DEVELOPING UNTAPPED POTENTIAL: GEOTHERMAL AND OCEAN POWER TECHNOLOGIES

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

MAY 17, 2007

Serial No. 110–32

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

35–236PS WASHINGTON : 2008

For sale by the Superintendent of Documents, U.S. Government Printing Office
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DEVELOPING UNTAPPED POTENTIAL: GEOTHERMAL AND OCEAN POWER TECHNOLOGIES

THURSDAY, MAY 17, 2007

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

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2325 of the Rayburn House Office Building, Hon. Nick Lampson [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

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Subcommittee on Energy and Environment

Hearing on:

Developing Untapped Potential: Geothermal and Ocean Power Technologies

Thursday, May 17, 2007
10:00 AM – 12:00
2325 Rayburn House Office Building

Witness List

Dr. Jefferson Tester
Meissner Professor of Chemical Engineering, Massachusetts Institute of Technology

Mr. Paul Thomsen
Public Policy Manager, Ormat Technologies, Inc.

Dr. Annette von Jouannne
Professor of Power Electronics and Energy Systems, Oregon State University

Mr. Sean O'Neill
President, Ocean Renewable Energy Coalition

Mr. Nathanael Greene
Senior Energy Policy Specialist, Natural Resources Defense Council

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Developing Untapped Potential Geothermal and Ocean Power Technologies

THURSDAY, MAY 17, 2007
10:00 A.M.–12:00 P.M.
2325 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, May 17, at 10:00 a.m., the Energy & Environment Subcommittee of the House Committee on Science and Technology will hold a legislative hearing on two renewable energy bills.

H.R. 2304, introduced by Mr. McNerney of California, directs the Secretary of Energy to support research, development, demonstration, and commercial application of advanced technologies to locate and characterize geothermal resources and produce geothermal energy. The bill is co-sponsored by Mr. Gordon of Tennessee and Mr. Lampson of Texas.

H.R. 2313, introduced by Ms. Hooley of Oregon, directs the Secretary of Energy to support research, development, demonstration, and commercial application of technologies to produce electric power from renewable marine resources, including: waves, tidal flows, ocean currents, and thermal gradients.

Witnesses

- **Dr. Jefferson Tester** is the H.P. Meissner Professor of Chemical Engineering at the Massachusetts Institute of Technology. Dr. Tester is an internationally recognized expert in Enhanced Geothermal Systems and he served as chair of the MIT-led panel that produced the report: *The Future of Geothermal Energy,* released in January, 2007.
- **Mr. Paul Thomsen** is Public Policy Manager for ORMAT Technologies, Inc., a leading provider of geothermal exploration, development, and power conversion technologies. Mr. Thomsen is responsible for ORMAT's federal, State and local legislative programs. He is testifying today on behalf of both ORMAT and the Geothermal Energy Association.
- **Dr. Annette von Jouannne** is a Professor in the School of Electrical Engineering and Computer Science at Oregon State University in Corvallis, Oregon. She specializes in Energy Systems, including power electronics and power systems, and she leads the Wave Energy program at OSU.
- **Mr. Sean O'Neill** is President of the Ocean Renewable Energy Coalition (OREC), a trade association representing the marine renewable energy industry.
- **Mr. Nathanael Greene** is a Sr. Energy Policy Specialist with the Natural Resources Defense Council. His areas of expertise include utility regulation, renewable energy, energy taxes and energy efficiency.

Overarching Questions

The hearing will address the following overarching questions:

Geothermal

1. What is the current state of development of geothermal energy technologies? Are they mature? If not, what major research, development, and demonstration work remains to be done to increase their commercial viability?
2. What new opportunities might be created by the development of Enhanced Geothermal Systems?

3. What are the largest obstacles to the widespread commercial development of geothermal energy? How can these hurdles be addressed?
4. What is the appropriate role for the Federal Government in supporting RD&D in marine renewable energy technologies?
5. Are there environmental concerns associated with geothermal energy development? What are they? Can they be mitigated?
6. Does the bill under consideration—the *Advanced Geothermal Energy Research and Development Act of 2007*—address the most significant RD&D barriers to the widespread development of geothermal energy? How can the bill be improved?

Ocean Power

7. What is the state of development of marine power technologies? Are they mature? Does this assessment vary by resource (i.e., waves vs. tidal vs. currents vs. thermal)? If these technologies are not mature, what major research, development, and demonstration work remains to be done to make marine renewable energy technologies commercially viable?
8. What are the largest obstacles to the widespread commercial development of marine renewable energy? How can these hurdles be addressed?
9. What is the appropriate role for the Federal Government in supporting RD&D in marine renewable energy technologies?
10. Are there environmental concerns associated with marine renewable energy development? What are they? Can they be mitigated?
11. Does the bill under consideration—the *Marine Renewable Energy Research and Development Act of 2007*—address the most significant RD&D barriers to the widespread development of marine power technologies?

Overview of Geothermal Energy

Hydrothermal Systems

Geothermal energy is heat from the Earth's core that is trapped in the Earth's crust. In locations where high temperatures coincide with naturally-occurring, underground, fluid-filled reservoirs, the resulting hot water or steam can be tapped and used either to generate electricity or for *direct use* (e.g., heating buildings, greenhouses, or aquaculture operations). Such locations are referred to as *hydrothermal* (hot water) resources, and they have been the focus of traditional geothermal energy development.

By tapping hydrothermal resources, the United States has become the world's largest producer of electric power from geothermal energy. About 2,800 megawatts (MW) of geothermal electrical generating capacity is connected to the grid in the United States; 8,000 MW of geothermal generating capacity is installed worldwide. Geothermal energy is currently the third largest source of renewably-generated grid power in the United States, behind hydropower and biomass. In 2003, it accounted for seven percent of U.S. electricity generated from renewable sources. The largest geothermal development in the world is at *The Geysers* in Northern California. This series of plants, which started to come online in 1960, has a cumulative capacity of over 850 MW and satisfies nearly 70 percent of the average electrical demand for the California North Coast region.

Although the United States is the world leader in hydrothermal development, significant potential remains untapped. The U.S. Geological Survey (USGS) has estimated there to be 22,000 MW of hydrothermal resources sufficient for electrical power generation in the United States. However, many of these resources remain hidden and unconfirmed. H.R. 2304 contains provisions to support research and development of advanced technologies to assist in locating and characterizing hidden hydrothermal resources, and to encourage demonstration of advanced exploration technologies by the geothermal industry.

Enhanced (or Engineered) Geothermal Systems (EGS)

Enhanced Geothermal Systems (EGS) differ from hydrothermal systems in that they lack either a natural reservoir (i.e., the cracks and spaces in the rock through which fluid can circulate), the fluid to circulate through the reservoir, or both. In EGS development, sometimes referred to as "heat mining," an injection well is drilled to a depth where temperatures are sufficiently high; if necessary, a reservoir is created, or "cracked," in the rock by using one of various methods of applying pressure; and a fluid is introduced to circulate through the reservoir and absorb the heat. The fluid is extracted through a production well, the heat is extracted to run a geothermal power plant or for some direct use application, and the fluid is re-injected to start the loop all over again.

Although it has been the subject of preliminary investigations in the United States, Europe, and Australia, the EGS concept has yet to be demonstrated as commercially viable. However, experts familiar with the resource and the associated technologies believe the technical and economic hurdles are surmountable. In January, 2007, a panel led by the Massachusetts Institute of Technology produced a report entitled *The Future of Geothermal Energy,* which contained an updated assessment of EGS potential in the United States. The authors of the report estimated the Nation's total EGS resource base to be "greater than 13 million quads or 130,000 times the current annual consumption of primary energy in the United States." [1] After accounting for the fact that the actual amount of recoverable energy will be much lower, due to technical and economic constraints, the authors conservatively estimate that two percent of the EGS resource could be economically recoverable—an amount that is still more than 2,000 times larger than all the primary energy consumed in the United States in 2005.[2] In other words, if the technological hurdles to EGS development can be overcome, the potential of the resource is enormous. H.R. 2304 contains provisions to support research and development of advanced technologies to advance the commercial viability of EGS development, and to encourage demonstration of reservoir engineering and stimulation technologies by the geothermal industry.

Applications of Geothermal Energy

- *Electric power:* Geothermal power plants pump hot fluid (usually water or brine) from the Earth and either use it to power a turbine directly, or run it through a heat exchanger to boil a secondary fluid into a gas, which then powers a turbine, to create electricity.
- *Direct use applications:* Geothermal water of at least 70°F can be used directly for heating homes or offices, growing plants in greenhouses, heating water for fish farming, and for other industrial uses. Some cities (e.g., Boise, Idaho) pipe geothermal hot water under roads and sidewalks to keep them clear of snow and ice. District heating applications use networks of piped hot water to heat buildings throughout a community.

Benefits of Geothermal Energy

- *Base load power:* Unlike most renewable energy sources, electric power from geothermal energy is available at a constant level, 24 hours a day. Because of this lack of intermittency, geothermal power may provide baseload power production.
- *Pollution prevention:* A geothermal steam plant emits almost 50 times less carbon dioxide (CO_2) than the average U.S. coal power plant per kilowatt of electricity produced.[3] Every year, geothermal electricity plants prevent 4.1 million tons of CO_2 emissions that coal-powered plants would have generated. A geothermal plant's cooling towers emit mostly water vapor, and emit no particulates, hydrogen sulfide, or nitrogen oxides. Plants that employ *binary* conversion technology emit only water vapor, and in very small amounts.
- *Jobs and security:* Geothermal energy can be produced domestically, thereby providing jobs for Americans and reducing security concerns associated with dependence on foreign sources of oil and natural gas. The large size of the resource, both in the United States and overseas, creates significant market opportunities for geothermal technology companies.

Cost

Electricity from *The Geysers* sells for a wholesale price of $0.03 to $0.035 per kilowatt-hour (kWh), while electricity from newer geothermal plants (using lower temperature resources) costs between $0.05 and $0.08 wholesale per kWh. Wholesale prices for electricity produced from EGS reservoirs is likely to be higher in the initial stages of developing the technology, but projections by the MIT panel that produced *The Future of Geothermal Energy* anticipate that it would fall to a comparable level (i.e., $0.05 to $0.08 per kWh) by the time a 100 MW of cumulative capacity

[1] *The Future of Geothermal Energy,* Massachusetts Institute of Technology, 2006; pp. 1–15.
[2] Ibid, pp. 1–17.
[3] According to the National Renewable Energy Lab, *http://www.nrel.gov/geothermal/geoelectricity.html*

have been developed in the United States, which amounts to bringing only a few EGS projects online.[4]

Direct use of geothermal resources is cost-competitive in many applications. For example, according to DOE, commercial greenhouses heated with geothermal resources, instead of traditional energy sources, average an 80 percent savings on fuel costs—about five to eight percent of average total operating costs.

Issues

- *Subsidence and production declines:* At some geothermal power plants, energy production may gradually decline over time, through a loss of water/steam or declining water temperatures. If water or steam is removed from an underground reservoir, the land above the reservoir may slowly start to sink. Municipalities can inject their treated wastewater into the underground reservoir to replenish the hot water supply and avoid land subsidence. Newer geothermal plants tend to employ binary conversion technology, which re-injects the geofluid into the ground after extracting the heat, thereby replenishing the reservoir. Since almost no fluid is lost in these systems, reservoir depletion and subsidence are less significant concerns.
- *Induced seismicity:* Good hydrothermal resources usually coincide with areas of volcanic activity and so are almost always seismically active to begin with, and developing a geothermal resource can cause additional earthquakes. These induced quakes are usually small and imperceptible by humans, registering only two to three on the Richter scale. The process of developing EGS resources may also induce some seismic activity through the act of cracking the rock to create an underground reservoir. Experience to date suggests that the induced quakes from EGS development are also quite small, but this is an area that warrants further study. H.R. 2304 calls for the Secretary of Energy to study induced seismicity as a consequence of EGS development.
- *Water use:* Geothermal projects require access to water throughout development and operation. Water is used during well drilling, reservoir stimulation, and circulation. Cooling water is also used in most plants for condensing the hot working fluid after it has powered the turbine. In locations where water resources are in high demand, as in the western U.S., water use for geothermal projects requires careful management and conservation. Steps must also be taken to ensure that geothermal development does not contaminate groundwater and that noxious geofluids that are produced from deep wells are not disposed of on the surface.

Geothermal Energy Programs at DOE

The United States has been involved in geothermal energy R&D since the 1970s. The program reached a high point in FY 1980 with funding of approximately $150 million (1980 dollars). Since then, funding has gradually declined to its present level of $5 million (2007 dollars) in FY 2007.

Historically, many important technological advances have emerged from DOE-supported work at the national labs and U.S. universities. The current geothermal program has allocated its FY 2007 budget of $5 million to support work on two EGS development projects, assess the potential of using hot water co-produced with oil and gas drilling to produce electricity, and to close down remaining program operations and establish an historical archive of the program.

In the *Energy Policy Act of 2005,* Section 931(a)(2)(C) included a broad authorization for research, development, demonstration, and commercial application programs for geothermal energy, with a 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."

While broad-ranging, the EPACT authorization lacks specific provisions for cost-shared programs with industry partners (which have led to many advances in geothermal technology in the past and facilitated adoption of those advances by the private sector) and it makes no specific mention of developing Enhanced Geothermal Systems (EGS), an area of significant potential. Also, the authorization expires after FY 2009. Despite the authorization in EPACT '05, the Administration requested zero dollars for geothermal programs at DOE for FY 2007 and FY 2008 and is currently making plans to shut down the geothermal program.

[4] *The Future of Geothermal Energy,* Massachusetts Institute of Technology, 2006; pp. 1–30.

As justification for terminating the geothermal program, the Administration has claimed that geothermal technologies are mature—a claim disputed by geothermal researchers and the industry. Recent indications suggest DOE officials may be open to reexamining investment in geothermal R&D, particularly in light of the opportunities in Enhanced Geothermal Systems that were highlighted in the recent MIT report: *The Future of Geothermal Energy.*

Overview of Marine Renewable Energy

Marine Renewable Energy refers to energy that can be extracted from ocean water. (In some contexts the term may also encompass offshore wind developments, but that is beyond the scope of H.R. 2313 and this hearing.) For purposes of H.R. 2313, the marine renewable energy refers to energy derived from ocean waves, tidal flows, ocean currents, or ocean thermal gradients. Each is these is described in greater detail below.

Moving water contains a much higher energy concentration, measured in watts per meter (for waves) or watts per square meter (for tides and currents), than other renewable resources, such as wind and solar. This creates an opportunity to extract comparable amounts of energy with a smaller apparatus. The challenge lies in developing technologies to effectively and efficiently harness the energy contained in ocean movement or thermal gradients and use it to generate electric power, or for other purposes.

Their potential debated for many years, marine renewable energy technologies appear to be on the verge of a technological breakthrough. Prototypes or small demonstration installations have recently been hooked into the power grid in Australia, Portugal, the United Kingdom, and the United States. H.R. 2313 would support technology research and development to ensure that U.S. companies are competitive in this emerging global market, and that emerging technologies are developed in an environmentally sensitive way.

- *Waves:* Ocean waves are really a super concentrated form of solar energy. The sun makes the wind blow, and the wind blowing across the ocean surface creates waves. Waves may travel unimpeded through the ocean for thousands of miles, accruing significant amounts of mechanical energy. Wave power devices extract energy directly from surface waves or from pressure fluctuations below the surface.

  According to a study by the Electric Power Research Institute (EPRI),[5] the total annual wave energy resource in the United States is approximately 2,300 TWh per year (2,300 terawatt hours = 2,300 billion kilowatt hours). If we were to harness 24 percent of that resource, at 50 percent efficiency, it would generate an amount of electricity roughly comparable to all of our current output from hydroelectric sources (~270 TWh per year, or approximately seven percent of current U.S. electricity generation[6]).

  Wave-power rich areas of the world include the western coasts of Scotland, northern Canada, southern Africa, Australia, and the northeastern and northwestern coasts of the United States. In the Pacific Northwest alone, DOE estimates that wave energy could produce 40–70 kilowatts (kW) per meter (3.3 feet) of western coastline.[7]

  Wave energy can be converted into electricity through either offshore and onshore systems. Offshore systems are situated in deep water, typically between 40 and 70 meters (131 and 230 feet). Most offshore systems take the form either of a single point absorber, which is a vertical buoy design, similar in appearance to a navigation buoy, or an attenuator, which is a long, segmented tube that generates energy as waves flow along its length, flexing the adjacent segments against one another and powering hydraulic pumps inside.

  Onshore wave energy systems are situated on the shoreline and exposed to oncoming waves. Oscillating water column designs enclose a column of air above a column of water. As waves enter the air column, they cause the water column to rise and fall, alternately compressing and depressurizing the air column, which powers a turbine. The tapchan, or tapered channel system, consists of a tapered channel, which feeds into a reservoir constructed on cliffs above sea level. The

[5] EPRI Offshore Wave Power Feasibility Demonstration Project, Final Report; *http://www.epri.com/oceanenergy/attachments/wave/reports/009_Final_Report_RB_Rev_2_092205.pdf*

[6] Energy Information Administration, *http://www.eia.doe.gov/fuelelectric.html*

[7] http://www.eere.energy.gov/consumer/renewable_*energy/ocean/index.cfm/mytopic=50009*

narrowing of the channel causes the waves to increase in height as they move toward the cliff face. The waves spill over the walls of the channel into the reservoir and the stored water is then fed through a turbine. Pendulor devices consist of a rectangular box, which is open to the sea at one end. A flap is hinged over the opening and the action of the waves causes the flap to swing back and forth, powering a hydraulic pump and a generator.

- *Tidal Flows:* Tides are controlled primarily by the Moon, and so can legitimately be thought of as lunar power. As the tides rise and fall twice each day, they create tidal currents in coastal locations with fairly narrow passages. Good examples include San Francisco's Golden Gate, the Tacoma Narrows in Washington's Puget Sound, and coastal areas of Alaska and Maine. Technologies of various designs may be used to harness these flows.

  Many tidal turbines look like wind turbines, and engineers of tidal technologies have been able to draw on many of the lessons learned from 30 years of wind-turbine development. They may be arrayed underwater in rows, anchored to the sea floor. Because the energy in moving water is so much more concentrated than the energy in moving air, the turbines can be much smaller than wind turbines and still generate comparable amounts of electricity. The turbines function best where coastal currents run at between 3.6 and 4.9 knots (four and 5.5 mph). In currents of that speed, a 15-meter (49.2 feet) diameter tidal turbine can generate as much energy as a 60-meter (197 feet) diameter wind turbine. Ideal locations for tidal turbine arrays are close to shore in water depths of 20–30 meters (65.5–98.5 feet).

- *Currents:* Ocean currents are similar to tidal flows, but significantly larger. As an example, the energy contained in the Gulf Stream current in the Atlantic Ocean is equivalent to approximately 30 times the energy contained in all the rivers on Earth.

  The only area in the United States where ocean currents come close enough to land to make potential power extraction attractive at this time is in South Florida, where the Gulf Stream swings in close to shore. It is envisioned that undersea turbines, similar to those being developed to harness tidal flows, might be deployed to tap into this massive current.

- *Ocean Thermal Energy Conversion (OTEC):* Thermal gradients are the only marine renewable energy resource addressed in this bill that is not based on moving water. Instead, thermal technologies use the difference in temperature between deep and shallow waters to run a heat engine. This temperature difference contains a vast amount of solar energy. If extraction could be done profitably, the resource is virtually limitless.

  OTEC works best when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is about 20°C (36°F), conditions that exist in tropical coastal areas. To bring the cold water to the surface, OTEC plants require a large diameter intake pipe, which is submerged a mile or more into the ocean's depths. Heat is extracted from warm surface water.

Applications of Marine Renewable Energy

- *Electric power production:* The primary application of marine energy technologies is electrical power production. Most planned installations would consist of arrays of multiple, small generating devices, optimally positioned to take advantage of a particular resource (e.g., waves, tidal flows, etc.). The multiple devices would feed their power into a centralized hub located on the sea floor, which, in turn, would be connected to a substation on the beach, and from there to the power grid.

