to advance EGS technology is through targets of opportunity as we develop conventional systems, have needs to enhance reservoir performance or stimulate entirely unproductive wells drilled in conventional geothermal projects (as is being done at Desert Peak, Nevada), and work with existing deep oil and gas wells. If we are really serious about getting renewable energy online quickly, we must focus on the known and as yet undiscovered (and newly discovered) geothermal resources in the west in the short term and expand from there. EGS applications in the eastern U.S. will follow a natural progression as the industry evolves and development of the western resources becomes more prevalent than is currently the case.

I believe the best way to promote alternate energy of all types to the states is to indicate that all sources of renewable energy are to be developed where they are available and most economical. We should pursue all forms of domestic energy where they make sense. For instance, solar in the northeast is probably not the best place to deploy that technology at this time, but we should still invest in improving the technology as it may be a contributor in the future even in areas with less sunlight than where the technology is currently deployed.

Question 2. What percent of our country's electricity supply do you estimate could come from geothermal sources? What percent of our country's heating and cooling needs could come from geothermal resources?

Answer. If we are very aggressive in the next 10 years, we could meet the 20% goal noted in the bill if we are including all sources of geothermal including ground source heat pumps, which could substantially offset the use of other energy sources. Attaining the goal strictly through electrical power production would be difficult without a massive mobilization and effort. But ground source heat pumps can be used throughout the entire country so the 20% goal is attainable, and there should be support nationwide for this effort. We have the geothermal resources to attain ambitious goals and our understanding of the systems is growing as we do research and gain experience developing the systems. Major limitations we may face are in the arena of policy, will, and degree of investment that materializes, all of which are difficult to predict. Lack of will is one issue we have faced in Nevada where a satellite campus of UNR sits on a geothermal resource, but does not utilize it because, in the short-term, it is less expensive to buy power than to invest in pipelines to carry the geothermal fluids. It is a shame, but remains reality at this time despite geothermal energy's potential to reduce dependence on other sources of power, which by itself is just as important as actual power production using geothermal. Direct uses of geothermal simply need to be accelerated. Heat pumps can be used practically everywhere in the country for heating and cooling needs. If the investment were made to deploy them through aggressive cost-shared programs we could eventually heat and cool much the nation (http://geoheat.oit.edu/ghp). Realizing geothermal's contribution to the nation's energy needs is a matter of will and investment, not resource availability.

RESPONSES OF DAVID R. WUNSCH TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Would a cooperative international technology exchange program accelerate the geothermal research, development, and demonstration?

Answer. I believe that an international scientific and technological exchange would be an appropriate mechanism to expand and enhance the U.S. Geothermal program. Several countries, notably Iceland and Australia, utilize geothermal resources in a much more diversified manner than the U.S. For example, Iceland not only uses hydrothermal resources for electric power generation, but they also maximize the use of thermal waters in many direct heat applications for business, public buildings and households. Demonstration and exposure to these systems by U.S. scientists, engineers, and business leaders could lead to a new paradigm for geothermal energy applications here. In addition, Iceland employs several innovative business models to encourage geothermal energy exploration and use. In Australia, they are actively pursuing the development of hot dry rock (HDR) engineered geothermal systems, and scientific exchange and first-hand experience with their R&D efforts would assist U.S. geothermal development efforts. In addition, the U.S. scientific workforce has not developed to a level that can participate and expand geothermal operations on a widespread, commercial scale; so an academic exchange would benefit U.S. interests as well.

Question 2. Who would the key international participants be?

Answer. As stated above, two leaders in geothermal research, development, and use are Iceland and Australia. Other countries that have shown interest in geothermal resource development are Japan, Switzerland, Sweden, and Germany.

Question 3. You represent both the state of New Hampshire, as well as the Association of American State Geologists. Your testimony asserts that there are geothermal technologies, such as the geoexchange system, that can be installed anywhere. The reality is that they are much underutilized. Why are such energy efficient technologies not being deployed more universally throughout our country?

Answer. Geothermal heat pumps—also known as ground source heat pumps or by trade names such as Geoexchange—work by concentrating the naturally existing heat stored in the ground. I believe that this technology is underutilized because of a lack of understanding as to how the systems work, and a lack of education about their other advantages. Many people do not equate the constant temperature of the earth at shallow depths as a form of "geothermal" energy, but instead equate geothermal with hot, boiling water. They are also not aware that geothermal systems are efficient, dependable, and can be used in most regions of the United States. Many energy companies, non-governmental organizations, and federal agencies such as the EPA are actively trying to promote the use of geothermal heat-pump systems because they are efficient, reliable, and a "green" technology.

Secondly, most current system designs are most suited for new homes and buildings because or design specifications, and are more difficult to retrofit into older homes that have more traditional heating systems. For example, the heated water that is generated by a geoexchange system is typically 10 degrees (Fahrenheit) or more lower than the water temperature that can be generated from a traditional gas or oil-fueled boiler system. Accordingly, the heat exchanger, such as baseboard heating coils, has to be larger to transmit an equivalent amount of heat compared to a traditional system. Thus, it would require major renovations (and concomitant costs) to retrofit older homes with the appropriate piping, heat exchangers, and ductwork for a new geothermal system, and this is not easily affordable for the average homeowner. Typically, geoexchange systems are integrated into the design of new homes or buildings so these accommodations to the heating and cooling infrastructure can be met. The initial installation of geothermal heat pumps may be as much as double that of conventional home heating and cooling systems, but the investment is returned within 3-10 years through drastic savings in heating and cooling bills. However, often a backup heating system is suggested to supplement heat pumps in the areas of the country that experience cold or severe winters. Perhaps tax incentives could be provided for owners of older homes to expand the use of this technology, and improve the return on the investment. Moreover, research and development of innovative ways to retrofit older buildings could promote the expanded use of geothermal systems.

RESPONSES OF DAVID R. WUNSCH TO QUESTIONS FROM SENATOR SALAZAR

Question 1. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. The national geothermal assessment being proposed in S.1543 would go a long way towards determining what areas of the United States might be appropriate for developing primary or engineered geothermal energy systems. As correctly noted, most of the nation's hydrothermal resources are located in western states, with additional resources in Hawaii and Alaska. However, several preliminary assessment tools suggest that areas of the country east of the Mississippi River may also hold potential for development if engineered systems such as binary Hot Dry Rock (HDR) can be developed and made operational. For example, heat-flow maps produced by Southern Methodist University show areas of the Atlantic Coastal Plain, northern Appalachian Plateau, and New England as having temperatures in excess of 100 degrees Celsius at depths of approximately 4 Km. However, more accurate temperature estimates, and the refinement of the geographic and geologic extent of areas of high heat flow could be identified through a new assessment using more recent and robust geophysical tools and technologies. It is very important that this assessment data be collected and synthesized in order to assist private industry with exploration, and subsequent investment in developing these resources in areas not traditionally recognized as hosting geothermal reservoirs. In addition, while other forms of renewable energy, such as wind and solar can contribute to the total energy portfolios of many states, they often cannot be counted on as continuous energy sources because they are directly influenced by changing weather conditions and daylight. Geothermal energy can be utilized 24 hours a day and for many years until the heat capacities or heat exchange capabilities of the reservoir are diminished. Hydroelectricity is also a viable form of renewable energy in the eastern US, and in many cases it was the primary power source for the industrialization of much of this region.

However, the amount of dams used for hydroelectric energy production have actually decreased over the last several decades, and environmental concerns related to fish habitat and maintaining in-stream flows have diminished the interest in hydroelectric development. Geothermal energy plants generally have a small footprint, do not produce green house gases, and can be relied upon for extended periods of time. Educating the public on the benefits of utilizing geothermal energy would be one of the best ways to promote it in regions not familiar with its use or accessibility.

Question 2. What percent of our country's electricity supply do you estimate could come from geothermal sources? What percent of our country's heating and cooling needs could come from geothermal resources?

Answer. S.1543 would set a goal of achieving 20 percent of total electrical production from geothermal resources by 2030. As I stated in my previous testimony, this may be an ambitious goal, especially if this number refers strictly to electrical energy production, and does not consider improvements to efficiency from other geothermal applications. For comparisons, Australia has a smaller population than the US, and is farther along in the development of HDR geothermal systems, but they have limited their geothermal power expectations to less than 10% of its base load power needs by 2030. The Office of Technology Assessment at the German Parliament estimates that theoretically 25% of gross electricity generation could come from geothermal, although 2 percent may be more reasonable within their current grid. From the US perspective, the 20 percent goal may be attainable if energy savings from the use of efficient geothermal systems, such as geothermal heat pumps and direct use, were counted. For example, the extreme efficiency of geothermal heat pump systems means that their owners see between 25-50% savings (30 to 70% in heating mode, 20 to 50% in cooling mode) on their heating and cooling costs. Although the systems have a higher installation cost, the energy savings combined with low maintenance costs often re-pay the initial investment within 3 to 10 years. Geothermal heat pumps are also safer than conventional combustion heating systems, with no risk of gas leaks, fires, or carbon monoxide poisoning. Maintenance is also less expensive with geothermal heating and cooling systems. An EPA study concluded that geothermal heating systems have the lowest life-cycle costs of all systems available today in addition to lowest impact on the environment, and highest customer satisfaction ratings. A heat pump heating and cooling system also adds to the market value of a home. There are also more and more innovative ways being developed to use geothermal heat. For example, large office buildings in Toronto, Canada, are utilizing the geothermal heat potential in waters of the Great Lakes by capturing the cold, constant-temperature water from deep areas of adjacent Lake Erie and circulating the water to air-condition buildings in the downtown area.

It is difficult to predict what percent of the nation's heating and cooling needs could be met from geothermal sources, but it is certainly much greater than we are currently utilizing now. It might also require a national effort equivalent to the "space race" program to conduct the research and development, and implementation of the technologies required to reach the goal of 20 percent of our energy needs by 2030. However, this would be goal well worth striving for, and would benefit our science, engineering, and industrial sectors while boosting our economy, and providing energy stability and national security as well.

RESPONSES OF KENNETH H. WILLIAMSON TO QUESTIONS FROM SENATOR BINGAMAN

Please note that my experience is in the exploration and development of high enthalpy geothermal resources and I do not have expert knowledge of climate change science, the electricity industry, geothermal leasing, permitting or tax policy, but I have tried to address the questions to the best of my ability. The answers represent my personal opinion and not that of any company or industry group.

Question 1. Would a cooperative international technology exchange program accelerate the geothermal research, development, and demonstration?

Answer. The technology for developing conventional geothermal resources is already being shared in such forums as the Geothermal Resources Council Annual Meeting[1], the Stanford Geothermal Workshop[2], and the World Geothermal Congress (International Geothermal Association)[3]. Technical cooperation by a group of countries and companies is currently coordinated by the International Energy Agency[4]. I recommend that these institutions be strengthened where necessary.

Large scale development of geothermal energy in the US will not come from conventional sources, but could be developed from Enhanced Geothermal Systems (EGS), if the technology can be proven to be commercial.