- *Desalination:* One virtue of locating a clean, renewable energy producing device in seawater is that it is optimally positioned to use that energy for desalination. In areas where fresh drinking water is at a premium, marine renewables can make an important contribution to solving that problem.

- *Air conditioning:* Air conditioning is a possible byproduct of some marine energy technologies. For example, spent cold seawater from a thermal conversion plant can chill fresh water in a heat exchanger or flow directly into a cooling system on shore. Simple systems of this type have air conditioned buildings at the Natural Energy Laboratory in Hawaii for several years.

Benefits of Marine Renewable Energy

- *Predictability:* Unlike some renewable energy sources, notably wind, marine renewable energy production can be forecast to a high degree of certainty well in advance. Using satellite observations, wave power can be forecast up to three days in advance. Tides can be forecast years in advance. Ocean thermal is capable of providing a constant, base-load supply of power. This predictability makes it easier to integrate marine renewables into a diverse generation portfolio.
- *No fuel costs:* Marine renewables benefit from a free and inexhaustible source of "fuel," freeing operators and consumers from concerns about future fuel availability and price volatility.
- *Pollution prevention:* Like other renewable energy technologies, marine renewables are attractive because they emit no pollutants or greenhouse gases in the process of producing energy. Devices are also designed to prevent any pollution to the ocean waters.
- *Jobs and security:* Marine renewable energy technologies can be produced domestically, thereby providing jobs for Americans and helping to reduce security concerns associated with depending on foreign countries for oil and natural gas. The large size of the resource, both in the United States and overseas, creates significant market opportunities for marine renewable energy technology companies.
- *Aesthetically unobjectionable:* Often opposition to energy development projects, whether onshore or off, is motivated by complaints that they obstruct or detract from otherwise beautiful land- or sea-scapes. In contrast to most other technologies, many marine renewable energy technologies are submerged out of sight. Other marine renewables have such a low profile and/or are located so far from shore that they generate no significant opposition on aesthetic grounds.

Cost

Cost estimates are difficult for wave and tidal, which, in contrast to offshore wind, lack operational history. For wave, costs have been estimated as between nine and 16 cents/kWh, far more favorable than the 40 cents/kWh that offshore wind cost "out of the box." For in-stream tidal, the Electric Power Research Institute has predicted costs from four to 12 cents/kWh, depending on the rate of water flow. Because of tidal power's similarities to wind, it may benefit from the advancements already made in wind turbine development and may potentially share economies of scale with that industry.

Issues

- *Environmental Impact:* The greatest concern with marine renewables is the impact of power generation technologies on the marine environment and ecosystems. Significant research remains to be done in this area to ensure that these devices do not have significant negative environmental impacts. Turbine technologies, to harness tides and ocean currents, have raised particular questions. There are open questions about the impact of tidal turbines on local fisheries and marine mammals. This is an area requiring in-depth study. It is important that studies look not just at the impact of individual turbines, but also the impacts of large arrays of multiple turbines in a give location, as such arrays are what would be necessary to generate power on a utility scale.

  For marine renewable technologies that engage in desalination, steps must be taken to ensure that the concentrated brine produced as a byproduct of these operations does not have a negative impact on local marine ecosystems.

  Finally, there are open questions relating to potential environmental impacts of extracting too much energy from tidal flows or ocean currents. In the case of tidal flows, care must be taken not to reduce the flow by too much to avoid harm to marine ecosystems. In the case of the Gulf Stream, the same ecological concerns apply, and in addition, since the thermal energy carried by the Gulf Stream plays an important role in regulating the climate in Europe, it is important to understand whether extracting energy from this system might have negative impacts on weather systems that depend on its steady flow. While this possibility may be remote, it is a question that warrants further study.
- *Marine navigation:* Since many marine renewable energy conversion devices float on the water, or rest on the bottom of navigable waterways, they raise concerns about possible interference with marine navigation. It is important that devices

be well-marked, easily visible by day and night, and appear on all current nautical charts. Efforts should be made to make devices visible to radar as well.

- *Survivability:* Marine renewable energy devices spend their entire life cycle immersed in corrosive seawater and exposed to severe weather and sea conditions. Steps must be taken to ensure the survivability, and reliability, of these devices in these harsh conditions to ensure the uninterrupted supply of power.

Marine Renewable Energy Programs at DOE

The United States became involved in marine renewable energy research in 1974 with the establishment of the Natural Energy Laboratory of Hawaii Authority. The Laboratory became one of the world's leading test facilities for Ocean Thermal Energy Conversion technology, but work there was discontinued in 2000. Existing OTEC systems have an overall efficiency of only one percent to three percent, but there is reason to believe that subsequent technology advances and changes in the overall electric power environment may make a fresh look at OTEC technologies worthwhile.

In the *Energy Policy Act of 2005,* Section 931(a)(2)(E) included a broad authorization for research, development, demonstration, and commercial application programs for "(i) ocean energy, including wave energy." However, that authorization contains no further instructions on how to structure such a program and the authorization expires after FY 2009. Despite this authorization, DOE has not made a budget request to support marine energy programs since EPACT '05 was passed, nor have funds been appropriated. This is despite the fact that FERC has begun to issue permits to companies and investors interested in developing in-stream tidal sites, and several private companies—in Europe, Australia, and the United States—have begun to test prototype marine renewable energy technologies of various design.

Chairman LAMPSON. Good morning, ladies and gentlemen. This hearing will come to order, and I want to welcome everyone to our hearing today on geothermal and ocean power technologies. We will be examining two bills: H.R. 2304, the *Advanced Geothermal Energy Research and Development Act of 2007,* introduced by our colleague from California, Representative McNerney, and H.R. 2313, the *Marine Renewable Energy Research and Development Act of 2007,* introduced by Representative Hooley of Oregon.

Things are quite busy this morning and I want to interrupt my comments for just a second. We are probably going to be interrupted with votes at around 10:30. We are going to do all that we can as quickly as we can and then come back and complete our effort.

Each of these bills is designed to accelerate the development of a specific renewable energy resource that has great potential as a source of clean power generation, is vast in size, and three, is currently receiving little support for research and development. In other words, these bills are about addressing overlooked opportunities in our collective efforts to create good American jobs, diversify our energy supply, increase our security and reduce the environmental impact of energy production.

At this time I want to yield to Mr. McNerney, the author of H.R. 2304, to make a brief opening statement.

[The prepared statement of Chairman Lampson follows:]

PREPARED STATEMENT OF CHAIRMAN NICK LAMPSON

Good morning everyone and welcome to our hearing today on geothermal and ocean power technologies. We will be examining two bills:

H.R. 2304, the *Advanced Geothermal Energy Research and Development Act of 2007,* introduced by our colleague from California, Rep. McNerney, and H.R. 2313, the *Marine Renewable Energy Research and Development Act of 2007,* introduced by Rep. Hooley of Oregon.

Each of these bills is designed to accelerate the development of a specific renewable energy resource that: has great potential as a source of clean power generation, is vast in size, and is currently receiving little R&D attention or support.

In other words, these bills are about addressing overlooked opportunities in our collective efforts to create good American jobs, diversify our energy supply, increase our security, and reduce the environmental impact of energy production.

For decades, the United States has tapped geothermal energy for heating applications and to produce clean electric power. We know this resource works. But most geothermal development has occurred in locations where underground reservoirs of very hot water or steam—so called hydrothermal systems—have been shallow and easily identifiable from the surface. Unfortunately, since obvious surface manifestations of geothermal energy do not occur in very many places, geothermal is often thought of as a marginal resource—not one that can play a major role in our power generation portfolio across the Nation.

This view is inaccurate. In actuality, the obvious locations barely scratch the surface of the total geothermal potential underneath the United States. By investing in advanced technologies for exploration and development, we can learn how to identify hidden resources that have no surface manifestations, and even learn to create new resources in hot rock where no natural reservoir or fluid exists. In doing so, we have the potential to dramatically expand our geothermal energy reserves.

In addition to being clean, domestic, and renewable, geothermal energy flows in an uninterrupted stream, making it great for baseload power production. And the amount of energy stored in the Earth's crust is enormous. A recent report by an MIT-led panel of experts estimated that, with a comparatively modest investment in technology development, as much as 200,000 "quads" of geothermal energy could become commercially accessible—an amount equal to 2,000 times the total energy consumed in the U.S. each year.

Marine renewable energy technologies are designed to harness the power contained in ocean waves, flowing tides, ocean currents, and ocean thermal gradients.

The theoretical potential of these resources has been debated for years, but now marine renewables appear poised on the verge of a breakthrough. Countries such as Australia, the United Kingdom, and Portugal are investing heavily in technologies to tap the ocean's energy potential and will soon hook the first commercial projects into their power grids.

In 2005, the Electric Power Research Institute completed a series of preliminary studies to quantify the wave and tidal resources in U.S. coastal waters. They found that the size of just one of these resources—waves—is big enough to provide as much electric power as all of the hydroelectric dams currently operating in the United States—almost seven percent of our nation's electricity in 2005. When other marine energy resources are added to the mix, the potential becomes truly significant.

The title of this hearing says it all: *Developing Untapped Potential.* We owe it to current and future generations to develop our ability to tap the vast potential of geothermal and ocean energy. Doing so will increase our security, foster competitive new American industries, and ensure that energy production of the future is compatible with the highest standards of environmental stewardship. This is the purpose behind H.R. 2304 and H.R. 2313.

Mr. MCNERNEY. I would like to thank Chairman Lampson and Ranking Member Inglis for holding this hearing on geothermal and ocean energy technologies, and I would like to thank Chairman Gordon for his support of geothermal research.

I have spent over 20 years of my professional career developing wind energy technology and there are some very interesting parallels. We saw the technology developed from very early stage, primitive technology to what we see today as a very successful, cost-effective technology in the wind industry that is now the fastest growing form of new energy technology. Much American money was spent and invested in this technology. Research was done here in the United States, especially in California, my home State. But what happened ultimately is the United States Government was very inconsistent in its support for the development and implementation of wind energy technology. Consequently, what happened is that the technology went overseas. It is now being produced in Europe and Japan, even though all the research dollars were spent here by American industry and by American government. The profits are now going to Europe and Japan.

So I see now a very similar situation happening with geothermal. Geothermal is in a state now where we can move forward and become a world leader. We can develop the technology. We can have the technology for use at home and for sale overseas but inconsistent or nonexistent government support or policies will drive that industry and that business overseas, so it behooves us to develop this new technology. Geothermal has a vast potential. The reports that Dr. Tester and others have produced show that it can produce 10 percent or more of our electrical needs by 2050. So we need to embark on a path that helps us develop this technology and keep it at home and be the world leaders in this new emerging technology that has such tremendous potential.

So with that, I will yield back to Mr. Lampson, to the Chairman.

Chairman LAMPSON. Thank you very much, Mr. McNerney.

At this time I would like to recognize the distinguished Ranking Member from South Carolina, Mr. Inglis, for his opening statement.

Mr. INGLIS. I thank you, Mr. Chairman, for holding this hearing and I appreciate the work of Ms. Hooley and Mr. McNerney on these bills and they do highlight the renewable energy sources that can help America achieve energy security.

The solution to our energy problems will come from a variety of sources, no doubt. We hope that they are clean, renewable and affordable. Surely geothermal and marine-related energy sources fit that description and I am looking forward to hearing from our witnesses today about the research that will make these alternatives affordable in a commercial market.

So thank you, Mr. Chairman, for holding this hearing and thank you to our colleagues, Ms. Hooley and Mr. McNerney, for these bills.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Thank you for holding this hearing, Mr. Chairman. I also appreciate Mrs. Hooley's and Mr. McNerney's work to introduce these bills that highlight two renewable energy sources that can help America achieve energy security.

The solution to our energy problems will come from a variety of sources, and they need to be clean, renewable, and affordable. Since geothermal and marine-related energy sources fit that description, I'm looking forward to hearing from our witnesses today about the research that will make these alternatives affordable in the commercial market.

Thank you again, Mr. Chairman, and I look forward to discussing these two bills before the Committee.

Chairman LAMPSON. Thank you, Mr. Inglis, Ranking Member.

I ask unanimous consent that all additional opening statements submitted by the Subcommittee Members be included in the record. Without objection, so ordered.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. Thank you, Mr. Chairman, for holding today's hearing to review two renewable energy bills regarding geothermal and marine power technologies.

First, H.R. 2304 directs the Secretary of Energy to support research, development, demonstration, and commercial application of advanced technologies to locate and characterize geothermal resources and produce geothermal energy. Geothermal energy is heat from the Earth's core that is trapped in the Earth's crust. In underground fluid-filled reservoirs, hot water or steam can be used either to generate electricity or to heat buildings, greenhouses, or aquaculture operations. The U.S. has become the world's largest producer of electric power from geothermal energy; however, according to the U.S. Geological Survey (USGS), a significant number of geothermal resource locations remain hidden and unconfirmed. H.R. 2304 contains provisions to support research and development (R&D) of advanced technologies to assist in locating these hot water resources, and to encourage demonstration of advanced exploration technologies by the geothermal industry. Funding has gradually declined for geothermal energy R&D, with only $5 million appropriated for 2007. Further, the Administration requested no funding for the geothermal programs at the Department of Energy (DOE) for FY08 because they believe that geothermal technologies are mature, although that claim is disputed by geothermal researchers and the industry. I look forward to hearing from our distinguished witness panel on this point.

Second, H.R. 2313 directs the Secretary of Energy to support research, development, demonstration, and commercial application of technologies to produce electric power from renewable marine resources. Marine renewable energy refers to energy that can be extracted from ocean water. H.R. 2313 would support technology research and development to ensure that U.S. companies are competitive in this emerging global market, and that emerging technologies are developed in an environmentally conscious way. One of the concerns with utilizing marine renewable energy is the impact of power generation technologies on the marine environment and ecosystems. It is my understanding that additional research needs to be completed in this area to ensure that these devices do not have significant negative environmental impacts. To this end, I would like to know if there are additional environmental concerns associated with marine renewable energy development and I look forward to hearing the witness panel address my questions.

With that, I again thank the Chairman for calling this hearing.

Chairman LAMPSON. At this I would like to introduce our distinguished panel of witnesses starting with Dr. Jefferson Tester, who is the H.P. Meissner Professor of Chemical Engineering at Massachusetts Institute of Technology. Dr. Tester is an internationally recognized expert in enhanced geothermal systems and he served as chair of the MIT-led panel that produced the recent report, the Future of Geothermal Energy.

Mr. Paul Thomsen is Public Policy Manager for ORMAT Technologies Inc., a leading provider of geothermal exploration, development and power conversion technologies. Mr. Thomsen is responsible for ORMAT's federal, State and local legislative programs, and he is testifying today on behalf of both ORMAT and the Geothermal Energy Association. At this time I would like to recognize Congresswoman Hooley for introduction of Dr. von Jouanne.

Ms. HOOLEY. Welcome. Dr. Annette von Jouanne has been a Professor in the School of Electrical Engineering and Computer Science at Oregon State University since 1995. She received her Ph.D. degree in electrical engineering from Texas A&M. She specializes in energy systems including power electronics and power systems. With a passion for renewables, Dr. von Jouanne is leading the wave energy program at Oregon State University. She is also the Director of Motor Systems Resource Facility, the highest power university-based energy systems lab in the Nation. Dr. von Jouanne has received national recognition for her research and teaching and she is a registered professional engineer as well as a National Academy of Engineering "Celebrated Woman Engineer." Welcome to Washington, D.C., and our committee.

Chairman LAMPSON. Don't you miss Texas? I am glad you are here.

Mr. Sean O'Neill is Co-founder and President of the Ocean Renewable Energy Coalition, OREC, a trade association formed in April 2005 to promote and advance commercialization of marine renewable energy in the United States. Mr. O'Neill is responsible for all federal legislation and regulatory issues impacting coalition members.

And Mr. Nathanael Greene, who is a Senior Energy Policy Specialist with the Natural Resources Defense Council. His areas of expertise include utility regulation, renewable energy, energy taxes and energy efficiency.

We welcome all of you this morning, and you will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When all five of you have completed your testimony, we will then begin with questions. Each Member will have five minutes to question the panel.

Dr. Tester, would you begin, please?

STATEMENT OF DR. JEFFERSON TESTER, MEISSNER PROFESSOR OF CHEMICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. TESTER. Mr. Chairman and Members of the Committee, I am grateful for the opportunity to speak with you this morning on the new bill, H.R. 2304, that deals with geothermal energy research and development. Along with my testimony, I have included a hard copy of the executive summary of our recently completed assessment that you referred to. As you know, I was honored to serve as the Chair of the panel that conducted that assessment.

First, I am very pleased to see that the enormous potential of geothermal energy is receiving the attention it deserves. This committee's attention to, and leadership on, these issues is important to the country. As a very large, well-distributed, and clean indigenous energy resource, geothermal's widespread deployment would have a positive impact on our national energy security, on our environment and on our economic health. Regrettably, in recent years geothermal has been undervalued by many and was often ignored as a portfolio option for widespread development in the country. If this bill is enacted and supported with a multi-year commitment at the levels recommended, it will completely reactivate an important national-scale effort that will pay substantial dividends. Investing now in geothermal R&D coupled to a program of field demonstrations will have far-reaching effects towards ensuring a sustainable energy future for the U.S. for the long-term.

Enactment of this bill 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 an excellent option for the United States, complementing interruptible renewables such as solar and wind and thus increasing the robustness of the national portfolio.

Although conventional, high-grade hydrothermal resources are already being used effectively in the United States, and will continue to be developed, they are somewhat limited by their locations and ultimate potential. Beyond these conventional systems are Enhanced, or Engineered, Geothermal Systems (EGS) resources with enormous potential for primary energy recovery using heat-mining technology. EGS feasibility today is a result of improvements in reservoir characterization and stimulation technologies and in deep directional drilling that have evolved in the past three decades. It is the EGS approach that puts geothermal on the map as a potentially more sizable energy resource for the United States.

In the past few weeks I was fortunate to be able to visit several geothermal plants in the American West and in Iceland to observe the positive impacts that geothermal technology is having first-hand. 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. In Iceland, geothermal has enabled an economic and environmental transformation of the country in less than 60 years. Iceland's extensive geothermal network, developed by Reykjavik Energy and other companies, now provides 100 percent of Iceland's heating needs and 25 percent of their electric power with hydro providing the remainder. Iceland's example of geothermal utilization is a model that the United States should strive to emulate. Obviously Iceland is a special place geologically and only some regions of the United States share those features.

However, the development of EGS technology puts geothermal within reach for a much larger portion of the United States.

Even though the United States is currently the largest worldwide producer of electricity from geothermal energy, the total capacity is barely 3,000 megawatts, much smaller than our total overall generating capacity. Fortunately, the actual potential for geothermal is much larger. As you pointed out, our analysis suggests that a focused national program could enable geothermal capacity to reach 100,000 megawatts in 50 years, comparable to the current generating capacity of our nuclear and hydropower plants. In order to achieve such levels, a natural transition from the country's high-grade hydrothermal systems in use today in the West to the massive EGS resources available over a range of grades across the country would need to occur in increasing amounts in the next ten to 15 years. The fact that this bill addresses both short- and long-term research, development, demonstration and deployment issues and needs across this continuum of geothermal grades is particularly noteworthy, and from my perspective, essential to the success of the national program.

I have included a few additional comments on some details of the bill in my written testimony. Thank you again for giving me the opportunity to support this landmark legislation and thank you for your leadership on this issue.

[The prepared statement of Dr. Tester follows:]

PREPARED STATEMENT OF JEFFERSON TESTER

The Future of Geothermal Energy

Overview:

Mr. Chairman and Members of the Committee, I am grateful for the opportunity to speak with you this morning on the new bill H.R. 2304 covering the *"Advanced Geothermal Energy Research and Development Act of 2007,"* which was introduced in the House of Representatives on May 14 to direct the Secretary of Energy to conduct a national program for geothermal energy. Along with my testimony, I have included a hard copy of the Executive Summary of our recently completed national assessment—*"The Future of Geothermal Energy."* I was honored to be the Chair of an expert interdisciplinary group that conducted that assessment which was released in January.

First, I am very pleased to see that the enormous potential of geothermal energy is receiving the attention it deserves. This committee's attention to and leadership on these issues is important to the country. As a very large, well-distributed, and clean, 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 bill is enacted and supported with a multi-year commitment at the levels recommended, it will completely reactivate an important national-scale effort that will pay substantial dividends. Investing now in geothermal research and technology development coupled to a program of field demonstrations will have far reaching effects towards insuring a sustainable energy future for the U.S. for the long-term.

Enactment of this bill will restore U.S. leadership internationally. It will put us on a path to utilize our massive geothermal resource to provide dispatchable, base-load capacity 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.

Let me briefly describe to the committee what geothermal energy is. Geothermal resources are usually described in terms of stored thermal energy content of the rock and contained fluids underlying land masses 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. Beyond these conventional hydrothermal systems are Enhanced Geothermal Systems or 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. EGS feasibility is a result of improvements in reservoir characterization and stimulation technologies 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. EGS would operate as a closed system with cool water pumped deep into hot fractured rock reservoirs where it would be heated and then returned to the surface to be used as an energy source to generate electricity or directly for heating applications Aside from conventional hydrothermal and EGS, other geothermal resources also include co-produced hot water associated with oil and gas production, and geo-pressured resources that contain hot fluids with dissolved methane.

In the past few weeks I was fortunate to be able to visit several geothermal plants in the American West and in Iceland to observe the positive impacts that geothermal technology is having firsthand. For example, ORMAT's new plant in Reno, Nevada completely re-injects 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. In Iceland, geothermal 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 1940s 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 100 percent of Iceland's heating needs and 25 percent of their electric power with hydro providing the remainder. They are now actively pursuing a means to eliminate their dependence on imported transportation fuels by substituting hydrogen produced by electricity generated from super-critical geothermal resources. Iceland's example of geothermal utilization is a model that the U.S. should strive to emulate. 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.

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 generating capacity, which now exceeds 1,000,000 MWe or one TWe. Fortunately, the actual potential for geothermal energy in the U.S. is substantially greater than 3000 MWe as pointed out recently by 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 RD&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.

The fact that this bill addresses both short- and long-term research, development, demonstration, and deployment issues is particularly noteworthy. 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 percent or more of our generating capacity by 2050 (that is >100,000 MWe), it is essential that a national program address both short and longer 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, to enhance the quantitative assessment of U.S. geothermal resource on a site-specific basis and second, to demonstrate and validate that reservoir stimulation and drilling technologies can repeatedly and reliably be implemented in the field to produce commercial-scale geothermal systems. Sound geoscience and geoengineering scientific approaches would be used that build on current methods for 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.

I have included a few additional comments on some details of the bill in my written testimony. Thank you again for giving me the opportunity to support this important landmark legislation, and thank you for your leadership on this issue.

Specific comments on the bill:

1. In Sec. 3. (1) Regarding the definition of EGS—As engineered systems, it would be good to point out that intervention is needed to address one or more of the following—1. lack of sufficient permeability or porosity or open fracture connectivity within the reservoir, 2. insufficient contained water and/or steam in the reservoir, and/or 3. lower average geothermal gradients requiring deeper drilling.
2. In Sec. 4(b,1)Resource assessment—In order for this task to be achieved effectively it will require proactive coordination and engagement of the DOE and its contractors with the USGS, MMS, BLM and other federal agencies.
3. Secs. 4 and 5 Opportunities for direct heat use and co-generation of heat and power—Given the large improvement in energy efficiency that occurs in direct or combined heat and power utilization of geothermal, co-generation applications for residential and commercial buildings should be considered for demonstrations along with providing baseload electric power generation.
4. Sec. 7 impact on Secs. 6(b)(1) and (2) Co-funding requirements for EGS technology development and early EGS field demonstrations—A 20 percent non-federal cost sharing for EGS technologies development and a 50 percent requirement for field demonstration plants are likely to be excessive at such an early stage of the reactivated geothermal program. In general, it may be difficult for universities to meet these cost sharing levels and some may inadvertently be excluded from participating in the R&D program.
5. Importance of international cooperation—Provisions should be included to enable vigorous international collaboration on EGS and hydrothermal technology where appropriate because such collaboration leverages U.S.-based support and will facilitate the incorporation of new scientific and technological developments for geothermal utilization into the U.S. program.
6. Sec. 10. (6) Utilization of co-produced fluids—Although not a conventional EGS or hydrothermal resource, co-produced fluids provide a short-term, economically attractive opportunity for utilizing the low grade thermal energy produced during the production of oil and gas. Provision for their consideration should indeed be part of a national effort, but they seem to be misplaced in Sec. 10. as they represent shorter-term opportunities.
7. Developing the next generation of U.S. scientists and engineers needed to deploy.
8. Geothermal—In order to achieve the high impact goals of geothermal deployment, it will be necessary to increase the number of professionals working on geothermal technology in the U.S.

This process would be enhanced by connecting the national RD&D program to education in science and engineering at the college, university and professional levels using internships, graduate fellowships, and similar instruments.

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 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 co-produced hot water associated with oil and gas production, and geo-pressured 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 percent in the past 10 years and is now more than one TWe. For the past two 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 re-licensing 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 baseload 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 two km^3 at depths from four to five km has been created and tested at fluid production rates within a factor of two to three 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 three to five km. We can now stimulate large rock volumes (more than two 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 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 six 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 down-hole 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 super-critical water region will lead to measurable gains. For example, at super-critical 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 down-hole 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 super-critical 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 one 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 (co-generation) 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 co-produced 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, multi-year 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 co-funding 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 baseload 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, multi-year 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.

References

The references listed below are part of those cited in the Synopsis and Executive Summary of *The Future of Geothermal Energy,* by Tester, J.W., B.J. Anderson, A.S. Batchelor, D.D. Blackwell, R. DiPippo, E. Drake, J. Garnish, B. Livesay, M.C. Moore, K. Nichols, S. Petty, M.N. Toksoz, R.W. Veatch, R. Baria, C. Augustine, E. Murphy, P. Negraru, and M. Richards, MIT report, Cambridge, MA (2006). A list of all the literature that was reviewed and evaluated is in the full report which is available at
http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf

Armstead, H.C.H. and J.W. Tester. 1987. *Heat Mining.* E. and F.N. Spon, London.

Blackwell, D.D. and M. Richards. 2004. *Geothermal Map of North America.* Amer. Assoc. Petroleum Geologists, Tulsa, Oklahoma, 1 sheet, scale 1:6,500,000.

Bodvarsson, G. and J.M. Hanson. 1977. "Forced Geoheat Extraction from Sheet-like Fluid Conductors." *Proceedings of the Second NATO–CCMS Information Meeting on dry hot rock geothermal energy.* Los Alamos Scientific Laboratory report, LA–7021:85.

Energy Information Administration (EIA). 2006–2007. *Annual Energy Outlook* and other EIA documents, U.S. Department of Energy (DOE), web site *http://www.eia.doe.gov/*

McKenna, J., D. Blackwell, C. Moyes, and P.D. Patterson. 2005. "Geothermal electric power supply possible from Gulf Coast, Mid-continent oil field waters." *Oil & Gas Journal,* Sept. 5, pp. 34–40.

Sanyal, S.K. and S.J. Butler. 2005. "An Analysis of Power Generation Prospects From Enhanced Geothermal Systems." *Geothermal Resources Council Transactions,* 29.

U.S. Geological Survey, Circulars 726 and 790, Washington, DC (1975, 1979).

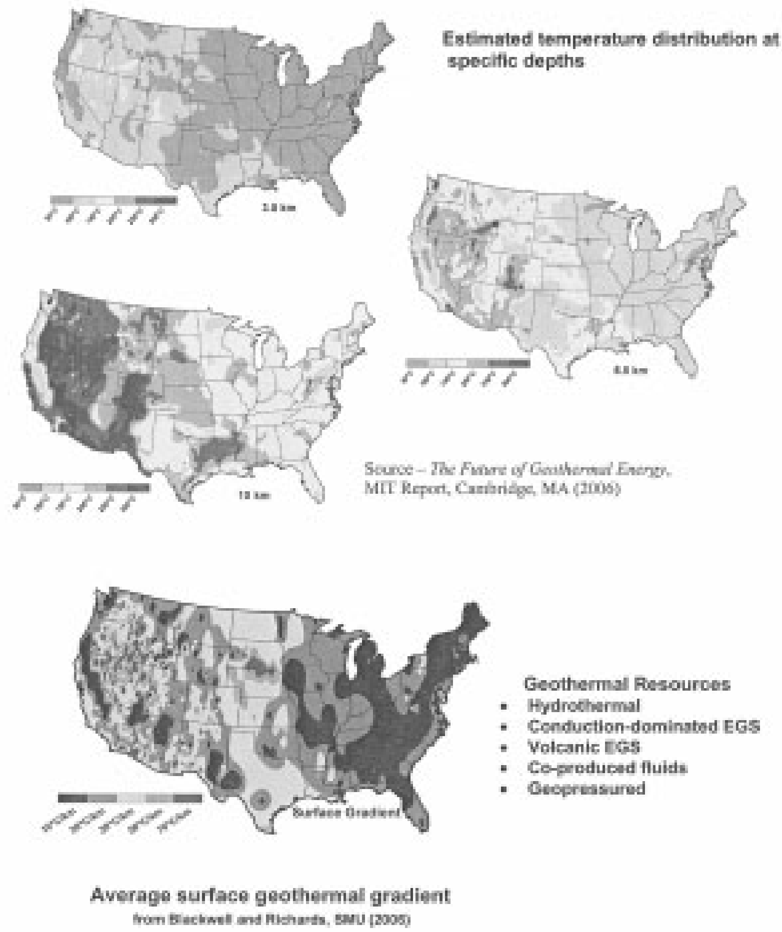


Figure 1. Estimated temperature distribution at specific depths and the average geothermal gradient distribution at the surface in the contiguous United States.

Table 1 Estimated U.S. geothermal resource base to 10 km depth by category (from *The Future of Geothermal Energy*, MIT Report, Cambridge, MA (2006)

Category of Resource	Thermal Energy, in Exajoules (1EJ = 10^{18} J)	Reference
Conduction-dominated EGS		
Sedimentary rock formations	>100,000	This study
Crystalline basement rock formations	13,900,000	This study
Supercritical Volcanic EGS*	74,100	USGS Circular 790
Hydrothermal	2,400 – 9,600	USGS Circulars 726 and 790
Coproduced fluids	0.0944 – 0.4510	McKenna, et al. (2005)
Geopressured systems	71,000 – 170,000**	USGS Circulars 726 and 790

* **Excludes Yellowstone National Park and Hawaii**
** **Includes methane content**

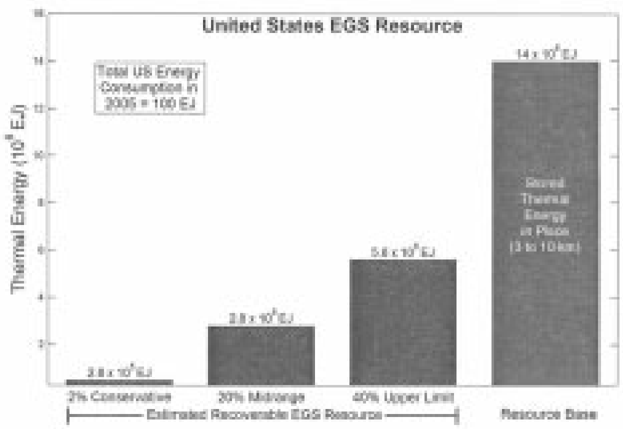


Figure 2. Estimated total U.S. geothermal resource base and recoverable resource the 40% upper limit is based on the analysis of Sanyal and Butler (2005) while lower recoverable amounts are estimates from *The Future of Geothermal Energy*, MIT report, 2006.

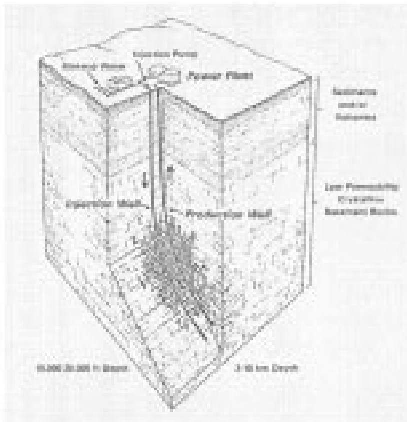


Figure 3. Schematic of a conceptual two-well enhanced geothermal system (EGS) in hot rock, in a low-permeability crystalline basement formation. Connectivity has been established by hydraulically stimulating the rock contained between the injection and production wells.

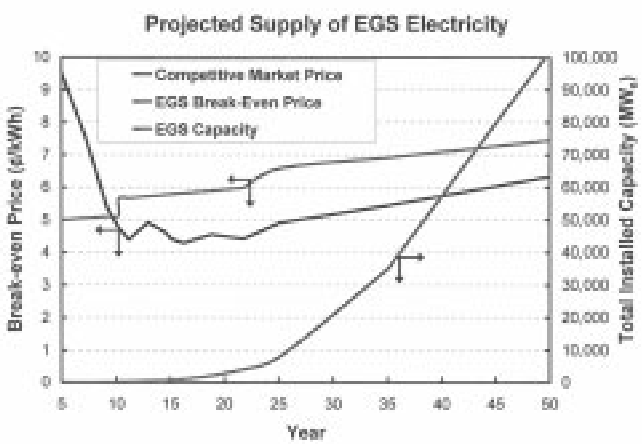


Figure 4. Estimated supply curve for EGS based on the MITEGS economic model. (from *The Future of Geothermal Energy*, MIT Report, Cambridge, MA (2006))

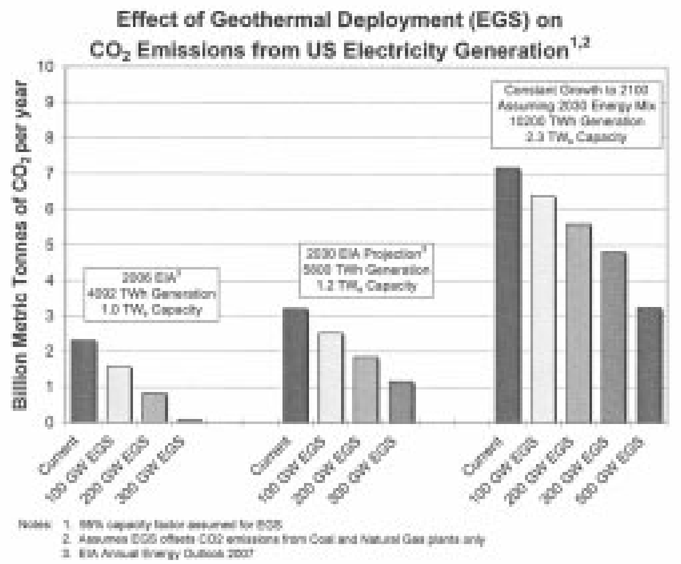


Figure 5. Estimated U.S. carbon emission reductions resulting from geothermal deployment

Chairman LAMPSON. Thank you, Dr. Tester.

Mr. Thomsen.

STATEMENT OF MR. PAUL A. THOMSEN, PUBLIC POLICY MANAGER, ORMAT TECHNOLOGIES, INC.

Mr. THOMSEN. Mr. Chairman, Members of the Committee, it is my honor to testify today on behalf of ORMAT Technologies, a leading producer of geothermal energy around the world and in the United States, and on behalf of the Geothermal Energy Association (GEA).

ORMAT and the GEA applaud Representative McNerney for introducing H.R. 2304, which directs the Secretary of Energy to conduct a program of research, development, and demonstration of commercial applications to expand the use of geothermal energy production. This legislation is crucial in directing the Department of Energy to implement what we feel was the legislative intent of the 2005 *Energy Policy Act* that was never realized due to the immediate reduction and termination of the geothermal budget only months after the 2005 *Energy Policy Act* was enacted. This bill, if passed, will seed the basic research, provide cost sharing and disseminate the information necessary to quickly and efficiently move this country away from its dependence on foreign oil.

I submit to you all that this bill is necessary to push the Administration in the direction of funding the research necessary to fully develop this country's homegrown, green, domestic geothermal energy supply. Geothermal energy currently provides this country with 2,800 megawatts of clean, renewable, domestic energy which generates on average 16 billion kilowatt-hours of energy, or enough power to light up two million homes. But I would like to point out, however, that in 1979 the U.S. Geological Survey estimated a hydrothermal resource base in this country between 95,000 and 105,000 megawatts. In 2006, the Geothermal Task Force of the Western Governors Association identified 5,600 megawatts of geothermal power that could be developed with existing incentives. Today the GEA believes that 74 new geothermal energy projects are under some form of development in the United States and can provide an additional 2,500 megawatts of electrical power capacity. As this new capacity comes online, it will represent an investment of roughly $8 billion. It will create 10,000 new full-time jobs and stimulate over 40,000 person-years of construction and manufacturing employment across this country. However, if we add the additional 2,500 megawatts coming online to our current production, we see that we will produce approximately 5,300 megawatts from a known hydrothermal resource base that was conservatively estimated at 150,000 megawatts in 1979. I ask you, is that the best we can do? Is 3.5 percent utilization of our clean, domestic, baseload resource acceptable to a country that imports 10 million barrels of oil a day and is 60 percent dependent on net petroleum imports?

H.R. 2304 recognizes that the answer is "no." The time to take action is now. There are substantial needs for improvements in technology, resource information and efficiency for which federal research is vital. Join me, please, in supporting H.R. 2304 and capitalizing upon one of our greatest national assets, human ingenuity. H.R. 2304 will allow the men and women of our national laboratories, universities, state energy offices and private enterprise to develop cutting-edge geothermal projects and technology that will make use of this country's vast untapped geothermal potential.

On behalf of ORMAT, I want to applaud this committee for its interest in a secure domestic baseload energy supply that is geothermal energy. We humbly realize that the decisions made by this committee impact our nation's energy security.

This concludes my introductory comments and I will be happy to respond to any questions this committee might have.

[The prepared statement of Mr. Thomsen follows:]

PREPARED STATEMENT OF PAUL A. THOMSEN

Mr. Chairman, Members of the Committee, it is my honor to testify today on behalf of not only ORMAT Technologies, but also on behalf of the Geothermal Energy Association whose testimony has been reviewed and approved by the entire Board of Directors and will be submitted along with my testimony into the record.

By way of introduction ORMAT Technologies, is a New York Stock Exchange registered company (symbol "ORA"). ORMAT technologies develops, owns, and operates geothermal and recovered energy facilities throughout the world. ORMAT has supplied 900 MWs of geothermal power plants in 21 countries. Here in the United States ORMAT owns and operates approximately 300 MWs of geothermal power plants in the states of California, Hawaii, Nevada, and we are pleased to be providing U.S. Geothermal Company with the technology needed to bring Idaho's first geothermal power plant online.

We applaud Rep. McNerney for introducing H.R. 2304 which would direct the Secretary of Energy to conduct a program of research, development, demonstration and commercial applications for geothermal energy. This legislation would authorize a program that will help develop the science and technology needed to utilize the vast untapped geothermal resources of our nation.

ORMAT believes a vast potential exists that could help meet the country's growing electricity needs, spur economic growth and help reduce emissions of greenhouse gases. The Geothermal Task Force of the Western Governors Association's Clean and Diversified Energy Advisory Group identified 5,600 MW of geothermal power that could be developed with existing incentives, and another 13,000 MW that could be tapped with additional time, higher prices, or both. Of course, these estimates assume today's level of technology, which is a major variable that could change these results.

H.R. 2304 would authorize and direct DOE to undertake a research program that would develop the tools and technology needed to find and successfully develop the hydrothermal resource base. Without the support of the Federal Government as proposed in H.R. 2304 it is our view that most of the hydrothermal resource base will not be developed under current conditions. H.R. 2304 would also direct the Department to take the steps towards developing full scale enhanced geothermal systems (EGS) technology. From ORMAT's experience every MW of clean, baseload, geothermal energy we bring on line represents a three million capital investment by our company.

H.R. 2304 also would establish centers of geothermal technology transfer. Information is important to improve exploration, application of technology, and improved performance of geothermal development and production efforts. ORMAT feels that the proposal to establish such centers would be an important aid in efforts to tap our nation's geothermal resources.