The potential that Enhanced Geothermal Systems (EGS) offer as a contributor to base-load electric power generation free of greenhouse gases, is so large, and so widespread, that it would benefit greatly from international cooperation. A key country in the greenhouse gas reduction effort that could benefit from strong engagement in EGS technology exchange is India. The first step, however, is to prove that EGS can be developed commercially.

I estimate that more than half a billion dollars were spent in the past 30 years on EGS experiments by governments in the US, UK, Japan, EU, without demonstrating commercial viability. Recent experiments by private industry in Australia look promising. I favor EGS drilling being done by private industry, supported by basic research in selected areas performed by government agencies.

Question 2. Who would the key international participants be?

Iceland, New Zealand, the Philippines and Indonesia are currently most active in conventional geothermal development. Australia[5] and the European Union (particularly Germany)[6] are leading in the attempts to develop EGS, through private companies in Australia and both private companies and government agencies in the EU.

There is a compelling need to help India find an alternative to coal for power generation, and India is reported[7] to have considerable potential for EGS. I recommend that the key international participants for the development of EGS be United States, Australia, European Union and India.

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[1] http://www.geothermal.org/
[2] http://pangea.stanford.edu/ERE/research/geoth/conference/workshop.html
[3] http://iga.igg.cnr.it/index.php
[4] http://www.iea-gia.org/
[5] http://www.pir.sa.gov.au/geothermal/ageg
[6] http://engine.brgm.fr/
[7] Chandrasekhar, V (2007) Enhanced Geothermal Resources: Indian Scenario. Geothermal Resources Council Transactions 31, pp 271—273.

Question 3. It is mentioned in your testimony that an annual growth rate of 18% geothermal energy will be needed to meet the goal that is stated in the bill. Is this reasonable? Can the goal actually be met?

Answer. S.1543 states that "it shall be a national goal to achieve 20 percent of total electrical energy production in the United States from geothermal resources by not later than 2030", and by my calculations this will require 130 GWe of geothermal capacity to reach 20% of EIA projected electricity demand by 2030. This is more aggressive than the findings of a report issued by MIT in 2006[8], which found that "EGS could provide 100 GWe or more of cost competitive generating capacity in the next 50 years".

The large scale development of EGS geothermal energy will require technical breakthroughs. The most optimistic scenario in my opinion is that technical breakthroughs will occur within the next year or so in Australia, and that legislation in the US (for example Renewable Portfolio Standards, or California Assembly Bill 32) combined with government incentives for early movers will motivate the private sector to begin exploitation of EGS in the US.

What goal is reasonable? I believe the goal should be set with two factors in mind—the urgent need to reduce greenhouse gases (GHG), and the cost of alternative sources of electricity that are low in GHG emissions. The limits on production of EGS will not be constrained by the availability of heat in the earth, but rather by its ability to compete in the marketplace with other sources of GHG-free energy.

Providing the marketplace for electric power is regulated to give priority to GHG-free, baseload sources, I favor a goal of 10 percent of total electrical energy production in the US from geothermal resources by 2030. This is more aggressive than the growth recommended in the MIT report[8], because I assume that EGS will have favorable pricing over coal and gas because of efforts by regulators to reduce greenhouse gases, and over wind and solar because of the electric utilities need to develop baseload power sources to replace coal.

Question 4. You also state that greater than $400 billion dollars of capital investment will be needed to expand the geothermal industry. Will the private sector be able to meet the investment requirements?

Answer. I do not foresee that the availability of capital will be a constraint providing the electric power market is regulated in a way that restricts GHG emissions, and providing that EGS is 1)shown to be technically feasible 2)competes economically with other baseload low-GHG sources and 3)is not subject to unpredictable delays due to e.g. permitting requirements.

Question 5. What types of incentives do you propose that could help the private sector accelerate new geothermal exploration and development projects?

Answer. I propose incentives that pay a premium for electric power generated by EGS from specified geological environments, for a limited time period and up to a limited capacity. The purpose of the incentives must be to motivate capable companies to take the early technology risk, in a way that leads to subsequent large scale development of EGS power at (GHG-regulated) market rates, if they are successful in overcoming technology risk and reducing development cost.

Profits during the early project years have a large influence on net present value, so providing the potential for greater profits for e.g. 5 years will motivate firms to take greater risk, improve EGS technology at a faster pace, and thereby accelerate the geothermal growth rate.

Question 6. In your many years of experience working in the geothermal industry, what were the largest challenges that you faced regarding geothermal exploration and development? Are those challenges addressed in this bill?

Answer. I experienced the following challenges during my career:

1) Over-development in the Geysers Field because of unregulated expansion by multiple operators tapping the same reservoir of steam.

2) Development of a promising geothermal project, Medicine Lake[9] in California, delayed for years due initially to low power market prices, and later to a District Court challenge[10] to the BLM permit.

3) Contract terms not upheld by governments in large geothermal projects in SE Asia, drastically reducing investment in the sector for many years.

[8] Tester, J., Anderson, B., Batchelor, A., Blackwell, D., DiPippo, R., Drake, E., et al. (2006). The Future of Geothermal Energy. Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century. Massachusetts Institute of Technology.

[9] http://www.blm.gov/ca/alturas/medicinelake.html

[10] http://www.sacredland.org/PDFs/pit—river—decision.pdf

The Bill does not address the need to expeditiously address permit delays and resolve legal challenges to projects on government land. The issue of geothermal fields with multiple operators can be solved in the future by unitization.

RESPONSES OF KENNETH H. WILLIAMSON TO QUESTIONS FROM SENATOR DOMENICI

Dr. Williamson, in your testimony you concluded that "the goal to generate 20 percent of our electricity from geothermal resources by 2030 is very aggressive relative to our previous experience."

Question 1. In your opinion, what would be a more realistic goal?

Answer. Providing the marketplace for electric power is regulated to give priority to GHG-free, baseload sources, I favor a goal of 10 percent of total electrical energy production in the US from geothermal resources by 2030. This is still aggressive relative to our previous experience, but is needed to address the issue of greenhouse gas reduction.

Question 2. In your testimony you indicated that it "will take hundreds of billions of dollars of capital, tens of thousands of geothermal wells, and millions of acres of land."

Answer. My calculations assume that most of the power is generated by EGS, which is likely to cost $3,000-$4,500/kW to install, unless technical breakthroughs increase well productivity beyond current expectations. 20% of the EIA projection for 2030 is 130 GW so capital cost would be approximately $400-600 billion.

Question 3. How much of that "billions of dollars of capital" do you believe the federal government should help with?

Answer. I believe that the government should motivate private industry to overcome the technical challenges to EGS development, by providing incentives in the early years of development to the first four companies to move in the sector. For example, providing 5 cents/kWh above market rates to the first four developers achieving 50 MW for five years of production would cost about $400 million. The federal government should also determine an appropriate cost for greenhouse gas emissions in electricity generation, and implement regulations to reflect that cost in the electricity market.

Question 4. How many wells do you think will be needed? Are you talking about something in the hundreds, or something closer to many thousands?

Answer. I believe that it is more likely to achieve the goal of an EGS technology breakthrough by motivating industry with higher power prices than cost-shared drilling. In my suggestion above, 200 MW would likely require roughly 30—60 wells.

To achieve the S.1543 20% (130 GW) goal by 2030 will require the drilling of 20,000 to 40,000 wells.

Question 5. I am most interested in your comment about "millions of acres of land."

Answer. I estimate that between 1 and 3 million acres of land will be needed to achieve the 20% goal of S.1543, by assuming a reasonable range of well productivity and using well spacing similar to that used in EGS experiments in the EU.

Question 6. Dr. Williamson, as I look at the maps that show where the "best" areas for development are, I see the current land owner is the federal government. I also know that many of those lands are within reserves that would preclude drilling and surface development and, in many instances, the development of the transmission lines needed to get the electricity to market.

Answer. There are many areas of high geothermal potential that are off-limits to developers. Ultimately the government will have to find a balance that addresses the need to reduce greenhouse gas emissions and improve energy security, while allowing reasonable protection of environmentally-sensitive public lands.

Question 7. Can you expand upon your comment about needing "millions of acres of land" and how we should view the need to provide sufficiency language to allow the rapid development of this resource?

Answer. Rapid development will require that adequate resources are available to the BLM and Forest Service to issue leases, expedite environmental assessments and environmental impact statements and deal with legal challenges to permits.

RESPONSES OF KENNETH H. WILLIAMSON TO QUESTIONS FROM SENATOR SALAZAR

Question 1. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. I believe the compelling argument to all citizens in the US should be the need to reduce greenhouse gases. Geothermal energy provides baseload power, and

EGS has the potential to supply a significant fraction of the nation's energy, reducing the reliance on CO_2-producing coal generation.

Geothermal Heat Pumps are an excellent way to reduce space heating and cooling costs, and are applicable country-wide.

If EGS technology can be proven, I anticipate that over time, through a process of technology development and process improvement, the cost of EGS will be reduced and EGS will become viable in regions of low to moderate geothermal gradient and therefore be applicable throughout the United States. This will be true providing the marketplace for electric power is regulated to give priority to GHG-free, baseload power sources.

Question 2. What percent of our country's electricity supply do you estimate could come from geothermal sources? What percent of our country's heating and cooling needs could come from geothermal resources?

Answer. Providing the marketplace for electric power is regulated to give priority to GHG-free, baseload sources, I favor a goal of 10 percent of total electrical energy production in the US from geothermal resources by 2030. This is still aggressive relative to our previous experience, but is I believe it is needed to address the issue of greenhouse gas reduction.

I do not have sufficient knowledge of the direct use of geothermal heat and geothermal heat pumps, or the US market for heating and cooling, to provide a quantitative estimate on the percent heating or cooling geothermal resources could provide. Direct use of heat from geothermal resources is a more efficient use of the energy than electricity generation, since the conversion of geothermal heat to electricity typically has an efficiency of 20% or less, depending on the resource temperature.

Responses of Alexander Karsner to Questions From Senator Bingaman

Question 1. Is it correct that Enhanced Geothermal Systems (EGS) did not factor into the Administration's reason(s) for eliminating the geothermal program?

Answer. The existing Geothermal Technology Program focused on conventional geothermal and the decision to terminate was based on the assessment that it was a mature technology, and that favorable policy changes have resulted in the growth of the industry, independent of a federally funded R&D program.

Question 2. Upon completion of the validation of the MIT study—is the Administration prepared to revitalize the DOE geothermal R&D program to explore the development of EGS?

Answer. The Department is carefully reviewing the MIT report and is conducting a technology evaluation of EGS technologies by assembling groups of industry, university, and national laboratory experts, along with other stakeholders, at workshops around the country. Three of those workshops have been held thus far. DOE plans to have a final report of findings by the end of this calendar year.

Responses of Alexander Karsner to Questions From Senator Domenici

Gentlemen, Dr. Williamson spoke of this legislation requiring millions of acres of land. As I look at the maps that show the "best" areas for development, I see the current land owner is the federal government. I also know that many of those lands are within reserves that would preclude drilling and surface development and, in many instances, the development of the transmission lines needed to get the electricity to market.