ORMAT recognizes that H.R. 2304 does list both co-production and geo-pressured resources as items to be addressed by the Secretary of Energy in a required report to Congress on advanced uses of geothermal energy. If additional provisions are not included in the bill, we would hope that the Department would take this opportunity to re-examine its views of these, and all geothermal technologies, to develop programs that would effectively tap this enormous, undeveloped domestic energy supply.

ORMAT believes cost-sharing is an appropriate and necessary component of a near-market partnership between the government and a for-profit entity. For an example of what can come from this type of collaboration I turn to the fact that ORMAT has signed a cost-shared Cooperative Research and Development Agreement (CRADA) with DOE to validate the feasibility of a proven technology already used in geothermal and Recovered Energy Generation (REG).

The project will be conducted at the DOE Rocky Mountain Oil Test Center (RMOTC), near Casper, Wyoming, and will use an ORMAT Organic Rankine Cycle (ORC) power generation system to produce commercial electricity. ORMAT will supply the ORC power unit at its own expense while the DOE will install and operate the facility for a 12-month period. ORMAT and the DOE will share the total cost of the test and the study, with ORMAT bearing approximately two thirds of the less than $1M total investment.

Presently there are two large unutilized sources of hot water at the RMOTC Naval Petroleum Reserve No. 3, which produces water in excess of 190 degrees Fahrenheit and at flow rates sufficient for generation of approximately 200 kW. This project will consist of the installation, testing and evaluation of a binary geothermal power unit in the field near these hot water sources. The ORC power unit will be interconnected into the field electrical system and the energy produced will be used by RMOTC and monitored for reliability quality.

The information gathered from this project may have implications to the some 8,000 similar type wells have been identified in Texas, by Professor Richard Erdlac of the University of Texas of the Permian Basin, and the U.S. DOE Geothermal Research Project Office. Lyle Johnson senior engineer at the RMOTC stated "The introduction of geothermal energy production in the oil field will increase the life of the fields and bridge the gap from fossil energy to renewable energy." Why are we zeroing out a research budget that provides such potential for this country.

ORMAT believes that the full geothermal potential of the western United States can be brought online in the near-term with the assistance of legislation as proposed by Rep. McNerney.

On behalf of ORMAT, I want to applaud this committee for its interest in the secure domestic baseload energy supply that **is** geothermal energy. We humbly realize that the decisions made by this committee impact our nation's energy security. This concludes my prepared comments I am happy to respond to any questions the Committee might have.

STATEMENT OF THE GEOTHERMAL ENERGY ASSOCIATION

Mr. Chairman and Members of the Subcommittee, we applaud the Subcommittee for holding this hearing entitled "Developing Untapped Potential: Geothermal and Ocean Power Technologies." We submit this statement on behalf of the Board of Directors of the Geothermal Energy Association.

While only a small fraction of the geothermal resource base is utilized today, geothermal energy provides significant energy for our nation. The United States is the world's largest producer of geothermal electricity. The 2,800 MW existing power capacity generates an average of 16 billion kilowatt hours of energy per year.

According to a GEA survey released last week, seventy-four new geothermal energy projects are under development in the U.S. that will provide an additional 2,900 megawatts of electric power capacity. This new capacity will represent an investment of roughly $6 billion, create 10,000 new full-time jobs, and stimulate over 40,000 person-years of construction and manufacturing employment across the Nation.

While this new development is impressive, much more potential exists that could help meet the country's growing electricity needs, spur economic growth, and help reduce emissions of greenhouse gases. The Geothermal Task Force of the Western Governors' Association's Clean and Diversified Energy Advisory Group identified 5,600 MW of geothermal power that could be developed with existing incentives, and another 13,000 MW that could be tapped with additional time, higher prices, or both. Of course, these estimates assume today's level of technology, which is a major variable that could change these results.

Yet, even if these resources were developed, they would represent only a fraction of the hydrothermal resource base. The U.S. Geological Survey (USGS), in its Circular 790, estimates a hydrothermal resource base of between 95,000 and 150,000 MW, of which 25,000 are known resources. Most of the resources identified in the WGA study were known resources in 1979 when the USGS completed its report. In 1979 we lacked the technology to find and characterize most of the hydrothermal resource base, and unfortunately today we still lack that technical capability.

In addition to significant electric power generation, direct uses of geothermal resources by businesses, farms, and communities have substantial additional potential for energy, economic, and environmental benefits. While geothermal resources have been used in communities and homes for decades—for example Boise, Idaho has been using geothermal resources for space heating for over 100 years—the extensive potential for direct use has been largely ignored and underutilized. Direct use resources span the entire country—from New York to Hawaii—and their expanded use could displace fossil fuels.

Beyond the conventional hydrothermal resources powering our existing generating plants and providing process heat, new types of geothermal resources are emerging. Recent estimates indicate a substantial potential for geothermal production from hot water co-produced in oil and gas fields, and there is renewed interest in geo-pressured resources in Texas, Louisiana and the Gulf. These hold significant future energy potential. Finally, development of the techniques for engineering geothermal systems (EGS) holds the promise of expanding economic production from known geothermal systems and someday allowing production from EGS power systems virtually anywhere in the U.S.

The benefits of expanding new geothermal production will be substantial. Geothermal power can be a major contributor to the power infrastructure and economic well-being of the United States. Geothermal power is a reliable, 24/7 baseload energy source that typically operates 90 to 98 percent of the time. Insulated from fuel market price volatility, geothermal power supports energy price stability and boosts energy security because it is a domestic resource. Geothermal power can help diversify the Nation's energy supply and is a clean, renewable energy source.

The surge in geothermal development portrayed in GEA's new survey has been stimulated by the federal production tax credit (PTC), which was first extended to geothermal power facilities in 2005. The PTC provides the incentive needed to encourage investment in new projects, and state renewable portfolio standards (RPSs) ensure that there is a market for geothermal power. In the near-term, both are essential to sustain the momentum we are witnessing in new project development, but to develop the full potential of the resource advances in technology will be essential.

There are substantial needs for improvements in technology, resource information, and efficiencies for which federal research is vital. The range of near-term needs is broad. Our knowledge of the geothermal resource base is limited and largely outdated. The technology available today to identify and characterize the resource is too unreliable to mitigate the high risk of development. Drilling in harsh geothermal environments is difficult and expensive. In locations where the resource cannot presently support commercial production, we need to be able to apply EGS techniques to achieve power generation at competitive prices.

The geothermal industry supports a continued geothermal research program to address the near-term need to expand domestic energy production and the longer-term need to find the breakthroughs in technology that could revolutionize geothermal power production. This includes an ongoing R&D program focused on further expanding the hydrothermal resource base, developing the technology needed to make the EGS concept commercially viable, and taking advantage of the substantial deep thermal resources associated with the petroleum formations along the Gulf Coast. These programs are critical if we are to maintain our national status in cutting-edge geothermal technology, which is increasingly in jeopardy.

The January 2006 report of the WGA Geothermal Task Force Report also supports the need for federal research efforts. The Task Force Report recommends: "a strong, continuing geothermal research effort at the Department of Energy that addresses the full range of technical problems encountered in achieving full production from the identified and undiscovered resources in the West." The report also supports ". . .continuation of advanced technology programs and outreach through GeoPowering the West." In addition, the report urges DOE to expand its program in critical areas "particularly the identification and development of new resources" and "support for exploration and exploratory drilling." Finally, it asks the Department of Energy (DOE) to "examine whether existing federal loan guarantee authority in law can be used to supplement these activities to reduce risk and encourage development of new resource areas." (*http://www.westgov.org/wga/initiatives/cdeac/geothermal.htm*)

We applaud Rep. McNerney for introducing H.R. 2304 which would direct the Secretary of Energy to conduct a program of research, development, demonstration and commercial applications for geothermal energy. This legislation would authorize a program that will help develop the science and technology needed to utilize the vast untapped geothermal resources of our nation.

One of the best overviews of that potential is presented in the National Renewable Energy Laboratory's (NREL) Technical Report published in November 2006, *Geothermal—The Energy Under Our Feet.* The report examines what it terms the "enormous potential of geothermal resources." It estimates what the full range of geothermal energy technologies could contribute by 2015, 2025 and 2050. (*Geothermal—The Energy Under Our Feet* is available at *http://www.nrel.gov/docs/fy07osti/40665.pdf*) The following chart shows NREL's estimate of this potential:

Table 1 – Findings by Resource Category

			Estimated Developable Resources		
	Estimated Accessible Resource (MWe)	2006 (Actual MWe)	2015 (MWe)	2025 (MWe)	2050 (MWe)
Shallow Hydrothermal[1] (Identified) >90°C/194°F	30,000	2,800	10,000	20,000	30,000
Shallow Hydrothermal[1] (Unidentified) >150°C/302°F	120,000		TBD	TBD	TBD
Co-Prod & Geo-Press[2]	>100,000	2[3]	10,000 to 15,000	70,000	>100,000
Deep Geothermal[4]	1,300,000 to 13,000,000	0	1000	10,000	130,000
Thermal Uses	(MWt)	(MWt)	(MWt)	(MWt)	
Direct Use[5]	>60,000	620	1600	4,200	45,000
GHP[6]	>1,000,000	7,385	18,400	66,400	>1,000,000
GHP[6] Avoided Power	120,000	880	2,100	8,000	120,000

The NREL report points to at least three areas where geothermal resources might contribute 100,000 MW of more to domestic energy supplies: first, the hydrothermal resource base; second, oil and gas co-production and geo-pressured resources; and, third, development of "deep geothermal" (or EGS) production. H.R. 2304 defines specific research efforts to address at least two of these three energy opportunities.

H.R. 2304 would authorize and direct DOE to undertake a research program that would develop the tools and technology needed to find and successfully develop the hydrothermal resource base. While tax incentives and State support may be able to double or triple current geothermal production, that would still be far short of tapping the Nation's hydrothermal potential. Developing 10,000 or even 20,000 MW of geothermal energy would be only a fraction of the estimated hydrothermal resource. But, without the support of the Federal Government as proposed in H.R. 2304, it is our view that most of the hydrothermal resource base will not be developed under current conditions.

H.R. 2304 would also direct the Department to take the steps towards developing full scale EGS technology. A Massachusetts Institute of Technology (MIT)-led study released in January 2007 found "that mining the huge amounts of heat that reside as stored thermal energy in the Earth's hard rock crust could supply a substantial portion of the electricity the United States will need in the future, probably at competitive prices and with minimal environmental impact." (An Executive Summary and the full MIT report, *The Future of Geothermal Energy,* are available at: *http://www1.eere.energy.gov/geothermal/future_geothermal.html*).

We understand that Professor Jeff Tester of MIT will testify before the Subcommittee, so we will defer a lengthy discussion of EGS technology and its potential. However, GEA supports development of EGS technology as a critical element of DOE's long-term research strategy.

H.R. 2304 also would establish centers of geothermal technology transfer. Access to information can help improve exploration, application of technology, and improved performance of geothermal development and production efforts. The proposal to establish such centers would be an important aid in efforts to tap our nation's geothermal resources.

The one major area of potential identified by NREL that H.R. 2304 does not address with specific authorizing direction is oil and gas field co-production and geopressured resources. These resources hold substantial energy potential, but serious uncertainties that keep the market from moving forward must be addressed by federal efforts.

For co-production, there are uncertainties about the resource information as well as the best fit for power technology. Until there is better and more detailed information about the resource potential, and companies have experience using small scale power technology in these applications, it is unlikely that there will be rapid commercialization of geothermal technology in oil field settings. Near-term cost-shared demonstrations at several sites would be the best approach to resolving these issues and accelerating development of the energy potential from co-production. We suggest the Committee consider adding this directly to the legislation rather than waiting for the report from the Secretary of Energy required by Section 10.

The potential of geo-pressured resources is impressive. They contain enormous quantities of hot water and gas. The recoverable gas from geo-pressured reservoirs has been estimated to be several hundred years supply for the entire Nation. Geopressured resources are to natural gas what oil shale resources are to liquid fuels—a potentially enormous source of energy. Unfortunately, the one demonstration conducted by DOE twenty years ago was terminated after a short period of operation, it did not seek to optimize for gas production, and it was based upon what is now somewhat dated technology. Today, we have begun to import greater quantities of natural gas, and projections show the U.S. becoming much more dependent upon natural gas imports in the future.

Developing the technology to produce gas from geo-pressured geothermal resources could curtail our growing dependence on imports, but the cost and extreme risk of geo-pressured development will not be undertaken by industry alone. It requires a partnership with the government. Given the enormous resource potential, such an effort is justified and in the national interest.

We recognize that H.R. 2304 lists both co-production and geo-pressured resources as items to be addressed by the Secretary of Energy in a required report to Congress on advanced uses of geothermal energy. If additional provisions are not included in the bill, we hope the Department will take this opportunity to re-examine its views of these, and all geothermal technologies, to develop programs that would effectively tap this enormous, undeveloped domestic energy supply.

The cost-sharing requirements of H.R. 2304 raise a number of questions. While in principle, GEA believes cost-sharing is an appropriate and necessary component of a near-market partnership between the government and a for-profit entity, it's not clear that the provisions of the legislation recognize appropriately the role of contractors and researchers who lack the resources and profit-potential motivation to enter into a significant cost-share. In addition, we suggest that the Subcommittee consider making all cost-share requirements ranges rather than single proposed percentages and including in the measure some of the basic criteria DOE should use to determine when a cost share is appropriate and at what percentage. This might provide better results while maintaining the principle which we believe the legislation seeks to affirm.

Finally, we encourage the Committee to examine whether the update of the national geothermal resource assessment being conducted by the U.S. Geologic Survey will be adequate and complete. This will be the first assessment in over 25 years, and it is critical to the future progress in geothermal energy production. Policy-makers at all levels need accurate and reliable information about the potential contribution of geothermal resources. To be adequate and complete, the USGS assessment should examine the full range of geothermal resources identified in the NREL Report and include field verification as necessary.

We have attached to this statement a letter from Leland Roy Mink, the former Manager of the DOE Geothermal Research Program, who expresses his support for the legislation and the Subcommittee's initiative.

We thank the Subcommittee for considering our views, and encourage all Members of the Subcommittee to support H.R. 2304. This legislation is urgently needed to ensure that federal energy programs work to tap the tremendous potential of our nation's geothermal energy resources.

Attachment

Honorable Congressman Lampson, Chairman
Subcommittee on Energy and Environment
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman,

I wish to express strong endorsement for draft legislation the Subcommittee is considering for support of DOE Geothermal Research and Development. This legislation is critical for continued development of the tremendous geothermal energy potential the U.S. possesses and the leadership role the U.S. has established in geothermal technology.

I am writing because of deep concern about the DOE decision to terminate the geothermal technology program. I have been active in geothermal and other energy development throughout the U.S. and internationally for over 35 years and recently retired as the manager of the U.S. DOE Geothermal Technologies Program. I feel it is definitely not in the best interest of the Nation to terminate a viable, domestic, renewable, non-polluting energy resource at this time. You, as the Subcommittee, have an opportunity now to make a significant contribution to the U.S. energy portfolio.

Geothermal energy could play a significant role in addressing the U.S. need for a clean renewable energy source. Historically electrical generation from geothermal has led both wind and solar and supplied significant power to several Western states. Geothermal heat pumps for heating and cooling of homes, schools and businesses has sizable potential throughout the U.S. Recent studies by the Massachusetts Institute of Technology and the National Renewable Energy Laboratory show significant electrical potential not only in the Western states, but indicate a strong potential throughout the U.S.

The DOE Geothermal Program support has resulted in significant technology breakthrough in areas of exploration, drilling, energy conversion and Enhanced Geothermal Systems (EGS), which has resulted in the U.S. being a leader in development of geothermal energy. Cost shared programs with industry have stimulated development of this important and valuable domestic resource and without this support, industry will not be able to maintain its technological lead. DOE support to our national laboratories and universities has resulted in the advances in technology and the training of scientists and professionals for the future. Support to State energy office also has resulted in effective technology transfer to stimulate and expedite geothermal development.

In conclusion, the Subcommittee is at a critical stage in deciding the Nation's energy future and I feel geothermal energy can play an important role in addressing the needs of the U.S. energy future. We need all of the domestic possibilities for the U.S. and geothermal is one of the only baseload, non-polluting, renewable energy sources we have available to us. It could play a significant role in reducing our dependence on fossil fuel and the addressing the issue of climate change as a result of CO_2 emissions.

I urge you to support legislation to direct DOE to conduct the best possible geothermal research program to tap the potential of this resource. Our nation needs it. It would also be a tragedy to see the U.S. lose its status as a world leader in geothermal technology development and the resultant decline in the U.S. Geothermal industry.

Respectfully submitted,

Leland Roy Mink
Past Geothermal Program Manager
22088 S Cave Bay
Worley, Idaho 83876

Chairman LAMPSON. Thank you very much, Mr. Thomsen.
Dr. von Jouanne.

STATEMENT OF DR. ANNETTE VON JOUANNE, PROFESSOR OF POWER ELECTRONICS AND ENERGY SYSTEMS, OREGON STATE UNIVERSITY

Dr. VON JOUANNE. Thank you. I have a PowerPoint presentation. It turns out they don't have it set up so no problem.

Mr. Chairman, Members of the Committee and in particular Congresswoman Hooley, thank you very much for this opportunity to present to you on wave energy opportunities and developments, and we are strongly in support of this marine bill which we think is imperative for the United States to lead the world in wave energy research, development and production.

So first off, I would like to state that I am Annette von Jouanne and I am a Professor of Power Electronics and Energy Systems. I have been leading our wave energy program at Oregon State University for the past several years and we have a terrific group of multi-disciplinary faculty including an excellent group of multi-disciplinary undergraduate and graduate students who are graduating with a keen understanding of the importance of renewables for our country, and with a real enthusiasm to make a strong impact on our energy future. At Oregon State, we have strong outreach efforts to the ocean community, which are coordinated by Oregon Sea Grant. We have been moving forward in four thrust areas: number one, to advance research on wave energy devices where we are designing devices to respond directly to the heaving motion of the ocean waves and convert that motion into electrical energy. We are proposing a national wave energy research and demonstration center and we are encouraging Federal Government investment dollars to further this research.

Wave energy is really in the preliminary stages of development with several topologies emerging and no clearly superior engineering solutions yet established, and so research and development dollars are essential for the Federal Government to really zero in on these optimum topologies, and you will see those topologies in the PowerPoint presentation which I had submitted to you. We also at Oregon State have been promoting the Oregon coast as an optimal place for commercial wave parks. Off the West Coast of the United States we now have 12 Federal Energy Regulatory Commission preliminary applications for wave parks and of those 12, seven are off the Oregon coast. Also, we are looking to examine the environmental and ecological impacts and we have a workshop planned on the Oregon coast this summer.

So the reason for all the excitement in wave energy is the tremendous opportunities that we see when compared to other renewables. When you look at the amount of energy that is available in the world's oceans, it is estimated that if just 0.2 percent of that unharnessed energy could be tapped, we could power the entire world, and of those forms of ocean energy, wave energy has been identified to have significant potential and significant advantages regarding energy density, availability, and predictability, and I am happy to answer further questions on those details during the question session.

So at Oregon State University, we have strategic facilities to advance this research. Our energy systems lab, also a wave research lab, has North America's largest system of wave basins and we have plans for our first ocean testing this summer. Again I want to emphasize that these technologies are in the preliminary stages and federal dollars are really necessary in order to zero in on optimal topologies to help the U.S. Government really lead the world in research and production. To give you an idea, we have done resource assessments off the Oregon coast, and we have found that during the winter months we see wave energy potentials in the range of 50 to 60 kilowatt per meter of crest length. Considering that an average coastal home uses about 1.3 kilowatts, there is substantial raw energy available in our waves.

We have substantial collaboration in Oregon with our universities, with the industry, with the utilities, and we therefore would like to encourage a national wave energy research and demonstration center to be located in Oregon in order to advance the research and the technologies. We are very pleased that the State of Oregon has recognized the need for public dollar investment in wave energy and we encourage the Federal Government to invest in this emerging renewable technology so that wave energy can be a strong component of our country's renewable energy portfolio.

Thank you very much for your time and this opportunity to testify.

[The prepared statement of Dr. von Jouanne follows:]

PREPARED STATEMENT OF ANNETTE VON JOUANNE

I. Introduction to Wave Energy Opportunities and Developments

Mr. Chairman, Members of the Committee, and Congresswoman Hooley in particular, thank you for inviting me to testify today before this Subcommittee. I am Annette von Jouanne and I am a Professor of Power Electronics and Energy Systems at Oregon State University. I am honored to testify before you today on the subject of Ocean Wave Energy.

Ocean energy exists in the forms of wave, tidal, marine currents (from tidal flow streams), thermal (temperature gradient) and salinity. Among these forms, significant opportunities and benefits have been identified in the area of wave energy extraction, which will be the focus of this testimony.

When we discuss Wave Energy, we are talking about harnessing the linear motion of the ocean waves, and converting that motion into electrical energy. Waves have several advantages over other forms of renewable energy, in that the waves are more available (seasonal, but more constant) and more predictable with better demand matching. Wave energy also offers higher energy densities, enabling devices to extract more power from a smaller volume at consequent lower costs and reduced visual impact.

Oregon State University (OSU) has a multi-disciplinary Wave Energy Team pursuing developments in four thrust areas: 1) researching novel direct-drive wave energy generators (we are on our fifth and sixth prototypes, with further wave lab and ocean testing planned this summer), 2) developing an action plan for a National Wave Energy Research and Demonstration Center in Oregon, 3) working closely with the Oregon Department of Energy (ODOE) and a variety of stakeholders to promote Oregon as the optimal location for the Nation's first commercial wave parks, and 4) examining the biological and ecosystem effects of wave energy systems.

II. Current Ocean Wave Energy Research, Development and Investment Activities

OSU's direct-drive wave energy buoy research focuses on a simplification of processes, i.e., replacing systems employing intermediate hydraulics or pneumatics with direct-drive approaches to allow generators to respond directly to the movement of the ocean by employing magnetic fields for contact-less mechanical energy transmission, and power electronics for efficient electrical energy extraction. The term "direct" drive describes the direct coupling of the buoy's velocity and force to the generator without the use of hydraulic fluid or air.

Leading Wave Energy companies, such as Ocean Power Technologies (OPT), Finavera Renewables, Ocean Power Delivery (OPD) and Oceanlinx, are using hydraulic and pneumatic technologies, because it makes sense for a company trying to accelerate their time to a commercial market to use more mature technologies. In the university environment, as we are working with students on advanced degrees, we endeavor to explore innovative and advanced technologies.

Wave energy developments in the United States are moving forward rapidly, with twelve (12) preliminary permits filed with FERC (Federal Energy Regulatory Commission) for off the West Coast (see Attachment 1). The first commercial wave energy device deployments are planned by the summer of 2008. Remaining obstacles include issues of survivability, reliability, maintainability, cost reduction, better understanding of potential environmental/marine impacts and synergistic ocean community interaction with wave parks. OSU has made great efforts over the past nine (9) years to develop a leading Wave Energy program, including building strong support at the state and federal levels, in addition to building essential collaborations with industries, utilities and the communities along with outreach to the ocean community of fishermen and crabbers, etc.

III. The Federal Role in Ocean Wave Energy Research and Development

Currently there has been very little investment by the Federal Government compared to the rest of the world, and thus as occurred similarly in the wind industry, the United States is lagging behind other countries in the development of wave energy technologies. For the United States to become a wave energy leader in what is projected to become a rapidly developing new set of industries, the Federal Government needs to significantly increase their investment in wave energy research and development.

It has been reported that since 1999, the British government has committed more than £25 million, or approximately $46.7 million, to research and development and £50 million to commercialize that research, and additional money to bring the energy into the electrical grid. In August of 2004, a £5.5 million ($10.72 million) European Marine Energy Center opened in Scotland. To date, the United State has no comparable facility.

Ideally, we believe the U.S. Department of Energy, the Office of Naval Research, and the National Oceanographic and Atmospheric Administration (NOAA) should all begin investing in Ocean Wave Energy research. However, we believe it is imperative for the U.S. Department of Energy to become the leader in this field and to begin making a robust investment in Wave Energy research. As DOE's National Renewable Energy Laboratory (NREL) is charged with leading the Nation in renewable energy and energy efficiency research and development, it is our belief that NREL should establish a unit dedicated to ocean wave energy research.

Along these lines, the combination of key facilities at OSU, ongoing successful wave energy research and collaboration, and a tremendous wave climate off the Oregon coast has led to the proposal of a National Wave Energy Research and Development Center. In order to ensure U.S. leadership in what will become a multi-million dollar industry worldwide (multi-"billion" dollar as the wind industry is tracked), the Center could advance wave energy developments through a number of initiatives including: explore and compare existing ocean energy extraction technologies, research and develop advanced systems, investigate efficient and reliable integration with the utility grid and intermittency issues, advancement of wave forecasting technologies, conduct experimental and numerical modeling for device and wave park array optimization, develop a framework for understanding and evaluating potential environmental and ecosystem impacts of wave energy, establish protocols for how the ocean community best interacts with wave energy devices/parks, develop wave energy power measurement standards, determine wave energy device identification/navigation standards, etc.

The Oregon Coast has an excellent Wave Energy climate, and combined with our strategic facilities at Oregon State University, Oregon is in an excellent position to advance Wave Energy research, development and production. For example, at OSU, we have the highest power Energy Systems lab in any university in the Nation, where we have conducted significant work in renewables, and where we can fully regenerate back on to the grid to comprehensively research and test renewable energy technologies. In addition, at OSU we have the O.H. Hinsdale Wave Research Lab, which has the largest system of wave basins in North America. At the coast in Newport, Oregon, we have the OSU Hatfield Marine Science Center, where land-based facilities for a National Wave Energy Research and Demonstration Center could be integrated. The OSU Hatfield Marine Science Center campus is already home to satellite labs and offices for a number of federal agencies—the U.S. Fish and Wildlife Service, NOAA, EPA, and USDA–ARS.

To properly explore these Wave Energy opportunities, we have been working closely with Oregon Department of Energy (ODOE) and about 40 other agencies, including the Oregon fishing and crabbing industries, to enable the Nation's first Commercial Wave Parks to be developed off the Oregon Coast.

IV. Other Issues and Conclusion

As mentioned above, a significant barrier to wave energy development is the above-market cost of the electricity. Due to the early stage of this industry, the current cost of electricity production from waves is estimated to be several times the market price, similar to wind when it was emerging 20 years ago. To ensure the success of wave energy as a promising renewable contribution to the Nation's energy portfolio, the production incentive is very important to offset the above-market costs of producing 'wave' generated electricity. At the federal level, it is critical that wave energy receive a similar incentive mechanism to the production tax credits that the wind industry receives.

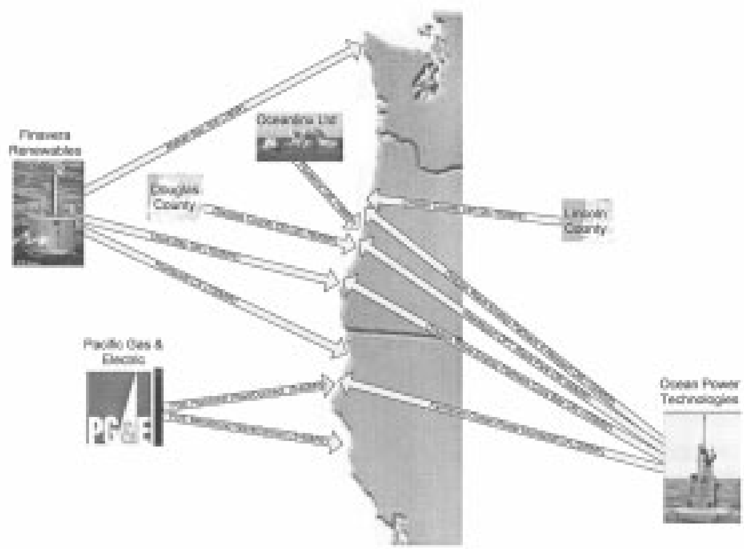
As the Nation tries to meet its renewable energy goals, ocean wave energy must be a part of the portfolio. Given that approximately fifty percent of the U.S. population lives within fifty miles of the U.S. coastline, we must invest in making ocean energy viable—this cannot be done without the robust support of the Federal Government's research agencies.

In the State of Oregon we are very excited to be a leader in wave energy development. We have the wave resource, the expertise through collaboration including tremendous industry, utility and community support, and the utility infrastructure along the coast to deliver this clean, renewable power into the grid.

Thank you for the opportunity to testify before this esteemed Subcommittee.

Attachment 1

Wave Energy preliminary permits filed with FERC



Wave Energy Opportunities and Developments

Wave Energy Lead Professors:
Annette von Jouanne, Ph.D., P.E.
Professor of Power Electronics and Energy Systems
School of Electrical Engineering and Computer Science (EECS)
Oregon State University (OSU)

Ted Brekken, Bob Paasch,
Solomon Yim, Alex Yokochi, and an
Excellent Multidisciplinary Group of *Undergraduate and Graduate Students*

Oregon Coastal Community Contributors:
Port Liaison Project Team (fishermen and crabbers)
Newport Wave Energy Team (local government, utilities, other stakeholders)

OSU's multidisciplinary wave energy team is pursuing Wave Energy innovation in four thrust areas:

1) Researching novel direct-drive wave energy generators

2) Developing an action plan for a National Ocean Wave Energy Research and Demonstration Center *(Goal)*

-Essential for the U.S. to be a leader in wave energy

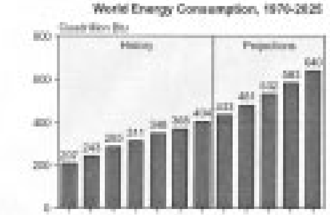
-Currently very little investment by Federal Government/DOE compared to the rest of the world

(OSU has received NSF, DOE STTR, BPA funding)

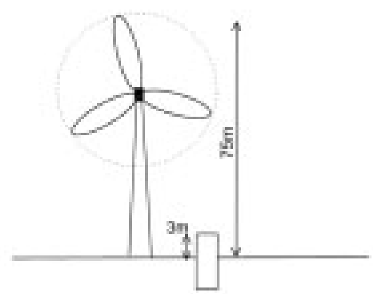
3) Working closely with the Oregon Department of Energy (ODOE) and a variety of stakeholders to promote Oregon as the optimal location for the *nation's first* commercial wave parks.

4) Examining the biological and ecosystem effects of wave energy systems

Introduction



Sources: History: Energy Information Administration (EIA), International Energy Annual 2001, DOE/EIA-0219(2001) (Washington, DC, February 2003), web site www.eia.doe.gov/iea/. Projections: EIA, System for the Analysis of Global Energy Markets (2003).



New forms of Energy are required !

- *It is estimated that if 0.2% of the ocean's untapped energy could be harnessed, it could provide power sufficient for the entire world.*

Compared to Other Renewables, Wave Energy Advantages:

Higher energy density, availability (80 – 90%) and predictability

- ***OSU is an Excellent Location to conduct ocean wave energy extraction research:***
- ***Highest Power University-Based Energy Systems Lab***
- ***O.H. Hinsdale Wave Research Lab***
- ***Hatfield Marine Science Center***
- ***Wave energy potentials of the Oregon coast.***

OSU Strategic Facilities to Advance Wave Energy

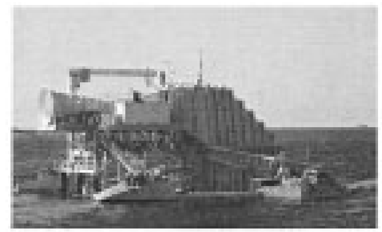
Motor Systems Resource Facility (MSRF)

O.H. Hinsdale Wave Research Lab (HWRL)

Wave Energy Extraction Technologies

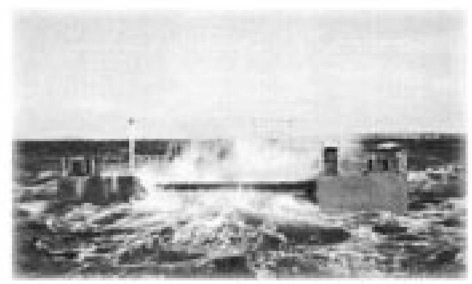
Point Absorber (OPT, Finavera)

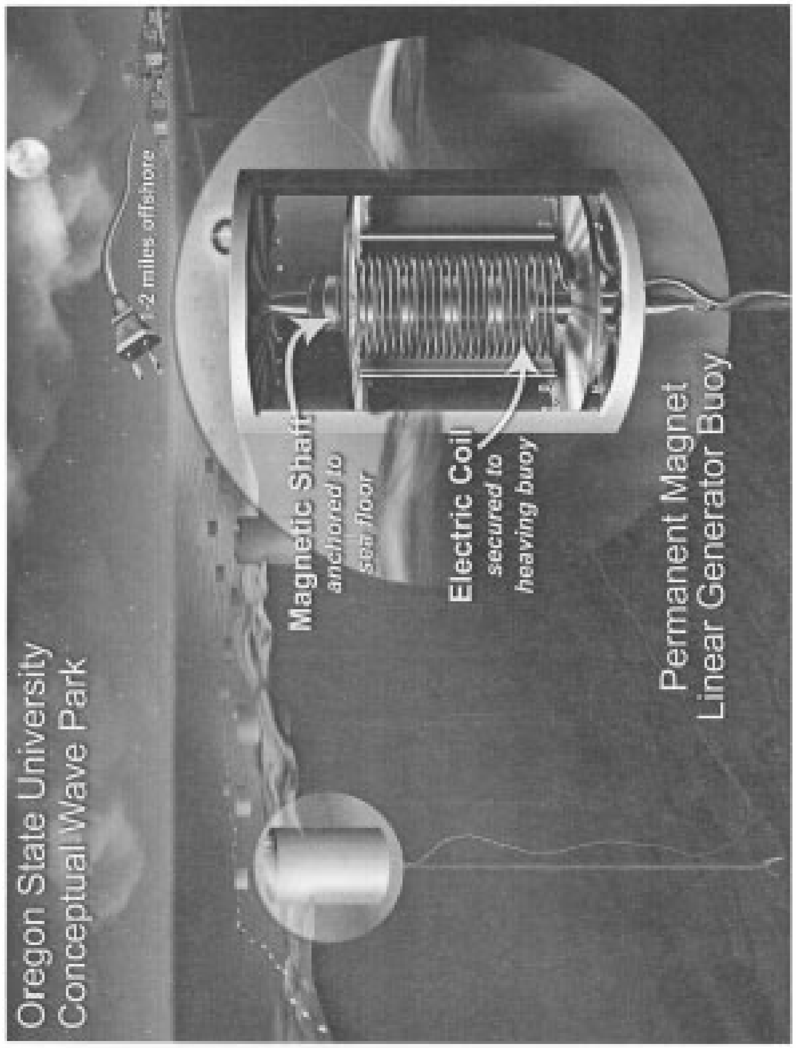
Oscillating Water Column (Energetech/Oceanlinx)



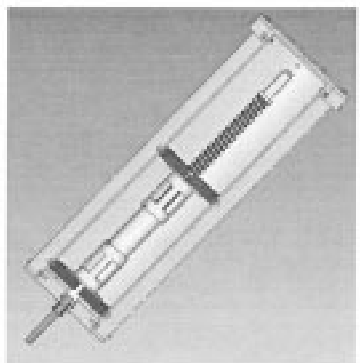
Attenuator, OPD

Overtopping, Wave Dragon



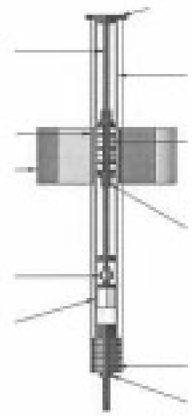

Oregon State University
Conceptual Wave Park
~2 miles offshore
Magnetic Shaft
anchored to
sea floor
Electric Coil
secured to
heaving buoy
Permanent Magnet
Linear Generator Buoy

OSU's Direct Drive Buoy Approaches (Now working on 5th and 6th prototypes)



Permanent Magnet Linear Generator

Permanent Magnet Rack and Pinion Drive



Contact-less Force Transmission

Licensing through Columbia Power Technologies
(Further Wave Lab and Ocean Testing Planned this summer)

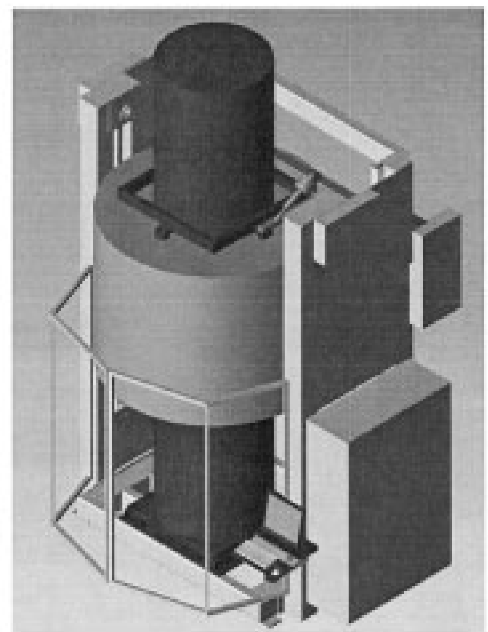
OSU Wave Energy Linear Test Bed

Creates the relative linear motion between a center "spar" and a surrounding "float" (active components)

Enables dynamic testing, using captured wave profiles, while simulating the actual response of ocean waves

Specifications:

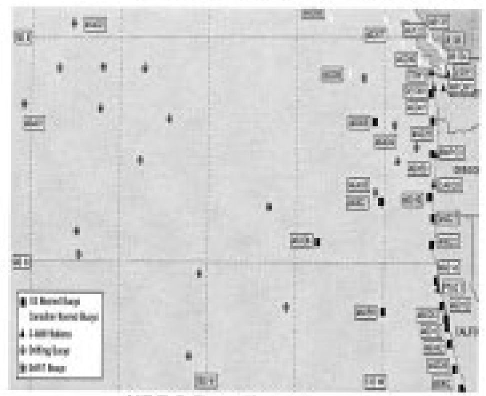
- 10kW with a 50% efficient device, and up to 19kW @ 95% efficiency, will also test generator sections
- 1m/sec @ 20,000 N Thrust (4500 lbf)
- 2m/sec @ 10,000 N Thrust (2250 lbf)
- Modes: Velocity, Point-Point, & Force Control (through feedback from load cells/force meters)
- 2m relative motion/stroke (6.5 feet)
- Upper & Lower Gimbal mounting (for alignment variation)
- 14ft tall x 10.5ft wide x 8.5ft deep



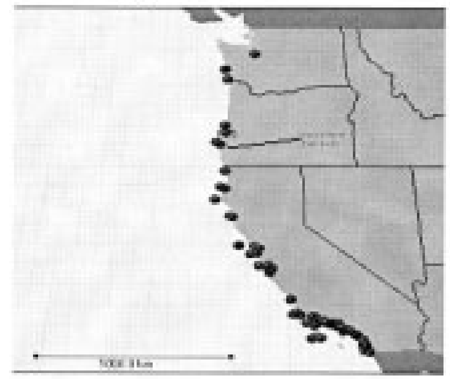
Design: Mundt and Associates Inc.