Question 1. Can you comment on Dr. Williamson's statement about needing millions of acres of land and tell me your views on the desirability and feasibility of doing this?

Answer. The Department of Energy defers to the Department of Interior as the appropriate entity to answer this question.

Question 2. Are we likely going to need to provide sufficiency language to allow the rapid development of this resource on federal lands to meet the stated goal of this bill?

Answer. The Department of Energy defers to the Department of Interior as the appropriate entity to fully answer this question.

Question 3. Do you believe this country can meet the goal of getting 20% of our electricity from geothermal by 2030?

Answer. This goal's attainment is improbable. The Department has significant concerns with the feasibility of the goal of generating 20 percent of our nation's electricity from geothermal resources by 2030, and has yet to see anything put forward that supports the assertion.

Question 4. How difficult will that be to accomplish?

Answer. Generating 20 percent of our nation's electricity from geothermal resources would require more than 165,000 megawatts of geothermal power plant capacity by 2030. The last time that the federal government performed a resource assessment was 1978, finding that 23,000 megawatts of identified conventional geothermal resources can be developed for electricity. The difference of more than 142,000 megawatts would have to come from new discoveries, conventional resources that were not viable at the time of the 1978 assessment, and unconventional means. None of the unconventional resources are presently used to generate commercial power. Given technological and resource constraints, the particular goal of this legislation is unlikely to be attainable within the timeframe specified.

Question 5. Do you believe that geothermal will compete economically with the available alternatives, or would we need to provide incentives or mandates to force its use?

Answer. Presently, conventional geothermal-generated electricity is cost competitive in the regions of the country where the resource can be most effectively utilized. Incentives to encourage the production of geothermal energy are included both in the Energy Policy Act of 2005 (EPACT 2005) and in the Tax Relief and Health Care Act of 2006.

EPACT 2005 provisions directed USGS to update its 1978 geothermal resource assessment by September 2008, and instructed the Bureau of Land Management and the U.S. Forest Service to develop a Programmatic Environmental Impact Statement for the major geothermal areas in the Western United States.

The Tax Relief and Health Care Act of 2006 extended the production tax credit for geothermal and other renewables that are put into service through December 31, 2008. This provision has had a significant impact on encouraging new installations of conventional geothermal power facilities.

Question 6. What is it going to take to complete the called-for assessment in terms of costs, time, and new technology?

Answer. The Department of Energy defers to the Department of Interior as the appropriate Agency to answer this question.

RESPONSES OF ALEXANDER KARSNER TO QUESTIONS FROM SENATOR SALAZAR

Question 1. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii. What is the best way to promote geothermal energy to States that may be more familiar with, and have better access to, other forms of renewable energy?

Answer. Possible methods of geothermal energy promotion include breaking down institutional barriers to decrease transactional costs, making decision makers aware of geothermal benefits, addressing policy constraints of land use plans, and addressing environmental problems, both real and perceived.

Question 2(a). What percent of our country's electricity supply do you estimate could come from geothermal sources?

Answer. Currently, the U.S. has approximately 2,850 megawatts electric (MWe) of installed capacity and about 2,900 MWe of new geothermal power plants under development in 74 projects in the Western U.S., according to industry estimates. In 2006, EIA estimates that geothermal energy generated approximately 14,842 gigawatt-hours (GWh) of electricity. The geothermal industry presently accounts for approximately 5% of renewable energy-based electricity consumption in the U.S.

Regarding near-term growth possibilities, the Western Governors Association geothermal task force recently identified over 140 sites with an estimated 13,000 MWe of power with development potential.

According to an EIA renewable trend 2005 report,[1] "Although geothermal capacity increased by only 130 MW during 2005, there are proposals to greatly expand the geothermal resource base to be exploited. These proposals are based on a recent study commissioned by the U.S. Department of Energy, in which scientists at the Massachusetts Institute of Technology concluded that the U.S. has 100,000 MW of 'enhanced geothermal capacity' which it could develop by 2050." The Enhanced Geothermal Systems (EGS) technology that MIT references in its report requires further study. To further explore this and other aspects of the MIT study, DOE is holding discussions with industry and academic experts, further defining technical barriers and gaps, and determining the technical and commercial actions that can help industry address the challenges of EGS.

Question 2(b). What percent of our country's heating and cooling needs could come from geothermal resources?

[1] Renewable Trends. 2005 edition http://www.eia.doe.govkneafisolar.renewables/page/trends/rentrends.html

Answer. In the U.S., more than 120 operations, with hundreds of individual systems at some sites, are using geothermal energy for district and space heating. In addition, geothermal heat pump installations have exceeded one million, according to the Geothermal Heat Pump Consortium. Although this is a very small percentage of the total HVAC market, the number of people who are choosing to install geothermal heat pumps is growing rapidly (about 20% every year) as more learn about the technology. According to EIA (Table 17, Renewable Energy Consumption by Sector and Source (quadrillion Btu, unless otherwise noted)) geothermal could meet approximately 2.1% by 2030.

RESPONSES OF ALEXANDER KARSNER TO QUESTIONS FROM SENATOR REID

The Energy Policy Act provides specific directives for DOE's renewable energy research efforts. In general, the overall approach is spelled out in Section 931, which states:

> (a)(1) OBJECTIVES.—The Secretary shall conduct programs of renewable energy research, development, demonstration, and commercial application, including activities described in this subtitle. Such programs shall take into consideration the following objectives:
>
> (A) Increasing the conversion efficiency of all forms of renewable energy through improved technologies.
> (B) Decreasing the cost of renewable energy generation and delivery.
> (C) Promoting the diversity of the energy supply.
> (D) Decreasing the dependence of the United States on foreign energy supplies.
> (E) Improving United States energy security.
> (F) Decreasing the environmental impact of energy-related activities.
> (G) Increasing the export of renewable generation equipment from the United States.

Subsection (c) of this section of EPAct specifically provides direction for geothermal energy research. It states:

> GEOTHERMAL.—The Secretary shall conduct a program of research, development, demonstration, and commercial application for geothermal energy. The program shall focus on developing improved technologies for reducing the costs of geothermal energy installations, including technologies for——
>
> (i) improving detection of geothermal resources;
> (ii) decreasing drilling costs;
> (iii) decreasing maintenance costs through improved materials;
> (iv) increasing the potential for other revenue sources, such as mineral production; and
> (v) increasing the understanding of reservoir life cycle and management.

Question 1. Please respond for the FY07 spending/operating plan and the FY08 budget request—How do the Department's decisions in each of those documents with respect to the geothermal energy research and development program comport with the statutory direction provided by Congress in section 931 of PL109-58?

Answer. The FY 2007 operating plan supports diversification of the energy supply, independence from foreign energy supplies, and national energy security. The FY 2007 operating plan for the Department included $5 million to support geothermal power co-produced with oil and gas demonstration efforts, for an evaluation of enhanced geothermal systems to help industry prioritize its technology needs, and to bring to completion selected projects on exploration, drilling, and/or conversion technologies.

The FY 2008 budget request recognizes that the Geothermal Technology Program's mission and activities were successful and directly support DOE's mission to promote scientific and technological innovation in support of advancing the national, economic and energy security of the United States. Industry application of technology and resources developed to date will continue to benefit the nation.

As noted above, The Energy Policy Act of 2005 (EPACT 2005) sets objectives for effective promotion of renewable energy in general, in addition to authorizing energy research in specific areas such as geothermal. Current Department priorities are focused on technology development with broadly applicable and more readily accelerated public benefits, consistent with the statutory direction of EPACT 2005.

The Administration's repeated efforts to close down and defend the geothermal research program also appears to contradict the recommendations of the last external review of the Department of Energy's renewable programs, the 2000 report of the

National Research Council entitled Renewable Power Pathways. That National Research Council's examination of the geothermal program states in clear terms the importance of the program, and the recommendation that it continue to be funded: "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."

Question 2(a). Does the Department agree with the National Research Council that the US geothermal resource base holds significant potential to contribute to national energy needs?

Answer. The Department agrees that the U.S. geothermal resource base is large, and can contribute to diversification of our national energy portfolio, primarily through increased private sector development.

One of the challenges our nation faces is meeting the growing demand for electric power, particularly in the West. The Western Governors Association has estimated that over 60,000MW of new electric power generation will be needed to meet growing demand in the next decade. How we meet these needs will have profound consequences for the West and the Nation.

The Department's Geothermal Program Strategic Plan stresses these values of geothermal energy. It states:

> The Earth houses a vast energy supply in the form of geothermal resources. These resources are equivalent to 30,000-years of energy for the United States at current rates of consumption. However, only about 2,600 MWe of geothermal power is installed today. Geothermal has not reached its full potential as a clean, secure energy alternative because of concerns or issues with resources, technology, commitment by industry, and public policies. These concerns affect the economic competitiveness of geothermal energy.
>
> The U.S. Department of Energy's Geothermal Technologies Program seeks to make geothermal energy the Nation's environmentally preferred baseload energy alternative. The Program's mission is to work in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the Nation's energy supply.

But, the geothermal strategic plan indicated that the program could not reach its goals until at least 2040 because of its limited funding. It also says, "Doubling the Program's budget" would accelerate achieving the program goals and they could "be attained by 2020, resulting in an overall budget savings of $100 million."

The Geothermal Task Force of the Western Governors Association, a part of the WGA's Clean and Diversified Initiative, has reviewed geothermal resources of the West. The Task Force identified sites where power production could occur in the next fifteen years, a capacity of some 13,000MW. However, the Task Force reported that only 1/3 of these sites could produce power at commercial prices using today's technology, assuming continued federal and state tax support. The Task Force recommended that "geothermal research by the US Department of Energy should be increased, particularly into technologies that can reduce risk, reduce costs, or expand the accessible resource base."

Question 2(b). What actions did the Department take to implement the recommendations made by the National Research Council in 2000?

Answer. Since 2000, the Department has taken actions to implement all ten recommendations made by the National Research Council, which relate to more than just geothermal. These actions include new or expanded research initiatives, technology demonstration projects, increased collaboration with other agencies, and improved international cooperation. Specifically in terms of geothermal, the National Research Council recommended that the Department should reinstate its resource assessments of geothermal energy at the U.S. Geological Survey. Subsequently, the Department provided both financial and technical support to the U. S. Geological Survey for its national resource assessment. The National Research Council also recommended that the Department should increase its collaboration with European countries and Japan on advanced technologies to provide cost-leveraged field testing and enabling reservoir technologies. The Department continues to share information on advanced technologies with European researchers through the International Energy Agency's Implementing Agreement on Geothermal Energy. The Japanese geothermal research program has ended. The National Research Council also recommended that the Department reactivate its programs for the development of advanced concepts for the long term, with its first priority on high-grade enhanced geothermal systems (EGS). The Department is analyzing a recent MIT report on EGS.

Question 2(c). Has the Department had further communications with the NRC about its assessment and any follow-up by the Department? Please provide any documents supporting these actions and communications.