Power from Ocean Waves

Available Resource off Oregon Coast



NDBC Data Buoys

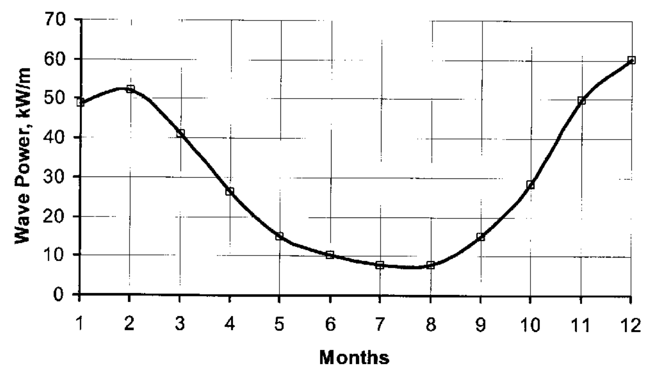


CDIP (SCRIPPS) Data Buoys

- 50% of the US population lives within 50 miles of the coast
- Wave Energy Resource Assessment Study carried out for Oregon Coast (Note that there are already a number of ocean monitoring buoys in the ocean)
- Report confirmed that Oregon has some of the richest ocean wave energy extraction sites in the world

Power from Ocean Waves
Available Resource off Oregon Coast

Seasonal variation – Good match for the NW load demand



(wave data From National Data Buoy Center, Power estimated from 5 buoys off the Oregon coast over past 10 years)

Data buoys are 2-200mi off shore, with waves traveling 15-20mph, gives 10+ hours forecast time for buoy generators located 2 mi out

Power from a wave is $P = \frac{\rho g^2 T H^2}{32\pi}$ W/m of crest length (distance along an individual crest)

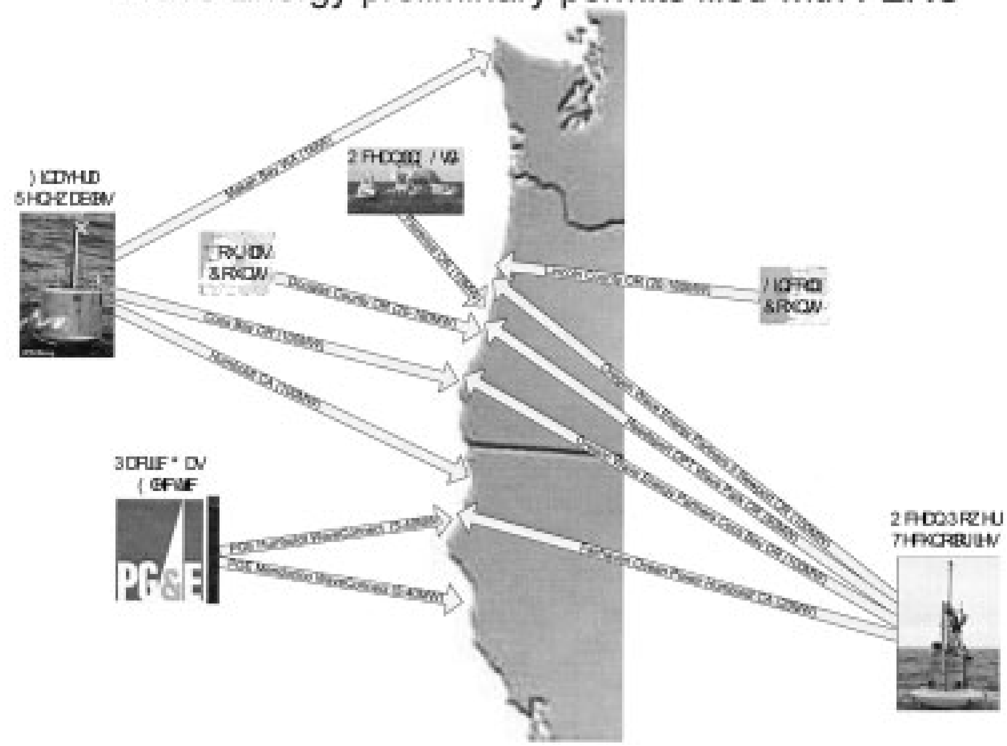
ρ = the density of sea water = 1025 kg/m^3

g = acceleration due to gravity = 9.8 m/s^2

T = period of wave (s) (averages 8s in the winter to 6s in the summer)

H = wave height (m) (averages 3.5m in the winter to 1.5m in the summer)

Wave Energy preliminary permits filed with FERC



Wave Energy Park Environmental Monitoring Protocol Development

Effects of Electromagnetic Fields:

- Sea bird attraction?
- Marine Mammal attraction, repulsion. Changes in whale migration pathways.
- Change in larval dispersion.
- Change in fish use of area, change in fish migration, change in fish reproductive success.
- Shark attraction.

Effects from construction/deployment/service of cables

- The most destructive aspect of laying natural gas lines is during the deployment of lines; the seafloor with its inhabitants are altered as the line is laid with large machinery. Similar effects could be expected with lying of electric cables if similar methods are used.
- Impact on invertebrates or seafloor structure from placement of anchors and power lines.
- Creation of a sediment plume and resulting impacts on fish/invertebrates.

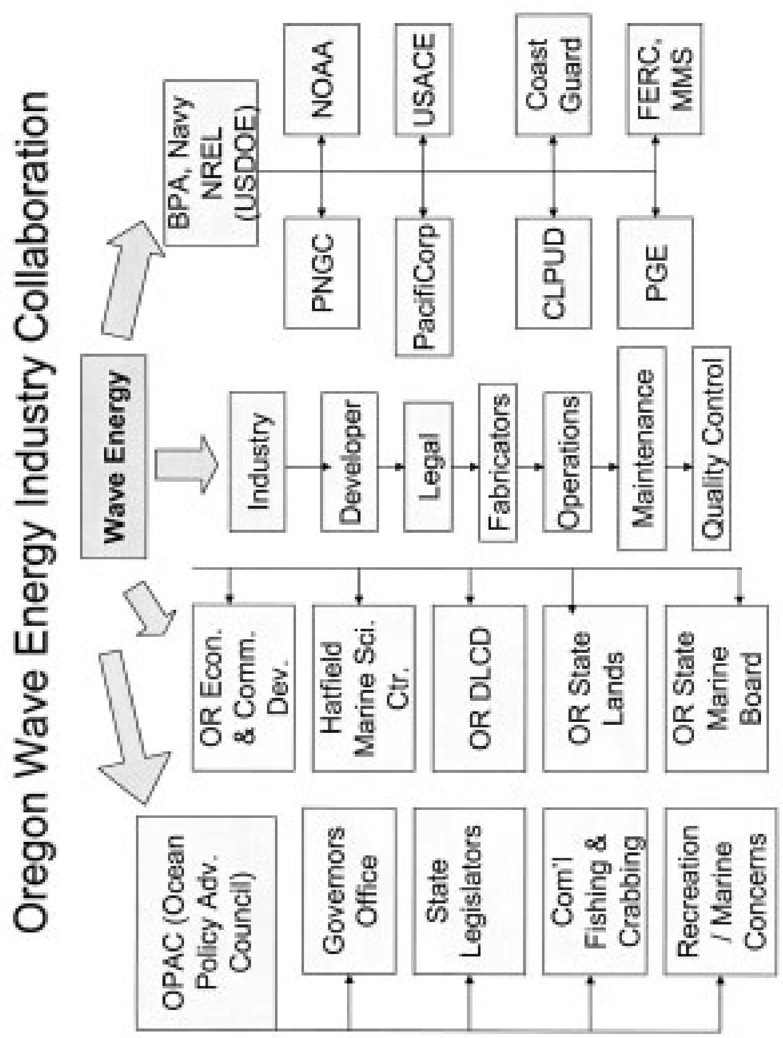
Effects of the physical structure of the buoy field.

- Entanglement of marine mammals: whales, dolphins.
- Effects of using antifouling agents: introduction of toxics.
- Creation of a new community:
  - Does the new structure act as a filter for larval dispersal so that recruitment in surrounding areas is decreased?
  - Will the structure create a new habitat that will facilitate recruit and production of marine organisms?

Monitoring needs to be scale appropriate.

- Impacts from small scale may not be scaleable to large energy generation farms.
- Monitoring program needs to be adaptive in design to respond to evolving impacts

Monitoring needs to compare manipulated and un-manipulated areas.



Oregon Wave Energy Industry Collaboration
Wave Energy
BPA, Navy NREL (USDOE)
PNGC
NOAA
PacifiCorp
USACE
CLPUD
Coast Guard
PGE
FERC, MMS
Industry
Developer
Legal
Fabricators
Operations
Maintenance
Quality Control
OR Econ. & Comm. Dev.
Hatfield Marine Sci. Ctr.
OR DLCD
OR State Lands
OR State Marine Board
OPAC (Ocean Policy Adv. Council)
Governors Office
State Legislators
Com'l Fishing & Crabbing
Recreation / Marine Concerns

Wave Energy Summary

- The Federal Government needs to significantly increase the investment in ocean wave energy R&D.
- A National Wave Energy Research and Development Center is necessary for the U.S. to lead the world in Wave Energy Research, Development and Production.
- Oregon is a "sweet spot" for ocean wave energy (facilities, successful research, wave climate, collaboration).
- The State of Oregon is currently reviewing a proposal to invest state dollars in ocean wave energy research, evaluation, and streamlining the permitting process.

BIOGRAPHY FOR ANNETTE VON JOUANNE

Dr. Annette von Jouanne has been a Professor in the School of Electrical Engineering and Computer Science at Oregon State University since 1995.

She received her Ph.D. degree in Electrical Engineering from Texas A&M University where she also worked with Toshiba International Industrial Division. Professor von Jouanne specializes in Energy Systems, including power electronics and power systems. With a passion for renewables, she is leading the Wave Energy program at OSU. She is also the Director of the Motor Systems Resource Facility, the highest power university-based Energy Systems Lab in the Nation. Dr. von Jouanne has received national recognition for her research and teaching, and she is a Registered Professional Engineer as well as a National Academy of Engineering "Celebrated Woman Engineer."

Chairman LAMPSON. Thank you very much.

Mr. O'Neill.

STATEMENT OF MR. SEAN O'NEILL, PRESIDENT, OCEAN RENEWABLE ENERGY COALITION

Mr. O'NEILL. Thank you, Mr. Chairman. I thank you and your colleagues for devoting your time and resources to the important topic of Congresswoman Hooley's Marine and—is my mic not working? I can normally fill up a room with my voice. Thank you. How is that? I think I was at the point of Congresswoman Hooley's *Marine and Hydrokinetic Energy Research and Development Act.*

The Ocean Renewable Energy Coalition is the national trade association for marine and hydrokinetic renewables including wave, tidal, ocean thermal and offshore wind. We are made up of 32 members including investment firms, investor-owned utilities, publicly owned utilities, consulting and law firms in countries including the United States, Canada, Scotland, Denmark and Ireland. The Electric Power Research Institute recently estimated the wave and tidal energy resource potential that could be commercially harnessed, not the total potential, in the United States as about 400 million megawatt-hours per year. That is about 10 percent of the national energy supply in 2004.

Projects underway in the United States include Finavera Renewables' Makah Bay project in Washington State, Verdant Power's Roosevelt Island project with six units that are installed and operating in the East River of New York City. New Jersey-based Ocean Power Technologies has projects in Hawaii, New Jersey and Reedsport, Oregon, with clients including the U.S. Navy and the New Jersey Board of Public Utilities. Multiple permits for sites in Maine, California, Oregon, Alaska and Florida have been filed with the Federal Energy Regulatory Commission including companies like Ocean Renewable Power Company, Tacoma Power and Snohomish PUD in Washington State, Pacific Gas and Electric in California, and Long Island Power Authority in New York. Europe has already installed 587 megawatts of offshore wind. Ocean Power Delivery of Scotland is presently developing the first commercial offshore wave farm off the coast of Portugal.

We are also finding new technologies emerging. University of Michigan has developed technology using free-flowing water and what they call vortex-induced vibrations which is being further developed by the company Vortex Hydro Energy. Offshore biomass using kelp and seaweed is also being looked at.

Dr. Robert Cohen, the former manager of Ocean System Division at DOE and member of the Ocean Energy Council, is in the audience today. He came out from Colorado, and I am confident that Dr. Cohen would agree when I say that encouraging innovation and supporting those technologies with commercial potential is vital to U.S. interests.

Naturally, costs vary with the type of technology. The Minerals Management Service's Whitepaper on Offshore Wind states that, where once the cost of offshore wind was about 40 cents a kilowatt-hour, over the past 20 years these costs have dropped to between four and six cents. For wave, costs have been estimated at nine to 16 cents a kilowatt-hour, far more favorable than the 40 cents a kilowatt-hour of the early offshore wind experience. For instream tidal, EPRI has predicted costs as low as six to nine cents per kilowatt-hour. Since the costs for all renewable resources is free from the fluctuating cost of fuel, the cost of energy to consumers from renewable sources functions like a fixed-rate mortgage as opposed to a variable-rate mortgage that resources that carry the burden of fuel cost have. In addition, non-technology costs are expected to drop as this industry matures. These include insurance and financing costs as well as much needed and anticipated regulatory and permitting reform.

Yes, the United States has fallen a bit behind other countries, but we are on track to quickly regain a competitive position. Portugal offers nearly 32 cents a kilowatt-hour in a feed-in tariff. Compare this to 1.9 cents per kilowatt-hour that wind gets in the United States. Britain offers 25 percent of capital cost reimbursement for wave and tidal projects.

We need to step up to the plate if we are going to compete. What the industry needs is more R&D funding and technology development including programs like the one at Oregon State University, resource assessment, environmental studies, incentives for private investment, reduced regulatory barriers. Development of a robust offshore renewables industry can do this. It can reduce our reliance on foreign oil and other carbon-emitting energy sources. It can reduce the demand for onshore land resources for power generation. We can revitalize shipyards, coastal industrial parks and shuttered naval bases; create jobs in coastal communities; allow the United States to export technology to other countries; provide low-cost power for niche and distributed uses like desalination plants, aquaculture, naval and military bases, powering stations for hybrid vehicles and for offshore oil and gas platforms. We could also provide a use for decommissioned oil platforms, using a rigs-to-renewables program. And last but not least, we could promote coastal planning that reflects the goals of biodiversity that maximize the best comprehensive use of resources and capitalizes on synergies between offshore industries. With the proper support, ocean renewable resources can become a robust part of a reliable, affordable, clean electric supply portfolio.

Thank you.

[The prepared statement of Mr. O'Neill follows:]

PREPARED STATEMENT OF SEAN O'NEILL

Introduction

Ocean Renewable Energy Coalition is the national trade association for marine and hydrokinetic renewable energy dedicated to promoting energy technologies from clean, renewable ocean resources. The coalition is working with industry leaders, academic scholars, and other interested NGO's to encourage ocean renewable technologies and raise awareness of their vast potential to help secure an affordable, reliable, environmentally friendly energy future.

We seek a legislative and regulatory regime in the United States that will accelerate the development of ocean renewable technologies and their commercial deployment. While other countries have already deployed viable, operating, power generating projects using the emission-free power of ocean waves, currents, and tidal forces, the U.S. is only beginning to acknowledge the importance these technologies.

Ocean energy can play a significant role in our nation's renewable energy portfolio. With the right support, the United States ocean energy industry can be competitive internationally. With the right encouragement, ocean renewable energy technologies can help us reduce our reliance on foreign oil—fossil fuels, in general—and provide clean energy alternatives to conventional power generating systems. And with the right public awareness, our coastline communities can use ocean renewables as a springboard for coastal planning that reflects the principles of marine biodiversity. Today, OREC will address the steps that we must take to realize the promise and potential of ocean renewables.

Is the resource there? Yes, and the resource is located near highly populated areas on the coast, placing fewer demands on already taxed transmission infrastructure.

Is the resource cost competitive? Not yet, but indications suggest a much shorter time to commercial viability than experienced by many other renewable technologies.

Is the resource environmentally friendly? Preliminarily yes. We already know that ocean renewables present some of the most potentially environmentally benign energy technologies available today—no air emissions, no fuel costs or associated mining or drilling effects, no fuel transportation costs. We are still learning about the effects of siting ocean renewable projects, though initial studies are showing minimal impacts. A Draft Environmental Impact Statement prepared by Finavera Renewables for its one MW Makah Bay project found no significant impacts; Ocean Power Technologies has received a "Finding of No Significant Impact" or FONSI from the U.S. Department of the Navy for its project in Hawaii; and most recently, Verdant Power, Inc. has been monitoring fish behavior at its Roosevelt Island Tidal Energy (RITE) facility in New York City since December of 2006 with no observations of fish strikes on their turbines. Verdant Power's experience began with two underwater turbines being installed and monitored by more than $2 million of fish monitoring equipment including a Didson sonar device that allows scientists and engineers to observe fish as they interact with turbines in the river. They have since installed six (6) turbines and continued monitoring. There are twenty-seven (27) different species of fish including herring and striped bass in this section of the East River. The project is presently producing one Mw/hr/day and scientists are watching the fish swim around the turbines with no fish striking any of the equipment.

As these are only early indications of how these technologies interact with the marine environment continued diligence is necessary to establish a thorough baseline of information.

Types of Technology

Ocean energy refers to a range of technologies that utilize the oceans or ocean resources to generate electricity. Many ocean technologies are also adaptable to non-impoundment uses in other water bodies such as lakes or rivers. These technologies can be separated into three main categories:

Wave Energy Converters: These systems extract the power of ocean waves and convert it into electricity. Typically, these systems use either a water column or some type of surface or just-below-surface buoy to capture the wave power. In addition to oceans, some lakes may offer sufficient wave activity to support wave energy converter technology.

Tidal/Current: These systems capture the energy of ocean currents below the wave surface and convert them into electricity. Typically, these systems rely on underwater turbines, either horizontal or vertical, which rotate in either the ocean current or changing tide (either one way or bi-directionally), almost like an underwater windmill or paddle wheel. These technologies can be sized or adapted for ocean or for use in lakes or non-impounded river sites.

Ocean Thermal Energy Conversion (OTEC): OTEC generates electricity through the temperature differential in warmer surface water and colder deep water. Of ocean technologies, OTEC has the most limited applicability in the United States because it requires a 40-degree temperature differential that is typically available in locations like Hawaii and other more tropical climates.

Offshore Wind: Offshore wind projects take advantage of the vast wind resources available across oceans and large water bodies. Out at sea, winds blow freely, unobstructed by any buildings or other structures. Moreover, winds over oceans are stronger than most onshore, thus allowing for wind projects with capacity factors of as much as 65 percent, in contrast to the 35–40 percent achieved onshore.

Other: Marine biomass to generate fuel from marine plants or other organic materials, hydrogen generated from a variety of ocean renewables and marine geothermal power. There are also opportunities for hybrid projects, such as combination offshore wind and wave or even wind and natural gas.

Q1. Please describe the potential for electric power generation from ocean renewables. How much energy could the ocean supply?

The U.S. wave and current energy resource potential that could be credibly harnessed is about 400 TWh/yr or about 10 percent of 2004 national energy demand.

EPRI has studied the U.S. wave energy resource and found it to be about 2,100 TWh/yr divided regionally as shown in the figure below. Assuming an extraction of 15 percent wave to mechanical energy (which is limited by device spacing, device absorption, and sea space constraints), typical power train efficiencies of 90 percent and a plant availability of 90 percent, the electricity produced is about 260 TWh/yr or equal to an average power of 30,000 MW (or a rated capacity of about 90,000 MW). This amount is approximately equal to the total 2004 energy generation from conventional hydro power (which is about 6.5 percent of total 2004 U.S. electricity supply).

EPRI has studied the North America tidal energy potential at fewer than a dozen selected sites. The tidal energy resource at those U.S. tidal sites alone is 19.6 TWh/yr. Assuming an extraction of 15 percent tidal kinetic energy to mechanical energy, typical power train efficiencies of 90 percent and a plant availability of 90 percent, the yearly electricity produced at the U.S. sites studied is about 270 MW (average power, rated capacity is about 700 MW). EPRI estimates that the total tidal and river in stream potential is on the order of 140 tWh/yr or about 3.5 percent of 2004 national electricity supply.

Q2. Please describe the current state of ocean power technologies in the United States and around the world.

The status of U.S. wave, current and tidal projects

At present, prototype offshore renewable projects are moving forward in the United States. These include the following:

- Finavera Renewables, Inc., has proposed a one MW pilot project for the Makah Bay off the coast of Washington State. The project is currently poised to complete a four-year permitting process at the Federal Energy Regulatory Commission (FERC).
- New York based Verdant Power is undergoing licensing at FERC and deployed two of six units of a tidal/current project located in the East River of New York in December 2006. Verdant Power, Inc. is in the process of deploying four more turbines scheduled for completion early May of 2007. These units will supply power to two commercial customers on Roosevelt Island imminently, once all regulatory clearances have been obtained.
- New Jersey based Ocean Power Technologies (OPT) has operated a test wave energy buoy off the coast of Hawaii for the U.S. Navy. It has also operated a buoy off the coast of New Jersey funded by Board of Public Utilities since 2005 and in July 2006, filed a preliminary permit for a commercial wave farm at Reedsport, off the coast of Oregon.
- ORPC Alaska, owned by Ocean Renewable Power Company (ORPC) of North Miami, Florida, recently secured Preliminary FERC permits for two sites in Alaska. ORPC Maine, also owned by ORPC, has applied for, and anticipates receiving very soon Preliminary FERC Permits for two sites in Maine. ORPC also has six Preliminary FERC Permits for sites off the east coast of Florida.
- Australian based Energetech, recently renamed to Oceanlinx Ltd, has formed a subsidiary in Rhode Island which has received funding from the Massachusetts Trust Collaborative and has planned a 750 kW project for Port Judith Rhode Island. Permitting has not yet commenced.
- Multiple permits for sites in Maine, California, Oregon, Alaska and Florida have been filed with the Federal Energy Regulatory Commission.
- The Mineral Management Service (MMS) now has authority to lease lands for offshore wind projects on the Outer Continental Shelf. MMS has conducted

environmental review of the proposed 420 MW Cape Wind Farm off the coast of Nantucket, MA and LIPA/FPL 100 MW project off the coast of Long Island, NY.

Status of Ocean Renewable Projects Overseas

In Europe, projects are moving ahead. Europe has already installed 587 MW of offshore wind in Denmark, Holland, Scotland, England and UK. See *http://www.bwea.com/offshore/worldwide.html*

Two near-shore wave projects, are operating in Scotland and Isle of Azores. Pelamis of OPD in Scotland is deploying the world's first commercial wind farm off the coast of Portugal and Marine Current Turbines has operated a prototype tidal project for two years.

Q3. What is the consumer price, per kWh, of ocean generated electricity. What are the projections for reduction in that price.

Naturally, costs vary with the type of technology. The MMS Whitepaper on Offshore Wind states that where once the cost of offshore wind was around forty cents/kWH, over the past twenty years, costs have dropped to between four and six cents/kwh. By 2012 and beyond, DOE envisions five MW and larger machines generating power for five cents/kWh.

Cost estimates are more difficult for wave and tidal, which in contrast to offshore wind, lack operational history. For wave, costs have been estimated as between nine and 16 cents/kWh, far more favorable than the 40 cents/kWH that offshore wind cost "out of the box." For in-stream tidal, the EPRI reports predicted costs as low as six to nine cents/kWH because tidal power's similarities to wind allow it to benefit from the advancements already made by wind and potentially share economies of scale.

And, the costs of offshore wind or wave are stable. Whereas natural gas and oil have fluctuated over the years (with natural gas now higher than ever), offshore wind and wave energy costs are stable, since the cost of renewable power sources like wind or wave are free. The analogy here is that the **cost to consumers for renewable energy, free from the fluctuating costs of fuel, functions like a fixed-rate mortgage as opposed to a variable rate mortgage associated with the use of finite fossil fuel resources.**

Also, costs are expected to decline as the industry matures and as economies of scale make ocean projects less costly. As the offshore wind industry makes advancements on mooring systems, turbine durability and other issues that bear on the cost of marine projects, these advancements will help bring down the cost of other ocean energy technologies. In addition, if we can gain a better assessment of our resources, we can target the most powerful sites first and learn from our experience in these locations to bring costs down further.

It is important to note that non-technology costs associated with these types of projects will also be reduced as the industry matures. These include insurance and financing, as well as much needed and anticipated regulatory and permitting reform.

Q4. Is the United States behind other countries in the development of the technology? Is this a result of a lack of federal investment?

Yes, the United States has fallen behind countries like Scotland, Portugal, Norway, and others; however, we are on a track to quickly regain a leading position. Portugal offers a €.235/kWH [equivalent to nearly $.32 (U.S.)] feed-in tariff. Compare this to the U.S., where the wind industry receives approximately $.019/kWH. and ocean renewables receive nothing. Britain pays substantial incentives including capital cost reimbursements of 25 percent. The United States needs to match these foreign incentives in order to attract and retain world class technology developers.

Permitting and regulatory obstacles are tremendous disincentives to companies developing ocean renewable projects in the United States, as well. While other countries have adopted permitting and regulatory regimes that appear to be more efficient, the United States is still struggling with exactly how to permit and regulate these technologies.

Q5. What kind of technological obstacles remain to the commercial viability of ocean power?

Advances in a number of other sectors have benefited the marine renewable industry sector including advanced materials, turbine design, and offshore construction. Listed below are the present day R&D requirements to support the development of marine and hydrokinetic technologies in the United States.

R&D Needs for the Ocean Renewable Energy Sector

(1) developing and demonstrating marine and hydrokinetic renewable energy technologies;

(2) reducing the manufacturing and operation costs of marine and hydrokinetic renewable energy technologies;

(3) increasing the reliability and survivability of marine and hydrokinetic renewable energy facilities;

(4) integrating marine and hydrokinetic renewable energy into electric grids;

(5) identifying opportunities for cross fertilization and development of economies of scale between offshore wind and marine and hydrokinetic renewable energy sources;

(6) identifying the environmental impacts of marine and hydrokinetic renewable energy technologies and ways to address adverse impacts, and providing public information concerning technologies and other means available for monitoring and determining environmental impacts; and

(7) standards development, demonstration, and technology transfer for advanced systems engineering and system integration methods to identify critical interfaces.

Specific R&D tasks

Wave Power

1. Technology road mapping
2. Resource characterization—Data and models to identify "hot spots"
3. Hydrodynamics—mathematical and physical modeling including arrays (especially non-linear and real fluid effects)
4. Control systems and methods for optimum performance (while ensuring survivability)
5. Power take off systems/smoothing especially direct drive
6. Materials—low cost
7. Materials, corrosion and biofouling
8. Construction methods—low cost
9. Performance specification standardization and test verification
10. Low cost moorings/deployment/installation/recovery methods
11. Ultra high reliability components (for minimum maintenance cost)
12. Electrical grid connection
13. System configuration evaluations (which are best under what circumstances)
14. Module size versus cost of electricity sensitivity
15. Results from pilot tests (especially to reduce cost and environmental impacts uncertainty).

Tidal Power

1. Technology road mapping
2. Resource characterization - Data and models to identify "hot spots" given complex bathymetry and turbulence
3. Hydrodynamics—mathematical and physical modeling including arrays (especially non linear and real fluid effects) and an evaluation of the efficacy of diffusers (i.e., ducted water turbine)
4. Control systems and methods for optimum performance
5. Power take off systems/smoothing especially direct drive
6. Materials—low cost
7. Materials, corrosion and biofouling
8. Construction methods—low cost
9. Performance specification standardization and test verification
10. Low cost moorings/deployment/installation/recovery methods
11. Ultra high reliability components (for minimum maintenance cost)
12. Electrical grid connection

13. System configuration evaluations (which are best under what circumstances)
14. Module size versus cost of electricity sensitivity
15. Results from pilot tests (especially to reduce cost and environmental impacts uncertainty).

Q6. What can Congress and/or the Federal Government do to help move the technology forward? Is there a role for federal support for R&D? Why is federal spending necessary?

The first thing Congress can do is pass designed to accomplish the following:

—More funding for R&D and technology development: Wind energy has benefited from substantial government investment. Thirty years ago, wind cost 30 cents/kWH to generate; today, that cost stands at three to seven cents/kWH. And even today, DOE continues to invest in wind. Just a few months ago, DOE announced a $27 million partnership with GE to develop large-scale turbines and also issued a $750,000 SBIR to Northern Power for offshore wind technology development.

Private developers have borne the costs of bringing the ocean energy technology forward for the past thirty years, but they need government support. Government funding will also give confidence to private investors and help attract private capital.

—Resource Assessment: At present, we do not even know the full potential of offshore renewables, because no agency has ever mapped the resource comprehensively. The *Energy Policy Act of 2005* directed the Secretary of DOE to inventory our renewable resources but that work has never been funded. And even as MMS moves forward with a rule-making for offshore renewables on the OCS, it has not received appropriations to map the resource.

Preliminary studies done by EPRI and private companies show that we have substantial ocean resources. But we will not know the full scope without further mapping and study.

—Incentives for Private Investment: Offshore renewables are compatible with other large industries in our country, such as oil and maritime industry. These industries, with the right tax incentives, can provide substantial support to offshore renewable development. Incentives could include investment tax credits for investment in offshore renewables and incentive to use abandoned shipyards and decommissioned platforms for prototypes and demonstration projects.

—Incentives for coastal communities: Coastal municipalities stand to gain tremendously from installation of offshore renewables. They need to be stakeholders in the process with a voice in development that takes place off their shores. Congress can support this by continuing to authorize Clean Renewable Energy Bonds (CREBS) and the Renewable Energy Portfolio Incentives (REPI) for coastal projects.

—Reduced regulatory barriers: Until companies get projects in the water, we will not learn about the environmental impacts or true costs of offshore renewables. Unfortunately, developers face onerous barriers to siting small, experimental projects. We should establish streamlined regulation and permitting for offshore renewables, with maximum cooperation between State and federal agencies.

Conclusion

Development of a robust offshore renewables industry can:

- Reduce reliance on foreign oil
- Rely upon ocean terrain for power generation as opposed to onshore land resources
- Revitalize shipyards, coastal industrial parks and shuttered naval bases
- Create jobs in coastal communities
- Allow the U.S. to transfer technology to other countries, just as a country like Scotland is exporting its marine renewables know-how
- Provide low cost power for niche or distributed uses like desalination plants, aquaculture, naval and military bases, powering stations for hybrid vehicles and for offshore oil and gas platforms
- Provide use for decommissioned oil platforms through "rigs to reefs program"
- Promote coastal planning that reflects the goals of biodiversity, that maximize best comprehensive use of resources and capitalizes on synergies between offshore industries.

Is the resource there? Yes, and the resource is located near highly populated areas on the coast, placing fewer demands on already taxed transmission infrastructure. The United States cannot afford to ignore

Ocean renewables can help diversify our energy portfolio and improve our environment. With the proper support, these resources will become a robust part of a reliable, affordable, clean electric supply portfolio.

BIOGRAPHY FOR SEAN O'NEILL

Sean O'Neill is co-founder and President of the Ocean Renewable Energy Coalition where he serves in a leadership role for all activities and is responsible for all federal legislative and regulatory issues impacting OREC members. He is also founder and principal of Symmetrix Public Relations & Communication Strategies where he serves the non-profit, energy, and human resources industries. Prior to founding Symmetrix, Mr. O'Neill served as Director of Public Affairs for U.S. Generating Company from 1993 to 2001. He has directed communications and public affairs programs in eighteen states supporting the development of over 8,000 megawatts of electric power generation. He has served numerous non-profit and non-governmental organizations in developing programs to encourage the development of ocean renewable technologies, electric industry deregulation, water conservation, municipal solid waste management and public safety contributing to broad public policy changes at State and federal levels, increased water and energy conservation, recycling, and seat belt use.

He has a Masters in Public Communications from American University where he has served on the adjunct faculty and holds an A.B. degree in English from Columbia College in New York.

Chairman LAMPSON. Thank you, Mr. O'Neill.

Mr. Greene.

STATEMENT OF MR. NATHANAEL GREENE, SENIOR POLICY ANALYST, NATURAL RESOURCES DEFENSE COUNCIL

Mr. GREENE. Mr. Chairman, esteemed Members of the Committee, thank you very much for having me here today. My name is Nathanael Greene. I am a senior policy analyst with the Natural Resources Defense Council. I spent a lot of time trying to think of a good joke that bridges geothermal and ocean energy but I just couldn't come up with one. So I will just leap right in here.

I think it is very appropriate that Congressman McNerney raised the history of the wind energy industry, onshore wind energy industry association. I think if we look at that, we can see one of the main points that I would like to talk about today, which is why when we do research and development, it is important to include the environmental impacts and study the baseline environmental conditions, the ecosystem conditions, the environmental interactions of the technologies that we are looking at. We are now at the fortunate stage in the onshore energy industry that we are seeing a lot of concentration of projects in certain parts of the country and so states have started to come together individually and as groups to really try to understand what the cumulative impacts of large-scale development will be, and I think as we look forward to expanding these technologies and NRDC certainly comes at these two technologies in reviewing these two bills with the hope that we can make these technologies large-scale contributors to our energy mix. But as we come at them, we need to think not just about what one project will look like, or what one pilot installation will look like, but what many projects will look like. Particularly in the ocean technologies, which are tapping an energy source that is generally less dense than, say, a fossil fuel or even some of the other renewable energy resources, the individual installation may just be one of hundreds of individual pieces of equipment that make up a single project. When you are looking at multiple projects in some areas, you may be looking at many, many pieces of equipment. So thinking about cumulative impact from the get-go is absolutely critical.

Similarly, in the wind energy industry association and the history, we can see the really significant impacts of an early black eye in the development of the industry. If you look out in California with the Altamont Pass project and the history of that project and its impacts particularly on endangered bird species, they have created at least two decades of slowdown in the development of that industry and questions around the development of that industry that could have been avoided if we had done more research and development, understood better what the interactions of wildlife and technology were from the get-go, and instead of developing some of our first projects in very sensitive areas, found better places where there were still good resources but fewer potential impacts, we might have been able to avoid that whole diversion and unfortunate slowdown in the industry.

And the last point I would like to make is really about the permitting. Building this baseline of information, the consensus between regulators, the public, and the industry about what are the real, valid environmental concerns and what are the red herrings—the issues that are just distracting us in the permitting process—can really help an open and transparent regulatory process and speed up permitting without giving up the important aspects of permitting to really guide the industry towards responsible development.

So building on that basic recommendation, particularly in the geothermal research and development act that we are looking at today, I think it is very important that we call out looking at environmental studies and environmental impacts. The ocean thermal energy act has a particular section on that. I think it is something I would recommend the Committee consider adding to the geothermal act. A lot of making sure that that sort of research done unfortunately is going to fall back on you in your oversight as the research and development actually occurs because you can't micromanage that from this stage, so I would encourage you particularly to look, and encourage the implementing agencies to look, at high-resources areas. Let us really focus our dollars, build baselines so we can really understand not just what the actual potential is but in these high-resource areas, what is the baseline ecosystem, and it helps us not just site an individual project, which will need to have that information as they go through the siting process, but also start to allow us to think about what the cumulative impacts will be of multiple projects, and similarly, to recognize that because these technologies are basically in their nascency right now, there are a lot of unknowns around how these technologies will interact with the environment. I am sure there is a known unknown joke here but I am not going to make that one.

We need to through the environmental research and development and really try to narrow the questions that we cannot answer at this point, characterize those issues as close, as specifically as we can so that they don't act as bottlenecks in the permitting process, and then study them extensively in the lesson-learned stage after we build the first projects. Particularly I would call out the need and the role that this research and development plays in a critical permitting tool which we need to develop much more extensively now and especially for these new technologies, which is adaptive management. If we can't figure out a way to permit projects without perfect information, we are going to see a real resistance on the part of the public to seeing these technologies go forward, but if we can figure out a way to allow the projects to go forward but also change the management if unanticipated impacts start to develop, we can speed the process up.

On the specific technologies, the enhanced geothermal systems, very exciting but also very much unknown. I don't think that there are likely to be huge impacts there. I am not anticipating that but again, if we don't study it, that uncertainty will act as a break and so focusing research and development dollars there to build that consensus is absolutely critical.

Another point I would draw just between the environmental impacts and the technology research and development around geothermal is the critical need to improve the efficiency of those systems, the total thermal efficiency. The more we can actually capture of the geothermal energy, the fewer projects we ultimately need to build to develop any certain amount of energy.

On the ocean side, again to recognize that we are dealing with a relatively unique environment, thinking now about the cumulative impacts and the consensus is absolutely critical.

Thank you for your time.

[The prepared statement of Mr. Greene follows:]

PREPARED STATEMENT OF NATHANAEL GREENE

Summary

General

- Carve out federal research and development (R&D) dollars for independent studies of environmental impacts to 1) understand the cumulative impacts of large scale deployment of these ocean and geothermal energy technologies, 2) avoid early public black-eyes that will set the industry back years, and 3) support an open and transparent permitting and regulatory process by building consensus among regulators, the public, and industry around the environmental benefits and impacts of real concern.
- Look at regions with resources that have high energy production potential and build baseline data on the nature of the resource and the ecosystems in place that surround the resources.
- Use the baseline data and analogous technologies to narrow and bound unknowable potential environmental impacts.
- Focus "lessons learned" studies on the areas of greatest environmental uncertainty.
- Use these studies to inform adaptive management strategies so that projects can proceed in the face of the real uncertainty surrounding some impacts and also still be eligible for private sector financing.
- Consider a federal fund to support the more extensive potential adaptive management options including removal for the first few projects.
- Utilize early successes in this approach as test cases for future, more large-scale deployment initiatives.

Geothermal Energy

- Include independent R&D on the environmental impacts of geothermal technologies in the *Advanced Geothermal Energy Research and Development Act of 2007.*
- Build consensus among regulators, the public, and industry around the real environmental impacts and ways to avoid, manage, and mitigate these impacts so that the technologies can be deployed as quickly as possible.
- Ensure that studies cover the environmental impacts of enhanced geothermal systems and of the cumulative effects of multiple large-scale projects in the same region.
- Ensure that technology R&D covers improving the thermal efficiency of geothermal systems to maximize the potential energy that can be captured and minimize the number of projects that need to be developed.

Ocean and Hydrokinetic Energy

- Focus federal R&D dollars on studies of a few regions with high resource potential, study other manmade installations in oceans, rivers, and lakes in order to anticipate impacts of ocean and hydrokinetic technologies, and prioritize post-installation lessons' learned studies.
- Require access for independent pre- and post-installation environmental studies as part of eligibility for any federal subsidies.
- Ensure that studies address the cumulative impact of multiple projects and of multiple installations within one project.
- Exclude offshore wind from the *Marine Renewable Energy Research and Development Act of 2007* except to study offshore wind projects to learn lessons that may inform other projects and as part of regional cumulative impact analyses.
- FERC should work with State and federal natural resource management agencies to do a programmatic environmental impact statement for the licensing of new hydrokinetic technologies.
- Regional studies should help build consensus around areas that are best suited for early development and those that should be avoided at least until the potential impacts of the technologies are much better understood.

Introduction

Thank you for the opportunity to share my views on geothermal, ocean, and hydrokinetic energy technologies, the environmental pros and cons of these important sources of renewable energy, and the environmental issues related to these technologies that should be addressed in the context of federally supported research and development. My name is Nathanael Greene. I'm a senior policy analyst for the Natural Resources Defense Council (NRDC) and one of our main experts on renewable energy technologies. NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco.

Mr. Chairman and esteemed Members of this committee, as you know, U.S. energy policy needs to address three major challenges: reducing global warming pollution, providing affordable energy services that sustain a robust economy, and increasing our energy security. Renewable energy technologies including geothermal, ocean, and hydrokinetic energy can play a critical role in meeting these goals, and these technologies have the potential for dramatically increased deployment over the coming decades. These sources of energy can be used to produce electricity and thermal energy with little or no global warming pollution or local or regional air pollution, and they draw on domestic energy sources that are naturally replenished and do not vary in cost. By using these technologies we avoid burning fossil fuels, particularly coal and natural gas and to a lesser degree oil. The heat-trapping gases released when we burn these fuels make the power sector the largest single source of global warming pollution. These fuels are also responsible for other significant environmental and public health impacts during mining, drilling, processing, and combustion, and they expose our economy to price volatility and energy insecurity.

All energy technologies cause some environmental damage. Being better than fossil fuels is a necessary condition, but hardly sufficient. Independent research and development focused on the environmental characteristics of these technologies is critical to maximizing their positive impacts and to avoiding, managing, and mitigating their negative ones. Good R&D on the environmental impacts is also critical to an open and transparent permitting process and in building a constructive relationship between regulators, the public, and the industry so that these technologies can be deployed in a manner that is quick, efficient and responsible.