Answer. The Department recently engaged with the National Research Council to support the NRC's new initiative, "America's Energy Future: Electricity from Renewables: Technology Opportunities, Risks, and Tradeoffs."

Question 3(a). Does the Department agree with the Western Governors assessment that at least 60,000 MW or more new power capacity will be needed in the next decade?

Answer. Energy Information Administration (EIA) baseline demand projections indicate that approximately 40,000 MW of new capacity will be needed in the western states by 2017 (Annual Energy Outlook 2007, Supplemental Tables, Electric Generation & Renewable Resource).

Question 3(b). How much of this will be baseload power?

Answer. According to EIA, of the 40,000 MW of new capacity needed, approximately 31,000 MW will need to be provided by base load technologies.

Question 3(c). What technologies and sources does the Department expect to provide new baseload power to the Western United States by 2015, 2025? And how much?

Answer. New capacity additions in the Western United States are projected to come from coal steam (approximately 12,700 MW in 2015 and 48,500 MW in 2025), combined cycle technologies (10,000 MW in 2015 and 11,500 MW in 2025), combustion turbine/diesel technologies (4,600 MW in 2015 and 9,900 MW in 2025), and renewable (7,900 MW in 2015 and 9,100 MW in 2025).[1]

Question 3(d). For the technologies that DOE expects will be meeting this new power demand, what is the projected cumulative DOE research and development expenditure that would be necessary to ensure these technologies are ready in 2015? 2025?

Answer. Research and development of conventional, hydrothermal geothermal energy is not required to achieve the projected results. Conventional, hydrothermal geothermal energy would benefit from a policy directed at commercialization, as in EPACT 2005.

Question 3(e). Does the Department agree with the WGA's Task Force on the estimates of the resource base and its cost of development?

Answer. DOE agrees with the WGA near-term estimate of developable geothermal resources at about 13,000 MW. These are hydrothermal sites that would produce base load power.

Question 3(f). What are the Department's views on the WGA's Task Force recommendations?

Answer. The Western Governors Association geothermal task force identified over 100 sites with an estimated 13,000 MWe of power with near-term development potential. DOE believes that the goal can be attained by industry alone with the production tax credit and streamlined leasing and permitting.

Question 3(g). Does the Department expect geothermal energy technology to advance at the same rate absent DOE support? Please provide evidence to support the response to this question.

Answer. The highest priority of the geothermal industry has been the attainment of the production tax credit, which the Energy Policy Act of 2005 provided. In addition, the Energy Policy Act streamlined geothermal leasing and changed the royalty structure to provide incentives for local governments to promote geothermal development. The Energy Policy Act also mandated that the U.S. Geological Survey update the national geothermal resource assessment by FY 2008. DOE has been supporting the USGS resource assessment by contributing financially and technically. These statutory changes have spurred development of hydrothermal resources without the Department's Geothermal Research and Development Program.

The Department's 2003 Strategic plan included geothermal energy research as part of its efforts to "Improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy ..." Geothermal power was part of DOEs "long-term vision of a zero-emission future in which the nation does not rely on imported energy."

But more recently, the Department of Energy seems not to agree with this assessment. In other budget documents the Department presents another rationale for closing out this program. Basically, it sees geothermal energy as a "regional resource" with limited applicability. (see "http://www 1.eere.energy.gov/ba/pdfs/FY07—budget—brief.pdf.)

[1] Annual Energy Outlook 2007, Supplemental Tables, Electricity and Renewable Fuel Tables.

Today, geothermal resources are used in 25 states for power and direct use purposes (not including heat pumps) and advanced "EGS" technology has the potential to bring geothermal power in use across the country according to recent reports. Including geothermal heat pumps, geothermal energy is used in all 50 states.

The Department used to consider the future potential of geothermal energy to be quite significant. Today, the nation produces about 2,800 Megawatts of power from geothermal resources, and the power potential alone was estimated to be many times that amount. The DOE Geothermal Strategic Plan used to say:

> The U.S. Geological Survey estimated that already-identified hydrothermal reservoirs hotter than 150°C have a potential generating capacity of about 22,000 MWe and could produce electricity for 30 years [1]. Additional undiscovered hydrothermal systems were estimated to have a capacity of 72,000-127,000 MWe. At depths accessible with current drilling technology virtually the entire country possesses usable geothermal resources. The best areas are in the western United States where bodies of magma rise closest to the surface.

The Department's strategic plan included a very interesting map that showed the potential of heat in the earth to contribute to our energy needs. As the map showed, DOE used to view the technical potential of geothermal energy to span the entire country from Maine to California.

Question 4(a). How does DOE view the potential of geothermal resources?

Answer. The Department's investment in geothermal has contributed to the identification of those resources, accurate characterization and modeling of hydrothermal reservoirs, improved drilling techniques, and advanced means of converting the energy for productive uses. In fact, such progress has been made in geothermal technology that it is at a point where it has reached market maturity.

The Department anticipates that geothermal resources will continue to play an important and potentially growing role in our nation's energy portfolio, as we look to rapidly expand the availability of clean, secure, reliable energy. The industry currently benefits from tax incentives and regulatory streamlining in EPACT 2005, and future industry investments in enhanced geothermal have the potential to significantly expand domestic geothermal energy production.

Question 4(b). What has happened in the past three years to apparently change the Department's views of the geothermal resource base and its enormous potential?

Answer. The Department's view on the size of the geothermal resource base has not changed. Geothermal technology has reached a point where it has reached market maturity, and the focus has therefore shifted to commercialization.

Question 4(c). What geothermal resource types does the Department now consider economic: hydrothermal, hot dry rock (EGS), geopressured, co-production from oil fields, direct uses, magmatic, others?

Answer. The Department considers high—temperature, shallow hydrothermal resources for power generation and low—temperature, shallow hydrothermal resources for nonelectrical purposes as economical.

Question 4(d). The Department had indicated that there were many technological challenges to achieving production from the vast geothermal resource base. Does the Department now consider these challenges are solved, does the Department have new information that indicates its prior assessments of geothermal resources are incorrect, or has the Department concluded that federal efforts and technology development cannot overcome them?

Answer. DOE has concluded that hydrothermal technology is mature. The FY 2007 Operating Plan for the Department included funding for an evaluation of enhanced geothermal systems to help industry prioritize its technology need.

The Office of Management and Budget, in the FY07 and FY08 budgets, offered some additional rationales for proposing to terminate the geothermal research program, which the Senate has already rejected with respect to FY07 and Congress will reject with respect to both years. There appear to be three main assertions by OMB.

1) geothermal technology is "mature" and doesn't really need more R&D,
2) the change in leasing royalty structure from 50/50 to 50/25/25 will make a substantial difference, so research isn't needed,
3) the forthcoming resource assessment by USGS will solve the industry's exploration problems,
4) with new tax incentives, geothermal power does not need research support.

Question 5(a). Does the Department consider geothermal energy a resource or a technology?

Answer. Geothermal energy is a national resource.

Question 5(b). If geothermal energy is a technology, is there one technology or are there a series of technologies used to produce energy from geothermal resources?

Answer. There are multiple technologies used to produce energy from geothermal resources, such as exploration, drilling, reservoir development, and energy conversion.

Question 5(c). How did the Department determine that geothermal technology was mature?

Answer. Conventional, known, high-temperature, shallow hydrothermal resources can be developed using available drilling and reservoir technologies. Utilizing such resources to produce electricity only requires off-the-shelf power conversion technology. Since the relevant technological tools are all available in the marketplace, the technology was considered mature.

Question 5(d). Please describe the criteria used in determining whether geothermal technology is or was mature.

Answer. Geothermal technology consists of the tools to find, access, extract, and use geothermal resources. In each of these areas, conventional, off-the-shelf technology is available to produce geothermal energy in commercial quantities. With the exception of energy conversion, technology for conventional geothermal development is adaptable from the available tools used to find and exploit oil and gas and other mineral resources. Energy conversion technology has evolved competitively from experience gained around the world in producing geothermal energy. The chief criterion for maturity is availability of a suite of technologies in the marketplace at costs sufficient to allow the development of a geothermal energy project at competitive prices.

Question 5(e). What other energy technologies or resources that are researched and developed with Department funds match that criteria?

Answer. Hydropower, biodiesel, and conventional ethanol technologies have the same level of commercial availability as technology for the development of geothermal resources.

Question 5(f). Please provide to the Committee any studies or analysis the Department has done of technological maturity and a chart showing the comparable maturity of the technologies it proposes to fund and not to fund.

Answer. The FY 2007 operating plan provided funds for an evaluation of enhanced geothermal systems to help industry prioritize its technology needs.

Question 5(g). How will the leasing provisions proposed by OMB satisfy the specific objectives for DOE's research efforts with respect to geothermal energy as directed by Sections 931 (a) and (c) of EPAct 2005?

Answer. The leasing provisions were included in EPAct 2005 and were not proposed by OMB in the FY 2008 Budget. The leasing provisions can provide "market pull" incentives for industry to achieve the research objectives specified in Sec. 931 (a) (2) (C) by helping to make commercial geothermal development easier and more profitable. Streamlined leasing works along with the production tax credit, the changes to the royalty structure, and the U.S. Geological Survey's national resource assessment, to help promote commercialization of geothermal energy. U. S. geothermal industry and its service companies can be expected to learn from the increased deployment and develop improved technologies for detecting geothermal resources, decreasing drilling and maintenance costs, and managing the resource to maximize reservoir life time. These market-driven technology improvements should satisfy the need for research, development, demonstration, and commercial application for geothermal as described in Subtitle C, Sec. 931 (a) (2) (C) of the Energy Policy Act.

The Office of Management and Budget, in the FY07 and FY08 budgets, offered some additional rationales for proposing to terminate the geothermal research program, which the Senate has already rejected with respect to FY07 and Congress will reject with respect to both years. There appear to be three main assertions by OMB.

1) geothermal technology is "mature" and doesn't really need more R&D,

2) the change in leasing royalty structure from 50/50 to 50/25/25 will make a substantial difference, so research isn't needed,

3) the forthcoming resource assessment by USGS will solve the industry's exploration problems,

4) with new tax incentives, geothermal power does not need research support.

Question 5(h). How would OMB's proposed changes to geothermal leasing make continued federal research unnecessary?

Answer. As noted above, the leasing provisions were included in EPAct 2005, not as proposals in the 2008 Budget. The Department's expectation is consistent with the position of the U.S. geothermal industry, which has determined that a change in leasing policy is likely to have greater impact on the rate of deployment than federally-funded R&D. They base this on Geothermal Energy Association data in which no growth is evident despite federal research funding of approximately $25 million per year from 1990 through 2005 (as estimated by GEA).[2]

Question 5(i). Please discuss the support, to date, from DOE for the USGS resource assessment efforts and the plans, if any, for continued support by DOE for this effort? What is the status and content of the cooperative agreement drafted or finalized between DOE and USGS?

Answer. DOE and USGS signed an MOU in June 2004 for three years to accomplish the following: Document lessons learned from other assessments, develop resource assessment methodology and resource classification system, compile data collected in a database, and develop various models using regional studies. So far, DOE has invested more than 1 million dollars in financial support and also provided other technical and administrative support. DOE is also committed to extend this agreement till the end of FY2008 and provide an additional $200K in financial support. The Department has shared the data collected from its GRED program with USGS and also offered its national laboratory expertise at no cost to USGS.

Question 5(j). Does the Administration's rationale presume that the USGS national resource assessment will discover new resources or develop new exploration technology?

Answer. The USGS resource assessment will not develop new exploration technology. The purpose of the assessment is to re-evaluate the geothermal resource base using new information that has come to light since the last assessment in the late 1970s. The new assessment will provide industry with indicators of areas in which geothermal resources are likely, allowing them to focus their exploration efforts with a higher probability of success.

Question 5(k). Please provide any information to support the Administration's and the Department's assertion that tax incentives substitute for the need for federal research support.

Answer. Since the Federal Production Tax Credit has been extended to geothermal energy, over seventy geothermal plants have begun development, after a period of more than a decade when no plants were built, despite continued research and development investments. This suggests that the tax credit has played a role in promoting development.

Question 5(l). Does the Administration support making the renewable energy production tax credit permanent or extending it beyond December 31, 2009?

Answer. The Administration has not taken a formal position on the extension of the production tax credit.

[2] http://www.geo-energy.org/publications/reports/States%20Guide.pdf

APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF UTC POWER, A UNITED TECHNOLOGIES COMPANY

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. This document focuses on issues related to 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. Earlier this year, UTC Power announced an agreement with Raser Technologies of Provo, Utah to provide up to 135 PureCycle® geothermal power systems totaling approximately 30 megawatts of renewable power for three Raser power plants to be located in Nevada.

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 cost shared Department of Energy (DOE) 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 United States is to translate this potential into reality. We support the introduction of the "National Geothermal Initiative" (S 1543) as a key element of the comprehensive policy framework that is necessary to advance our nation's use of geothermal energy.

UTC Power recommends several revisions to the bill as introduced including recognition of geothermal energy's ability to provide base load power as the basis for more favorable tax treatment; and explicit reference to research needs related to advanced low temperature geothermal energy power production.

DESCRIPTION OF PURECYCLE® TECHNOLOGY

The PureCycle® system 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.

UTC Power's PureCycle® system can operate 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.

WHAT IS THE SIGNIFICANCE OF LOW TEMPERATURE GEOTHERMAL ENERGY?

Historically, 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 can 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 across the country and around the world with significant export potential. The low temperature capability also can be used to bottom higher temperature geothermal flash plants and many existing ORC binary power plants thus extracting more useful energy with no emissions. Compared to other geothermal technologies, the PureCycle® system produces electrical power at much lower pressure and utilizes non-flammable working fluids and therefore doesn't require attended operation.

In addition to traditional stand alone geothermal opportunities, there are more than 500,000 oil and gas wells in the US, many of which are unprofitable due to their high volume content of water and relatively low percent oil. The use of this co-produced 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 for both oil production and production of renewable electricity. 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

Government action is needed on a variety of fronts to fully realize the potential of our nation's significant geothermal resources. UTC Power recommends:

1. Extension of the geothermal production tax credit (PTC) and revised "placed in service" rules

While the Senate Energy and Natural Resources Committee does not have jurisdiction over this critical incentive program, UTC Power would like to take this opportunity to register its support for the longest term extension possible of the existing PTC. This important incentive is needed to support the introduction of advanced geothermal energy technologies as an essential element of market development efforts. We also believe that given the ability of geothermal energy to provide continuous, base load power and the long lead times necessary to develop projects, it should qualify for more favorable terms and conditions and the longest extension possible. UTC Power also recommends that the PTC be amended to allow facilities under construction by the placed in service date of the law to qualify.

2. Robust funding for DOE's Geothermal Research Program

There are a variety of geothermal energy research, development and demonstration needs including full optimization of the potential of low temperature geothermal energy production. We support a balanced portfolio of geothermal energy RD&D activities that simultaneously addresses near and longer term efforts. We urge that Congress authorize DOE to pursue advanced low temperature geothermal energy power production opportunities including:

—enhancing the performance of existing successful low temperature geothermal power production systems;
—improving the efficiency of geothermal resource utilization;
—assessing additional refrigerant options and evaluating their environmental, safety and operability impacts;
—developing systems that can operate at even lower temperatures than today; and
—demonstrating the benefits for other applications including the oil and gas market as well as bottoming higher temperature geothermal flash plants and existing binary power plants.

3. Comprehensive nationwide geothermal resources assessment

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. A comprehensive assessment is essential including characterization of low and moderate temperature geothermal energy resources.

4. Incentives for geothermal exploration and drilling

According to the Geothermal Energy Association, 90 percent of geothermal resources are hidden with no surface manifestations. Exploration is essential to expand production, but exploration is expensive and risky. Cost-shared support for exploration and drilling should be continued and expanded.

SPECIFIC COMMENTS ON S 1543

We applaud Senator Bingaman's leadership in introducing the "National Geothermal Initiative" (S 1543). This legislation addresses many of the pressing research, development, demonstration, education, outreach and commercial application needs related to geothermal energy. UTC Power offers the following suggestions to clarify the Congressional intent and enhance the legislation's effectiveness.

1. Geothermal Energy's Base Load Attributes Should Be Favorably Recognized in Federal Tax Policy

Sec. 2 (3) calls for modification of federal tax policies to support the longer lead times and higher risks related to geothermal energy. UTC Power also recommends adding language pointing out that geothermal energy has the added advantage among technologies defined as renewable for its ability to provide continuous power throughout the year. This "base load" attribute is an important distinguishing feature and also supports the rationale for providing more favorable tax treatment to geothermal energy projects.

2. Low Temperature Geothermal Energy Resources Should Be Explicitly Addressed in National Resource Characterization

Sec 5 (c)(1) calls for the Departments of Energy and Interior to "characterize the complete geothermal resource base (including engineered geothermal systems) of the United States by not later than 2010." UTC Power recommends that explicit reference also be made to the inclusion of low and moderate temperature geothermal resources in the resource base characterization.

3. Advanced Low Temperature Geothermal Power Production Technology Should be Specifically Included in DOE's R&D Program

Sec. 5 (c) (1)(C) calls for policies and programs to "demonstrate (emphasis added) state of the art energy production from the full range of geothermal resources in the United States". Sec. 5 (d)(2)(H) directs DOE to "support the development (emphasis added) and application of the full range of geothermal technologies and applications". There is, however, no specific reference to geothermal power production research efforts generally or advanced low temperature geothermal power production specifically. UTC Power recommends that language be added to S 1543 specifically authorizing geothermal power production research efforts including advanced low temperature geothermal technology to:

a. Enhance performance of existing successful geothermal power production systems;
b. Improve efficiency of geothermal capture rates;
c. Use alternative refrigerants; and
d. Develop systems that operate at even lower temperatures than today.

3. Demonstration of Geothermal Energy Production from Oil and Gas Wells Should be Explicitly Authorized

Sec. 5 (d)(2)(F) calls for demonstration of "geothermal applications in settings that, as of the date of enactment of this Act, are noncommercial". UTC Power recommends that S 1543 establish a specific program to demonstrate geothermal energy production from oil and gas fields. We believe the language in Sec. 4207 of HR 3221 and the funding levels specified in Sec. 4214 should be incorporated in S 1543 to ensure this promising opportunity is pursued.

4. Inclusion of International Component is Welcomed

UTC Power supports the inclusion of this provision that recognizes the significant market potential of international geothermal resources such as those located in the "Ring of Fire" countries including China, Indonesia, the Philippines and Taiwan. The inclusion of language authorizing grants and financial assistance for feasibility and resource assessment studies under the authority of the US Trade and Development Agency is particularly important and useful.

CONCLUSION

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. We welcome the opportunity to work with Members of the Committee and other stakeholders to refine and enhance S 1543 and ensure its enactment and implementation as part of a comprehensive package of initiatives that support geothermal energy production.

STATEMENT OF JEFFERSON TESTER, MEISSNER PROFESSOR OF CHEMICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

OVERVIEW

Mr. Chairman and Members of the Committee, I am grateful for the opportunity to provide comments on Senate Bill 1543, the "National Geothermal Initiative Act of 2007," which was introduced in the Senate on July 2 to direct the Secretary of Energy and the Secretary of the Interior to conduct a national program for geothermal energy.

I am updating earlier testimony that I was privileged to provide on House Bill 3221 on May 17, 2007 to offer additional perspective on the newly proposed legislation introduced by the Senate and how it compares to House Bill 3221. My remarks reflect, in large part, the analysis in our recently completed national assessment—"The Future of Geothermal Energy," which was supported by the DOE (See Appendix A for a summary of findings and recommendations). I was honored to chair an interdisciplinary panel that conducted the assessment. Susan Petty was a member of that panel and will be providing her perspectives to you this morning. The final report was published by MIT and released in January of this year. I believe the members of the committee and their staffs have copies of the report.

Geothermal resources are usually described in terms of the stored thermal energy content of the rock and contained fluids underlying land masses that that are accessible by drilling. The United States Geological Survey and other groups have used a maximum accessible depth of 10 km (approx. 30,000 ft) to define the U.S. resource. Although conventional hydrothermal resources are already being used effectively for both electric and non-electric applications in the United States and will continue to be developed, they are somewhat limited by their locations and ultimate potential because they require highly permeable and porous rock reservoirs containing sufficiently large amounts of hot water or steam that are located reasonably near the surface to be economically competitive in today's energy markets. Beyond these conventional hydrothermal systems are Enhanced or Engineered Geothermal Systems or EGS resources, which have enormous potential for primary energy recovery using heat-mining technology to extract and utilize the earth's stored thermal energy. EGS operates as a closed system with cool water pumped deep into hot fractured rock reservoirs where it is heated and then returned to the surface to be used as an energy source to generate electricity or directly for heating applications. EGS resources require stimulation of a reservoir in hot rock large enough to maintain fluid production rates and temperatures between a set of production and injection wells drilled into the reservoir in the range currently achieved by today's commercial hydrothermal resources. EGS feasibility is a result of improvements in geothermal technology for reservoir characterization and stimulation and in deep, directional drilling that have evolved in the last three decades. It is this EGS approach that puts geothermal on the map as a potentially much more sizable energy resource for the U.S.

In addition to conventional hydrothermal and EGS, other geothermal resources also include coproduced hot water associated with oil and gas production, and geopressured resources that contain hot fluids with dissolved methane.

As a very large, well-distributed, carbon free, indigenous energy resource, geothermal's widespread deployment would have a very positive impact on our national energy security, on our environment, and on our economic health. Regrettably, in recent years geothermal energy has been undervalued by many and was often ignored as a portfolio option for widespread deployment in the U.S. If this legislation is enacted and supported with a multi-year commitment at the levels recommended, it will pay substantial dividends in achieving high levels of geothermal power deployment. Investing now in geothermal research and technology development coupled to a program of field demonstrations at the levels recommended in Senate Bill 1543 for the next 5 years will accelerate the impact of geothermal energy on the U.S. energy portfolio.

The prominence that Congress is giving to restarting a national geothermal R&D program is critical to the country. Most importantly, the proposed legislation, like the earlier House bill, recognizes the enormous potential of geothermal energy to become a major provider of clean energy in the U.S. for the long term and describes a robust and balanced research, development, and deployment program to be implemented by the DOE that would reactivate a national-scale program and set the stage for restoring American capacity to advance and deploy geothermal technology. The Senate bill also appropriately addresses support needed in the resource assessment area to be carried out by the USGS.

In the past few months, I have been fortunate to be able to visit several new geothermal plants and projects in the American West, in Australia, and in Iceland, to observe firsthand the positive impacts that geothermal technology is having. For example, ORMAT's new plant in Reno, Nevada completely reinjects all produced geothermal fluids, produces no carbon dioxide or other emissions, and uses no cooling water in a region where water is a limited commodity. Enthusiasm for geothermal in Australia is very high with a strong partnerships of private and government support underway to develop advanced geothermal technology at Cooper Basin and other sites. In Iceland, deployment of geothermal energy has enabled an economic and environmental transformation of the country in less than 60 years—from Iceland's early years as a poor society that was completely dependent on imported fossil fuels in the 1940's to an economically rich society in 2007, due in large part to developing a more sustainable, renewable energy supply. Iceland's extensive geothermal network developed by Reykjavik Energy and other companies now provides 89% of Iceland's heating needs and 27% of their electric power, with hydropower providing the remainder. Iceland is now actively pursuing a means to eliminate their dependence on imported transportation fuels by substituting hydrogen produced by electricity generated from supercritical geothermal resources. Iceland's example of geothermal utilization is a model that the U.S. should strive to emulate, as I am sure that President Grimsson will confirm in his testimony. Obviously, Iceland is a special place geologically, and only some regions of the U.S. share those features. However, the development of EGS technology puts geothermal within reach for a much larger portion of the U.S. To maximize our benefits from geothermal technology development programs ongoing in Iceland, Australia, as well as in many European, Asian and Latin American countries, it is important that we encourage international partnerships and collaborations.

Enactment of this legislation will restore U.S. geothermal leadership internationally. It will put us on a path to utilize our massive geothermal resource to provide dispatchable, baseload generating capacity, essentially with no emissions of carbon dioxide and using modular plants that have small environmental "footprints." These attributes make geothermal a very attractive renewable deployment option for the U.S.—complementing interruptible renewables such as solar and wind, and thus increasing the robustness of a national renewable portfolio.

Even though the U.S. is the largest worldwide producer of electricity from geothermal resources with about 3000 MWe of capacity, this is only a small fraction of our country's total electrical generating capacity, which now exceeds 1,000,000 MWe or 1 TWe. Fortunately, the actual potential for geothermal energy in the U.S. is substantially greater than 3000 MWe as pointed out recently in the MIT-led assessment, by the Western Governors Association, and by the National Renewable Energy Laboratory. For example, our analysis suggests that with a focused and aggressive national R, D&D program, we could enable U.S. geothermal capacity to reach 100,000 MWe in 50 years—comparable to the current generating capacity of our nuclear and hydropower plants. In order to achieve such levels of geothermal capacity, a natural transition from the country's high grade hydrothermal systems in use today to the massive EGS resource over a range of grades would need to occur in increasing amounts in the next 10 to 15 years.

Within the geothermal continuum there is a range of resource types and grades from high-grade conventional hydrothermal systems that are currently in use and being developed in the West to lower-grade Enhanced (or Engineered) Geothermal System or EGS resources in the East. In order to enable geothermal technology to develop to a level where it could provide 10% or more of our generating capacity by 2050 (that is >100,000 MWe), it is essential that a national program address both short and long term technology components simultaneously in a comprehensive and coordinated manner. The bill is balanced and effectively structured to support critical program elements for both hydrothermal and EGS.

The proposed national program is appropriately ambitious, with a multi-year commitment to support both field testing and laboratory work in conjunction with analysis, characterization technique development, and modeling. Overall, two critical areas would be emphasized—first, support for the USGS to enhance the quantitative assessment of the U.S. geothermal resource on a site-specific basis, and second, by demonstration and validation of reservoir stimulation and drilling technologies that can repeatedly and reliably be implemented in the field to produce commercial-scale geothermal systems. A scientific approach strongly grounded in geoscience and geoengineering fundamentals would be used that builds on current methods for stimulating extraction of oil and gas and conventional hydrothermal resources worldwide. The proposed comprehensive research, development, and demonstration effort will lead to both improved and new technologies capable of lowering development risks and costs and thereby making investments in geothermal development more attractive for the private sector.

It is important to maintain a balanced effort, utilizing high grade conventional hydrothermal resources in the short term and realizing the massive opportunities for EGS technology in the longer term. For a balanced program across the geothermal continuum, I firmly believe that the funding levels recommended in Senate Bill 1543 will need to be appropriated in order to achieve the national deployment goals. If appropriations fall below the levels recommended in the Senate and House authorization bills, there is a major risk of significantly slowing progress and de-stabilizing the U.S. program because of competition between near-term hydrothermal and longer term EGS objectives. It is essential to support work in both areas in parallel. In order to achieve high levels of generating capacity of 100,000 MWe or more, it is necessary to support a vigorous EGS field testing effort now in three major areas relevant to its eventual deployment, including resource assessment, geothermal drilling and well completion, and reservoir stimulation.

I have included a few specific comments on the bill in the section of my written testimony that follows. Thank you again for giving me the opportunity to support this important landmark legislation, and thank you for your continued leadership on this issue.

SPECIFIC COMMENTS ON SENATE BILL S.1543

1. Section 2. Findings.—Article 3 states that "Federal tax policies should be modified to appropriately support the longer lead-times of geothermal facilities and address the high risks of geothermal exploration and development" but does not provide any details on how long a suitable timeframe for tax policies for geothermal is. Because new conventional hydrothermal power plant projects starting from unexplored "green field" conditions now take from 5 to 7 years to become fully operational, a long term tax policy that parallels the timetable for key goals set forth in the bill needs to be implemented to encourage private investment,.

2. Section 3. National Goal.—Setting a national goal for geothermal to provide 20% of U.S. electrical capacity by 2030 suggests that 130 GWe or more of new geothermal generating capacity will be needed according to electricity supply projections by the EIA. While laudable, such a goal is very ambitious and may lead to a distorted understanding of actual progress. The Future of Geothermal Energy assessment developed pathways for U.S. geothermal capacity to reach 100 GWe in 50 years. Even in Australia, which is years ahead of the U.S. in terms of demonstration programs, EGS is projected to provide 6.8% of Australia's base load power by 2030. If geothermal (both EGS and conventional hydrothermal) were to reach perhaps only 5 or 10% of national generating capacity instead of 20% by 2030, that should not be considered a failure as it will have demonstrated the viability of geothermal on a national scale with a capacity comparable to U.S. hydro and nuclear. Furthermore, given the large magnitude of the EGS resource base, with 14,000,000 EJ of accessible stored thermal energy, having such enabling technology and technical know how in hand would permit continued increases in EGS capacity for the foreseeable long term.

3. Section 4. Definitions.—The Senate Bill's definition of geothermal is too general. It would be helpful to provide examples of different types of geothermal resources such as hydrothermal, geopressured, EGS, and co-produced hot water associated with oil and gas production. Also, it would be helpful to point out that all EGS resources can be appropriately and efficiently utilized where at least one of the following factors is missing: sufficient natural permeability and porosity, naturally occurring geothermal fluids, and/or high rock temperatures close to the surface.

4. Section 5. National Geothermal Initiative (c) Energy and Interior Goals.—(1)(A)—It is crucial to have the resource assessment specifically mentioned and it is extremely important to keep it in the bill along with the separate appropriations for it.

(1)(B)—It is a good goal to keep the annual growth to at least 10%. That would bring geothermal electricity capacity to about 25 GW in 2030.

(1)(C)—The mandate "to demonstrate state-of-the-art energy production from the full range of geothermal resources in the United States" needs to be much more specific. The geothermal provisions of the House energy bill, H.R. 3221, have specific measures for how to obtain this goal by carrying out three demonstration projects in oil and gas and five demonstration EGS projects. This more specific approach is preferable because it delineates the scope of the demonstration steps which will need to be undertaken to actually meet the goals.

The bill should also have a section (1) (F) calling for the development of electricity production from co-produced fluids from oil and natural gas production in the short-term.

5. Section 5. National Geothermal Initiative (d) Geothermal Research, Development, Demonstration, and Commercial Application.—(2)(B) "Expand funding for cost-shared drilling". It would be useful to include the detail given in the House Energy Bill.

(2)(C)(i) "Establish a national geothermal center at a national laboratory or a university." If there is to be only one center, it should be located to work in close conjunction with the National Renewable Energy Laboratory (NREL) to increase the effectiveness of a national geothermal program. Given the development of the next generation of American geothermal scientists and engineers that will be needed to reach the Senate Bill's deployment goals, NREL should develop strong educational as well as research relationships with a consortium of universities.

(2)(C)(ii) "support development and application of new exploration and development technologies through the center". This element lacks adequate detail for effective implementation. For instance, stating that hydrothermal, EGS and general geothermal systems research should be conducted would provide appropriate guidance to the DOE to maintain a balanced technology research program. To achieve a national goal in the range of 20% geothermal power by 2030, it is important both to support geothermal resource development using evolving technologies and to promote the development of innovative breakthrough technologies relevant to EGS development over a range of grades from high to low. This should be noted in the bill.

6. Section 5. National Geothermal Initiative.—It would be helpful to incorporate a recommendation of specific EGS field development sites that are described in Section 6 (b) (2) of the House Energy Bill.

7. Section 7. International market support.—As discussed above, a strong program of international collaboration and partnerships with countries that are active in geothermal development should be formally recommended, if possible. Such collaboration would be very beneficial to the U.S. effort.

Appendix A—Summary of a national—scale assessment of EGS resources—"The Future of Geothermal Energy" (portions of a previous statement provided on April 19, 2007 to Congress)

For 15 months starting in September of 2005, a comprehensive, independent assessment was conducted to evaluate the technical and economic feasibility of EGS becoming a major supplier of primary energy for U.S. base-load generation capacity by 2050. The assessment was commissioned by the U.S. Department of Energy and carried out by an 18-member, international panel assembled by the Massachusetts Institute of Technology (MIT). The remainder of my testimony provides a summary of that assessment including the scope and motivation behind the study, as well as its major findings and recommendations. Supporting documentation is provided in the full report (Tester et al., 2006)—of which copies of the Executive Summary have been provided for your review. The complete 400+ page report is available on the web at http://geothermal.inel.gov/publications/future—of—geothermal—energy.pdf

In simple terms, any geothermal resource can be viewed as a continuum in several dimensions. The grade of a specific geothermal resource depends on its temperature-depth relationship (i.e. geothermal gradient), the reservoir rock's permeability and porosity, and the amount of fluid saturation (in the form of liquid water and/or steam). High-grade hydrothermal resources have high average thermal gradients, high rock permeability and porosity, sufficient fluids in place, and an adequate reservoir recharge of fluids; all EGS resources lack at least one of these. For example, reservoir rock may be hot enough but not produce sufficient fluid for viable heat extraction, either because of low formation permeability/connectivity and insufficient reservoir volume, or the absence of naturally contained fluids.

A geothermal resource is usually described in terms of stored thermal energy content of the rock and contained fluids underlying land masses that that are accessible by drilling. The United States Geological Survey and other groups have used a maximum accessible depth of 10 km (approx. 30,000 ft) to define the resource. Although conventional hydrothermal resources are already being used effectively for both electric and non-electric applications in the United States, and will continue to be developed, they are somewhat limited by their locations and ultimate potential. Beyond these conventional resources are EGS resources with enormous potential for primary energy recovery using heat-mining technology, which is designed to extract and utilize the earth's stored thermal energy. In addition to hydrothermal and EGS, other geothermal resources include coproduced hot water associated with oil and gas production, and geopressured resources that contain hot fluids with dissolved methane. Because EGS resources have such a large potential for the long term, the panel focused its efforts on evaluating what it would take for EGS and other unconventional geothermal resources to provide 100,000 MWe of base-load electric-generating capacity by 2050. Three main components were considered in the analysis:

1. Resource—mapping the magnitude and distribution of the U.S. EGS resource.
2. Technology—establishing requirements for extracting and utilizing energy from EGS reservoirs, including drilling, reservoir design and stimulation, and thermal energy conversion to electricity. Because EGS stimulation methods have been tested at a number of sites around the world, technology advances, lessons learned and remaining needs were considered.
3. Economics—estimating costs for EGS-supplied electricity on a national scale using newly developed methods for mining heat from the earth, as well as developing levelized energy costs and supply curves as a function of invested R&D and deployment levels in evolving U.S. energy markets.

MOTIVATION

There are compelling reasons why the United States should be concerned about the security of our energy supply for the long term. Key reasons include growth in demand as a result of an increasing U.S. population, the increased electrification of our society, and concerns about the environment. According to the Energy Information Administration (EIA, 2006), U.S. nameplate generating capacity has increased more than 40% in the past 10 years and is now more than 1 TWe. For the past 2 decades, most of the increase resulted from adding gas-fired, combined-cycle generation plants. In the next 15 to 25 years, the electricity supply system is threatened with losing capacity as a result of retirement of existing nuclear and coal-fired generating plants (EIA, 2006). It is likely that 50 GWe or more of coal-fired capacity will need to be retired in the next 15 to 25 years because of environmental concerns. In addition, during that period, 40 GWe or more of nuclear capacity will be beyond even the most generous relicensing accommodations and will have to be decommissioned.

The current nonrenewable options for replacing this anticipated loss of U.S. base-load generating capacity are coal-fired thermal, nuclear, and combined-cycle gas-combustion turbines. While these are clearly practical options, there are some concerns. First, while electricity generated using natural gas is cleaner in terms of emissions, demand and prices for natural gas will escalate substantially during the next 25 years. As a result, large increases in imported gas will be needed to meet growing demand—further compromising U.S. energy security beyond just importing the majority of our oil for meeting transportation needs. Second, local, regional, and global environmental impacts associated with increased coal use will most likely require a transition to clean-coal power generation, possibly with sequestration of carbon dioxide. The costs and uncertainties associated with such a transition are daunting. Also, adopting this approach would accelerate our consumption of coal significantly, compromising its use as a source of liquid transportation fuel for the long term. It is also uncertain whether the American public is ready to embrace increasing nuclear power capacity, which would require siting and constructing many new reactor systems.

On the renewable side, there is considerable opportunity for capacity expansion of U.S. hydropower potential using existing dams and impoundments. But outside of a few pumped storage projects, hydropower growth has been hampered by reductions in capacity imposed by the Federal Energy Regulatory Commission (FERC) as a result of environmental concerns. Concentrating Solar Power (CSP) provides an option for increased base-load capacity in the Southwest where demand is growing. Although renewable solar and wind energy also have significant potential for the United States and are likely to be deployed in increasing amounts, it is unlikely that they alone can meet the entire demand. Furthermore, solar and wind energy are inherently intermittent and cannot provide 24-hour-a-day base load without mega-sized energy storage systems, which traditionally have not been easy to site and are costly to deploy. Biomass also can be used as a renewable fuel to provide electricity using existing heat-to-power technology, but its value to the United States as a feedstock for biofuels for transportation is much higher, given the current goals of reducing U.S. demand for imported oil.

Clearly, we need to increase energy efficiency in all end-use sectors; but even aggressive efforts cannot eliminate the substantial replacement and new capacity additions that will be needed to avoid severe reductions in the services that energy provides to all Americans.

PURSUING THE GEOTHERMAL OPTION

The main question we address in our assessment of EGS is whether U.S.-based geothermal energy can provide a viable option for providing large amounts of generating capacity when and where it is needed.

Although geothermal energy has provided commercial base-load electricity around the world for more than a century, it is often ignored in national projections of evolving U.S. energy supply. Perhaps geothermal has been ignored as a result of the widespread perception that the total geothermal resource is only associated with identified high-grade, hydrothermal systems that are too few and too limited in their distribution in the United States to make a long term, major impact at a national level. This perception has led to undervaluing the long-term potential of geothermal energy by missing a major opportunity to develop technologies for sustainable heat mining from large volumes of accessible hot rock anywhere in the United States. In fact, many attributes of geothermal energy, namely its widespread distribution, base-load dispatchability without storage, small footprint, and low emissions, are very desirable for reaching a sustainable energy future for the United States.

Expanding our energy supply portfolio to include more indigenous and renewable resources is a sound approach that will increase energy security in a manner that parallels the diversification ideals that have made America strong. Geothermal energy provides a robust, long-lasting option with attributes that would complement other important contributions from clean coal, nuclear, solar, wind, hydropower, and biomass.

APPROACH

The composition of the panel was designed to provide in-depth expertise in specific technology areas relevant to EGS development, such as resource characterization and assessment, drilling, reservoir stimulation, and economic analysis. Recognizing the possibility that some bias might emerge from a panel of knowledgeable experts who, to varying degrees, are advocates for geothermal energy, panel membership was expanded to include other experts on non-geothermal energy technologies and economics, and environmental systems. Overall, the panel took a completely new look at the geothermal potential of the United States. This study was partly in response to short-and long-term needs for a reliable low-cost electric power and heat supply for the nation. Equally important was a need to review and evaluate international progress in the development of EGS and related extractive technologies that followed the very active period of U.S. fieldwork conducted by Los Alamos National Laboratory during the 1970s and 1980s at the Fenton Hill site in New Mexico.

The assessment team was assembled in August 2005 and began work in September, following a series of discussions and workshops sponsored by the Department of Energy (DOE) to map out future pathways for developing EGS technology. The final report was released in January of 2007.

The first phase of the assessment considered our geothermal resource in detail. Earlier projections from studies in 1975 and 1978 by the U.S. Geological Survey (USGS Circulars 726 and 790) were amplified by ongoing research and analysis being conducted by U.S. heat-flow researchers and were analyzed by David Blackwell's group at Southern Methodist University (SMU) and other researchers. In the second phase, EGS technology was evaluated in three distinct parts: drilling to gain access to the system, reservoir design and stimulation, and energy conversion and utilization. Previous and current field experiences in the United States, Europe, Japan, and Australia were thoroughly reviewed. Finally, the general economic picture and anticipated costs for EGS were analyzed in the context of projected demand for base-load electric power in the United States.

FINDINGS

Geothermal energy from EGS represents a large, indigenous resource that can provide base-load electric power and heat at a level that can have a major impact in the United States, while incurring minimal environmental impacts. With a reasonable investment in R&D, EGS could provide 100 GWe or more of cost-competitive generating capacity in the next 50 years. Further, EGS provides a secure source of power for the long term that would help protect America against economic instabilities resulting from fuel price fluctuations or supply disruptions. Most of the key technical requirements to make EGS economically viable over a wide area of the country are in effect. Remaining goals are easily within reach to provide performance verification and demonstrate the repeatability of EGS technology at a commercial scale within a 10- to 15-year period nationwide.

In spite of its enormous potential, the geothermal option for the United States has been largely ignored. In the short term, R&D funding levels and government policies and incentives have not favored growth of U.S. geothermal capacity from conventional, high-grade hydrothermal resources. Because of limited R&D support of EGS in the United States, field testing and support for applied geosciences and engineering research have been lacking for more than a decade. Because of this lack of support, EGS technology development and demonstration recently has advanced only outside the United States, with limited technology transfer, leading to the perception that insurmountable technical problems or limitations exist for EGS. However, in our detailed review of international field-testing data so far, the panel did not uncover any major barriers or limitations to the technology. In fact, we found that significant progress has been achieved in recent tests carried out at Soultz, France, under European Union (EU) sponsorship; and in Australia, under largely private sponsorship. For example, at Soultz, a connected reservoir-well system with an active volume of more than 2 km^3 at depths from 4 to 5 km has been created and tested at fluid production rates within a factor of 2 to 3 of initial commercial goals. Such progress leads us to be optimistic about achieving commercial viability in the United States in the next phase of testing, if a national-scale program is supported properly. Specific findings include:

1. The amount of accessible geothermal energy that is stored in rock is immense and well distributed across the U.S. The fraction that can be captured and ultimately recovered will not be resource-limited; it will depend only on extending existing extractive technologies for conventional hydrothermal systems and for oil and gas recovery. The U.S. geothermal resource is contained in a continuum of grades ranging from today's hydrothermal, convective systems through high-and mid-grade EGS resources (located primarily in the western United States) to the very large, conduction-dominated contributions in the deep basement and sedimentary rock formations throughout the country. By evaluating an extensive database of bottom-hole temperature and regional geologic data (rock types, stress levels, surface temperatures, etc.), we have estimated the total U.S. EGS resource base to be about 14 million exajoules (EJ). Figure 1 and Table 1 highlight the results of the resource assessment portion of the study.* Figure 1 shows an average geothermal gradient map and temperature distributions at specific depths for the contiguous U.S. while Table 1 lists the resource bases for different categories of geothermal. Figure 2 compares the total resource to what we estimate might be technically recoverable. Using conservative assumptions regarding how heat would be mined from stimulated EGS reservoirs, we estimate the extractable portion to exceed 200,000 EJ or about 2,000 times the annual consumption of primary energy in the United States in 2005. With technology improvements, the economically extractable amount of useful energy could increase by a factor of 10 or more, thus making EGS sustainable for centuries.

2. Ongoing work on both hydrothermal and EGS resource development complement each other. Improvements to drilling and power conversion technologies, as well as better understanding of fractured rock structure and flow properties, benefit all geothermal energy development scenarios. Geothermal operators now routinely view their projects as heat mining and plan for managed injection to ensure long reservoir life. While stimulating geothermal wells in hydrothermal developments is now routine, understanding why some techniques work on some wells and not on others can come only from careful research.

3. EGS technology advances. EGS technology has advanced since its infancy in the 1970s at Fenton Hill. Field studies conducted worldwide for more than 30 years have shown that EGS is technically feasible in terms of producing net thermal energy by circulating water through stimulated regions of rock at depths ranging from 3 to 5 km. We can now stimulate large rock volumes (more than 2 km^3), drill into these stimulated regions to establish connected reservoirs, generate connectivity in a controlled way if needed, circulate fluid without large pressure losses at near commercial rates, and generate power using the thermal energy produced at the surface from the created EGS system. Initial concerns regarding five key issues—flow short circuiting, a need for high

* Figures 1–5 and Table 1 have been retained in committee files.

injection pressures, water losses, geochemical impacts, and induced seismicity—appear to be either fully resolved or manageable with proper monitoring and operational changes.

4. Remaining EGS technology needs. At this point, the main constraint is creating sufficient connectivity within the injection and production well system in the stimulated region of the EGS reservoir to allow for high per-well production rates without reducing reservoir life by rapid cooling (see Figure 3). U.S. field demonstrations have been constrained by many external issues, which have limited further stimulation and development efforts and circulation testing times—and, as a result, risks and uncertainties have not been reduced to a point where private investments would completely support the commercial deployment of EGS in the United States. In Europe and Australia, where government policy creates a more favorable climate, the situation is different for EGS. There are now seven companies in Australia actively pursuing EGS projects, and two commercial projects in Europe.

5. Impact of Research, Development, and Demonstration (RD&D). Focus on critical research needs could greatly enhance the overall competitiveness of geothermal in two ways. First, such research would lead to generally lower development costs for all grade systems, which would increase the attractiveness of EGS projects for private investment. Second, research could substantially lower power plant, drilling, and stimulation costs, thereby increasing accessibility to lower-grade EGS areas at depths of 6 km or more. In a manner similar to the technologies developed for oil and gas and mineral extraction, the investments made in research to develop extractive technology for EGS would follow a natural learning curve that lowers development costs and increases reserves along a continuum of geothermal resource grades.

Examples of benefits that would result from research-driven improvements are presented in three areas:

- Drilling technology.—Evolutionary improvements building on conventional approaches to drilling such as more robust drill bits, innovative casing methods, better cementing techniques for high temperatures, improved sensors, and electronics capable of operating at higher temperature in downhole tools will lower production costs. In addition, revolutionary improvements utilizing new methods of rock penetration will also lower costs. These improvements will enable access to deeper, hotter regions in high-grade formations or to economically acceptable temperatures in lower-grade formations.
- Power conversion technology.—Although commercial technologies are in place for utilizing geothermal energy in 70 countries, further improvements to heat-transfer performance for lower-temperature fluids, and to developing plant designs for higher resource temperatures in the supercritical water region will lead to measurable gains. For example, at supercritical temperatures about an order of magnitude (or more) increase in both reservoir performance and heat-to-power conversion efficiency would be possible over today's liquid-dominated hydrothermal systems.
- Reservoir technology.—Increasing production flow rates by targeting specific zones for stimulation and improving downhole lift systems for higher temperatures, and increasing swept areas and volumes to improve heat-removal efficiencies in fractured rock systems, will lead to immediate cost reductions by increasing output per well and extending reservoir lifetimes. For the longer term, using CO_2 as a reservoir heat-transfer fluid for EGS could lead to improved reservoir performance as a result of its low viscosity and high density at supercritical conditions. In addition, using CO_2 in EGS may provide an alternative means to sequester large amounts of carbon in stable formations.

6. EGS systems are versatile, inherently modular, and scalable. Individual power plants ranging from 1 to 50 MWe in capacity are possible for distributed applications and can be combined—leading to large "power parks," capable of providing thousands of MWe of continuous, base-load capacity. Of course, for most direct-heating and heat pump applications, effective use of shallow geothermal energy has been demonstrated at a scale of a few kilowatts-thermal (kWt) for individual buildings or homes and should be continued to be deployed aggressively when possible. For these particular applications, stimulating deeper reservoirs using EGS technology is not necessary. Nonetheless, EGS also can be easily deployed in larger-scale district heating and combined heat and power (cogeneration) applications to service both electric power and heating and cooling for buildings without a need for storage on-site. For other renewable options

such as wind, hydropower, and solar PV, such co-generation applications are not possible.

7. A short term "win-win" opportunity. Using coproduced hot water, available in large quantities at temperatures up to 100°C or more from existing oil and gas operations, makes it possible to generate up to 11,000 MWe of new generating capacity with standard binary-cycle technology, and to increase hydrocarbon production by partially offsetting parasitic losses consumed during production.

8. The long term goal for EGS is tractable and affordable. Estimated supply curves for EGS shown in Figure 4 indicate that a large increase in geothermal generating capacity is possible by 2050 if investments are made now. A cumulative capacity of more than 100,000 MWe from EGS can be achieved in the United States within 50 years with a modest, multiyear federal investment for RD&D in several field projects in the United States. Because the field-demonstration program involves staged developments at different sites, committed support for an extended period is needed to demonstrate the viability, robustness, and reproducibility of methods for stimulating viable, commercial-sized EGS reservoirs at several locations. Based on the economic analysis we conducted as part of our study, a $300 million to $400 million investment over 15 years will be needed to make early-generation EGS power plant installations competitive in evolving U.S. electricity supply markets.

These funds compensate for the higher capital and financing costs expected for early-generation EGS plants, which would be expected as a result of somewhat higher field development (drilling and stimulation) costs per unit of power initially produced. Higher generating costs, in turn, lead to higher perceived financial risk for investors with corresponding higher-debt interest rates and equity rates of return. In effect, the federal investment can be viewed as equivalent to an "absorbed cost" of deployment. In addition, comparable investments in R&D will also be needed to develop technology improvements to lower costs for future deployment of EGS plants.

To a great extent, energy markets and government policies will influence the private sector's interest in developing EGS technology. In today's economic climate, there is reluctance for private industry to invest funds without strong guarantees. Thus, initially, it is likely that government will have to fully support EGS fieldwork and supporting R&D. Later, as field sites are established and proven, the private sector will assume a greater role in cofunding projects—especially with government incentives accelerating the transition to independently financed EGS projects in the private sector. Our analysis indicates that, after a few EGS plants at several sites are built and operating, the technology will improve to a point where development costs and risks would diminish significantly, allowing the levelized cost of producing EGS electricity in the United States to be at or below market prices.

Given these issues and growing concerns over long-term energy security, the federal government will need to provide funds directly or introduce other incentives in support of EGS as a long-term "public good," similar to early federal investments in large hydropower dam projects and nuclear power reactors.

9. Geothermal energy complements other renewables such as wind, solar and biomass operating in their appropriate domains. Geothermal energy provides continuous base-load power with minimal visual and other environmental impacts. Geothermal systems have a small footprint and virtually no emissions, including no carbon dioxide. Geothermal energy has significant base-load potential, requires no storage, and, thus, it complements other renewables—solar (CSP and PV), wind, hydropower—in a lower-carbon energy future. In the shorter term, having a significant portion of our base load supplied by geothermal sources would provide a buffer against the instabilities of gas price fluctuations and supply disruptions, as well as nuclear plant retirements. Estimates of the carbon emission reductions possible for different levels of EGS capacity are shown in Figure 5.

RECOMMENDATIONS FOR RE-ENERGIZING THE U.S. GEOTHERMAL PROGRAM

Based on growing markets in the United States for clean, base-load capacity, the panel believes that with a combined public/private investment of about $800 million to $1 billion over a 15-year period, EGS technology could be deployed commercially on a timescale that would produce more than 100,000 MWe or 100 GWe of new capacity by 2050. This amount is approximately equivalent to the total R&D investment made in the past 30 years to EGS internationally, which is still less than the cost of a single, new-generation, clean-coal power plant. Making such an investment now is appropriate and prudent, given the enormous potential of EGS and the technical progress that has been achieved so far in the field. Having EGS as an option will strengthen America's energy security for the long term in a manner that complements other renewables, clean fossil, and next-generation nuclear.

Because prototype commercial-scale EGS will take a few years to develop and field-test, the time for action is now. Supporting the EGS program now will move us along the learning curve to a point where the design and engineering of well-connected EGS reservoir systems is technically reliable and reproducible.

We believe that the benefit-to-cost ratio is more than sufficient to warrant such a modest investment in EGS technology. By enabling 100,000 MWe of new base-load capacity, the payoff for EGS is large, especially in light of how much would have to be spent for deployment of conventional gas, nuclear, or coal-fired systems to meet replacement of retiring plants and capacity increases, as there are no other options with sufficient scale on the horizon.

Specific recommendations include:

1. There should be a federal commitment to supporting EGS resource characterization and assessment. An aggressive, sufficiently supported, multiyear national program with USGS and DOE is needed along with other agency participation to further quantify and refine the EGS resource as extraction and conversion technologies improve.

2. High-grade EGS resources should be developed first as targets of opportunity on the margins of existing hydrothermal systems and in areas with sufficient natural recharge, or in oil fields with high-temperature water and abundant data, followed by field efforts at sites with above-average temperature gradients. Representative sites in high-grade areas, where field development and demonstration costs would be lower, should be selected initially to prove that EGS technology will work at a commercial scale. These near-term targets of opportunity include EGS sites that are currently under consideration at Desert Peak (Nevada), and Coso and Clear Lake (both in California), as well as others that would demonstrate that reservoir-stimulation methods can work in other geologic settings, such as the deep, high-temperature sedimentary basins in Louisiana, Texas, and Oklahoma. Such efforts would provide essential reservoir stimulation and operational information and would provide working "field laboratories" to train the next generation of scientists and engineers who will be needed to develop and deploy EGS on a national scale.

3. In the first 15 years of the program, a number of sites in different regions of the country should be under development. Demonstration of the repeatability and universality of EGS technologies in different geologic environments is needed to reduce risk and uncertainties, resulting in lower development costs.

4. Like all new energy-supply technologies, for EGS to enter and compete in evolving U.S. electricity markets, positive policies at the state and federal levels will be required. These policies must be similar to those that oil and gas and other mineral-extraction operations have received in the past—including provisions for accelerated permitting and licensing, loan guarantees, depletion allowances, intangible drilling write-offs, and accelerated depreciations, as well as those policies associated with cleaner and renewable energies such as production tax credits, renewable credits and portfolio standards, etc. The success of this approach would parallel the development of the U.S. coal-bed methane industry.

5. Given the significant leveraging of supporting research that will occur, we recommend that the United States actively participate in ongoing international field projects such as the EU project at Soultz, France, and the Cooper Basin project in Australia.

6. A commitment should be made to continue to update economic analyses as EGS technology improves with field testing, and EGS should be included in the National Energy Modeling System (NEMS) portfolio of evolving energy options.

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