General Comments Relevant to Both Families of Technologies

The environmental impacts of renewable technologies such as geothermal, ocean and hydrokinetic energy must be considered in the context of the detrimental alternative outcomes if we choose to not actively deploy these technologies. Most of the traditional energy sources (e.g., coal, natural gas, oil) ensure a far different and potentially much more devastating environmental future. Meeting our energy service needs through improved energy efficiency is the fastest, cleanest, cheapest option, but even the most efficient technologies require some energy to operate. Outside of the transportation sector, if we're not using renewable energy then chances are we're using coal, natural gas, and nuclear power and some oil primarily for heating.

The consequences of not moving away from these traditional fuels to energy efficiency and renewable energy are severe, and impact almost every aspect of the environment and public health. None of these consequences are ultimately more urgent than reducing global warming. The recent Intergovernmental Panel on Climate Change report concluded that there was at least a 90 percent chance that heat-trapping pollution was the main cause of warming since 1950. The science is clear: global warming is real, it's already occurring, and we're responsible for it. We can avoid catastrophic damage, but only if we start reducing our rate of pollution seriously within the next 10 years and achieve 60 to 80 percent reductions by 2050.

This is where renewable energy technologies such as geothermal, ocean, and hydrokinetic energy can be so beneficial. The heat-trapping gases emitted during combustion of fossil fuels make the power sector the largest single source of global warming pollution. Developing geothermal, ocean, and hydrokinetic energy, as part of a renewable energy portfolio, is a vital step towards replacing a significant amount of the fossil fuel-generated power. Moreover, there is a domestic argument as well. The United States is the largest emitter of heat-trapping gases, causing 25 percent of global warming despite having just four percent of the world population. Geothermal, ocean, and hydrokinetic energy are domestic renewable energy sources that can reduce our carbon footprint globally, and encourage other countries to do the same.

Of course, no energy technology is without environmental impacts, and simply being better than fossil fuels is a little like being better than a poke in the eye—it's a necessary but not sufficient aspect of a truly sustainable energy mix. Studying the environmental characteristics of renewables serves two critical purposes: 1) it allows us to identify, avoid, manage, and mitigate the real environmental impacts of renewable energy technologies; and 2) it builds a constructive relationship between regulators, the public, and industry that focuses on the real impacts and not "red herring" issues that have limited impact and can obstruct the deployment of strong projects. Taken together these outcomes are needed to allow for the best public review and permitting process.

Ocean energy is currently used to produce just a few megawatts and geothermal just a few thousand megawatts of energy, in spite of the fact that both families of technologies could easily be scaled up to produce tens of gigawatts within the next few decades. However, the relative infancy of these technologies presents two important challenges. First to understand the real sustainability of the technologies, it is insufficient to look at the impacts from a single project. We must also study the cumulative impact of these technologies brought fully to scale, and lay out our vision of what we want these industries to ultimately become. Second, both families of technologies are particularly vulnerable to major setbacks that could stifle growth if early projects become notorious environmental failures.

In the context of federal research and development legislation, we should focus on two types of environmental risks to understand the cumulative impacts and avoid early public black-eyes. The first type of risk involves impacts that we can predict with increasing accuracy with greater experience and data collection. An example of this type of risk would be determining the chance of whales being hurt by the sounds of construction. The more we learn about whales' habits in the region of the project, and what effective mitigation measures we can take to avoid and minimize impacts on whales, the more we can quantify the probability of whales being affected by project construction.

The second type of risk involves impacts that we cannot predict because they result from new types of interaction that simply have never occurred before. An example of this type of risk would be how a geofluid would spread when introduced into a hot-dry rock geothermal heat source to create an engineered aquifer. Another example would be how fish might adapt to underwater turbines in a river. These would be first-of-a-kind interactions and the probability of the possible impacts is fundamentally unknowable.

We can address the first kind of risk by building a detailed understanding of the baseline conditions in the area of a potential project. Unfortunately, given that many species may pass through a given part of the ocean or land only during certain seasons, developing this database may significantly slow a proposed project. If, instead of studying the baselines on a project-by-project basis, we identified a few regions with high resource potential, and focused federal R&D dollars on building the necessary baseline data in those areas, we could facilitate the permitting of individual projects. This would help us develop a better understanding of what the cumulative impacts might be in a region where multiple projects are likely.

Research and development dollars can also help narrow and bound the uncertainty associated with unknowable risks. For instance, if we were considering a certain type of ocean thermal technology, previously collected baseline data would allow us to conclude that a project in that region of the ocean would have a very low chance of interacting with endangered or at-risk fish populations. Further study of similar equipment coupled with modeling the worst-case scenarios might allow us to conclude that even the development of multiple projects would be very unlikely to have any significant impacts of the fish populations. In other words, even for unknowable risks associated with putting new technologies into new conditions, federal R&D can help build consensus around the issues of greatest potential concern and those that are very unlikely to impose significant restraints.

Of course this type of work should be followed with "lessons learned" studies to help avoid, manage, and mitigate future impacts and provide more information to help narrow and bound other unknowable risks. Indeed, given the much higher level of uncertainty surrounding these technologies, the lessons learned from each project during operation should be used to update the management of future projects, and the conditions of future permits, especially during the early development stage of each industry. In particular these studies should be used to inform adaptive management requirements in permits. Adaptive management requirements establish a process for changing a project operations and equipment configuration to avoid or reduce environmental impacts that are larger than anticipated. This is a critical tool for allowing projects proceed when there is a level of uncertainty around impacts that would be unacceptable if the projects' management strategies are fixed over time.

Further research on the potential environmental impacts associated with these nascent renewable technologies is needed to support adaptive management permitting requirements. Given the limits on our ability to establish baseline data and the unknowable risks associated with new technologies in new conditions, regulators must be able to require projects to adapt their management to address unacceptable levels of impacts (that may not appear at present). The baseline data and studies to narrow and bound unknowable risks will be critical to identifying unacceptable levels of impacts (e.g., is the line crossed at one bird or fish or caribou or one hundred?) and what alternative management options are possible.

Making adaptive management work is not only important from the environmental perspective; it is also critical to making projects acceptable for private sector financing. Lenders and investors will not support projects that face potentially significant costs or lost capacity as a result of management being forced to avoid or manage an unforeseen impact. Developing a clear, transparent permitting process, that includes State and federal agency input in developing adaptive management requirements, will also help attract private funding.

Indeed, given the importance of adaptive management to making some first-of-a-kind projects acceptable from an ecological and public health risk perspective, and the challenge that some adaptive management options might pose to a project's financing, the Federal Government could play an important facilitating role in ensuring geothermal, ocean, and hydrokinetic energy deployment. The government could create a fund that covers a portion of the costs associated with the most extreme and expensive changes in management that might be necessary for early projects. For example, if there is a very small chance that geofluid could leak from an engineered aquifer into ground water or to the surface, but such a leak would require the project to immediately cease operations, the Federal Government could help insure against such a risk for the first few projects. I recognize that this specific recommendation is beyond the scope of R&D legislation, but the types of studies I have discussed above would help identify and limit the conditions where this type of fund would be necessary.

Recommendations

- Carve out federal research and development (R&D) dollars for independent studies of environmental impacts to 1) understand the cumulative impacts of large scale deployment of these ocean and geothermal energy technologies, 2) avoid early public black-eyes that will set the industry back years, and 3) support an open and transparent permitting and regulatory process by building consensus among regulators, the public, and industry around the environmental benefits and impacts of real concern.
- Look at regions with resources that have high energy production potential and build baseline data on nature of the resource and the ecosystems in place that surround the resources.
- Use the baseline data and analogous technologies to narrow and bound unknowable potential environmental impacts.
- Focus "lessons learned" studies on the areas of greatest environmental uncertainty.
- Use these studies to inform adaptive management strategies so that projects can proceed in the face of the real uncertainty surrounding some impacts and also still be eligible for private sector financing.
- Consider a federal fund to support the more extensive potential adaptive management options including removal for the first few projects.
- Utilize early successes in this approach as test cases for future, more large-scale deployment initiatives.

Geothermal

Geothermal energy is a particularly attractive source of renewable energy because it can serve as baseload power (e.g., provide steady electricity on a consistent and predictable basis). This gives it the potential to displace some of the dirtiest power generation—coal-fired baseload power. Direct use of geothermal heat and geothermal heat-pump technology also allows industry, commercial, and residential buildings to avoid natural gas and oil that are currently used for heating and cooling needs.

There are already an important number of geothermal projects in operation today, but the next 10 to 15 years could easily see a ten-fold increase in deployment. In addition, enhanced geothermal systems represent a new technology and an area of significant potential growth. As a result, it is important that the R&D bills under consideration by the Subcommittee be amended to explicitly require research and development related to the potential environmental impacts of geothermal development along the lines discussed above.

For the traditional geothermal technologies, R&D would help especially in terms of building consensus among regulators, the public, and industry around the most significant environmental impacts. It could also prove useful in determining which impacts are "red herrings" that might need to be monitored, but don't need to be a focus of concern. However, it is important to recognize that many geothermal resources are remote from demand centers and thus land-use impacts will grow considerably with cumulative development of multiple projects in the same region.

Beyond the traditional geothermal technology, the enhanced geothermal systems are an entirely new area for development and thus even more in need of R&D on their potential environmental impacts. Particular care must be taken that the geofluids injected to bring the geothermal energy to the surface do not escape the targeted heat reservoir and contaminate drinking water or reach the surface in an uncontrolled manner. Research into the steps necessary to avoid this and to understand the potential impacts of such an escape if it occurred would increase the comfort-level with this new technology.

For all classes of geothermal technologies, a key area of technology R&D that overlaps with siting-related environmental impacts is work to improve the thermal efficiency of the technologies. The efficiency of current projects is unfortunately low. Doubling this would cut in half the number of projects necessary to achieve a given level of energy production.

Recommendations

- Include independent R&D on the environmental impacts of geothermal technologies in the *Advanced Geothermal Energy Research and Development Act of 2007.*

- Build consensus among regulators, the public, and industry around the real environmental impacts and ways to avoid, manage, and mitigate these impacts so that the technologies can be deployed as quickly as possible.
- Ensure that studies cover the environmental impacts of enhanced geothermal systems and of the cumulative effects of multiple large-scale projects in the same region.
- Ensure that technology R&D covers improving the thermal efficiency of geothermal systems to maximize the potential energy that can be captured and minimize the number of projects that need to be developed.

Ocean and hydrokinetic energy

There are three reasons that study of the environmental impacts of ocean and hydrokinetic energy is particularly important: 1) the technology is in a nascent stage of development with only a few pilot scale projects in operation around the world; 2) due to the diffuse nature of the energy resource in the ocean and moving water, this family of technologies necessarily requires many pieces of equipment spread out over great distances to capture traditional electric utility-scale amounts of electricity; and 3) the oceans are prized for their open vistas, importance in the global ecosystem, and are particularly vulnerable to global warming.

As recommended above, R&D looking at the environmental impacts of this family of technologies should focus on a few regions with especially high resource potential, ideally for multiple technologies. Studying the ecosystems of oceans, rivers, and lakes is obviously a complicated and time-consuming process. Furthermore because so much is unknown about the interaction of wildlife with the various technologies being developed to capture ocean and hydrokinetic energy, special effort should be made to find other man-made infrastructure that can give us insights into the potential impacts. The novelty of the technologies makes post-installation studies of impacts and adaptive management even more important.

Of course the novelty of the technologies also creates understandable concerns from project developers about allowing scientists access to proprietary information regarding system design. However, these concerns should not be allowed to hinder pre- and post-installation studies. Access for independent environmental research and development should be a prerequisite for any federal support.

The idea of cumulative impacts takes on even greater importance in the context of ocean and hydrokinetic technologies. Not only should studies consider the impacts associated with multiple projects, initially, they should develop an understanding of the cumulative impacts of the multiple pieces of equipment being installed within the bounds of one project. Utility scale projects are likely to require more than one hundred individual generators. In a river, lake, or in certain parts of the ocean, the cumulative impacts of this many pieces of equipment could be dramatically different than the impacts of just one or two generators.

The only exception to the newness of this family of technologies is offshore wind energy. Given the more mature nature of this technology it is appropriate that offshore wind be generally not included in the *Marine Renewable Energy Research and Development Act of 2007.* The only area where offshore wind should be explicitly included is in lessons' learned studies and studies that build baseline data on regions with high ocean energy resources. Offshore wind energy projects could be an important source of information about energy project development and thus should be considered as part of post-construction studies of impacts. Also to the extent that regions are picked due to their having high resource value, the environmental effects of wind power should be considered in impact studies, as wind projects could contribute to the cumulative impacts concept described above.

Lastly, federal R&D should recognize the unique nature of our oceans, rivers, and lakes. They provide unique ecosystem services, they are used differently than land from both a commercial and recreational perspective, and they are extremely vulnerable to global warming. As a result of these differences, the policies and procedures for access for renewable energy projects are still being developed. The Minerals Management Service has taken the important step of conducting a programmatic environmental impact statement on its offshore energy permitting process. The Federal Energy Regulatory Commission should work with state and federal natural resource management agencies to do the same with new hydrokinetic technologies. On land, many individual states and some collections of states, which are anticipating significant wind power development, have taken the valuable step of conducting resource mapping to identify both productive sites and places that projects simply should not be developed. Ocean and hydrokinetic energy may be too new for studies to offer anything other than preliminary guidance, but that is an important first step and only highlights the need to get started with environmental impact R&D now.

Recommendations

- Focus federal R&D dollars on studies of a few regions with high resource potential, study other manmade installations in oceans, rivers, and lakes in order to anticipate impacts of ocean and hydrokinetic technologies, and prioritize post-installation lessons' learned studies.
- Require access for independent pre- and post-installation environmental studies as part of eligibility for any federal subsidies.
- Ensure that studies address the cumulative impact of multiple projects and of multiple installations within one project.
- Exclude offshore wind from the *Marine Renewable Energy Research and Development Act of 2007* except to study offshore wind projects to learn lessons that may inform other projects and as part of regional cumulative impact analyses.
- FERC should work with State and federal natural resource management agencies to do a programmatic environmental impact statement for the licensing of new hydrokinetic technologies.
- Regional studies should help build consensus around areas that are best suited for early development and those that should be avoided at least until the potential impacts of the technologies are much better understood.

BIOGRAPHY FOR NATHANAEL GREENE

Nathanael Greene is a senior energy policy specialist working on issues including utility regulation, renewables, energy taxes and energy efficiency. He has particular expertise in biofuels, biopower, wind and small, clean-generating technologies such as fuel cells, as well as the State and federal regulations and policies to promote these technologies. Nathanael received a Bachelor's degree in public policy from Brown University and a Master's in energy and resources from the University of California at Berkeley.

DISCUSSION

Chairman LAMPSON. Thank you for your explanation.

PAST FUNDING CUTS TO GEOTHERMAL ENERGY RESEARCH

At this point we will start the first round of questions, and the Chairman will recognize himself for five minutes. I want to start with Dr. Tester and Mr. Thomsen.

The Administration, through the Office of Management and Budget, has attempted to justify terminating DOE's geothermal technology program by saying research supported by the geotechnology program has contributed to reduced costs of geothermal power to the point that it is now a mature technology. Can you respond to that statement, both of you, and is geothermal power a "mature technology"?

Dr. TESTER. Let me try to begin. In this, I think it is necessary to separate substance from semantics in the OMB decision. I have been having a lot of trouble understanding their rationale for the decision that they made in calling geothermal technology mature. If I assume that they are thinking of geothermal as a single technology, then I think they are flawed in their analysis. Geothermal is a resource. Like other mineral resources such as oil and gas, it has a variety of grades and there is always room and important room for improvement. As we just heard this morning and I think we pointed out in our assessment, we are using such a small fraction of the available geothermal resource right now that it would be—can hardly be regarded as a mature technology.

Mr. THOMSEN. Mr. Chairman, I would like to add to that. The first point I would like to add or make is that we have never seen an analysis for that recommendation, that this technology has become mature. Being unable to define what mature is, it makes it a bit of an ambiguous mark to find and describe. I would like to echo what Dr. Tester said and say that geothermal is a resource. It is utilized and captured by a suite of technologies and we have hydrothermal technologies which are slightly more mature, we have technologies like EGS that haven't been commercialized. H.R. 2304 looks at specifically those heat-capturing technologies that haven't been commercialized and are not mature and says what we can do to better capture this resource, and so I think if I were to come to the defense of OMB I would say that they mischaracterized geothermal as a single technology and not a resource and we need to do everything we can to utilize all of the technologies in our suite to capture this great domestic resource.

Chairman LAMPSON. Thanks.

GEO-PRESSURED RESOURCES

Dr. Tester, can you please describe geo-pressured resources and their potential? I understand they are particularly prevalent in my corner of the world, the Gulf Coast of Texas. Should this geothermal legislation contain a provision to specifically address that resource?

Mr. TESTER. Geo-pressured resources are, as you have pointed out, largely in the Gulf Coast area of the United States. They have three features to them that make them attractive: high temperatures, the presence of dissolved methane and also relatively high pressures. I would classify them in this continuum of geothermal resources as we have talked about from today's very high-grade systems that we utilize in the West that are liquid- or vapor-dominated systems across the full spectrum to very low-grade systems in the East. So geo-pressured is in there. There are others as well that also would be relevant to discuss today including co-produced fluids and things like that. Whether they should be explicitly pointed out in the bill I think is a matter for consideration but if the bill is written generally enough, and I think it is now, they would be considered part of that continuum, in my view.

Chairman LAMPSON. Thank you.

U.S. ARMY CORPS OF ENGINEERS AND OCEAN POWER TECHNOLOGIES

Dr. von Jouanne, is the Corps of Engineers involved at all in any of your research?

Dr. VON JOUANNE. The U.S. Army Corps of Engineers is key in the regulatory process and so we have filed permits for ocean demonstration with the Corps as well as with our Oregon Department of State Lands and Department of State Lands and Conservation Development and the Ocean Coastal Zone Management, so——

Chairman LAMPSON. As far as their participating in research with as much material as they move and the impact that it can have on so much of what is happening on our coastline, it seems to me that that would be something that they would be interested in.

Dr. VON JOUANNE. Absolutely, and I think that will come. You know, with them now being an integral part of that permitting process, I think they will see the opportunities that they would have to contribute because there are a lot of other research issues that need to be looked at, such as sand transport, when wave energy devices are deployed, and that is another big area that the Corps of Engineers could provide input on.

H.R. 2313 RECOMMENDATIONS

Chairman LAMPSON. Mr. O'Neill, since you strongly advocate for increased federal research and development funding for marine renewable energy technologies, may I infer that you support H.R. 2313, and are there specific changes to the legislation that you would recommend?

Mr. O'NEILL. Well, in terms of the bill itself, we support the bill absolutely and we support all efforts in this area. Any specific changes—we actually worked with staff on the bill a bit and they were very receptive. There are so many technologies. Mr. Thomsen mentioned the suite of technologies within geothermal. We have got a lot of technologies and the newer emerging, like the vortex-induced vibrations, et cetera, aren't covered. I would encourage this particular committee going forward that developing ways to really foster innovation—right now the regulatory process as Mr. Greene mentioned, we should have an adaptive management program and we wholeheartedly endorse something like that. On the R&D side of it though, I think that Congresswoman Hooley's bill is great.

Chairman LAMPSON. Thank you very much.

The Chair now recognizes Ranking Member Mr. Inglis.

Mr. INGLIS. I thank the Chair.

GEOTHERMAL GENERATING CAPACITY

Dr. Tester, you testified I believe that 100,000 megawatts is available from geothermal. Is that correct?

Dr. TESTER. Well, let me clarify my remarks. When we started our assessment, we undertook the idea that in order to have geothermal be an important player in the United States, that it would have to get to a point where it would be roughly 10 percent of the generating capacity that we have now. That would correspond to, in today's figures, 100,000 megawatts. However, if you look carefully at the analysis that we made of the regional U.S. resource, including Alaska and Hawaii, but just looking at it state by state, we are really talking about an enormously large stored amount of thermal energy, and if you were to envision a future where you might want to develop it beyond this 10 percent level, there would not be an issue with having enough energy in place to do it, and although geothermal is clearly different than other renewables such as solar and wind, the sustainability of it is clear, given the massive amount of stored thermal energy that we have access to at, let us say, to depths from the surface to 30,000 feet or to 10 kilometers. And I think it is important to keep this in mind, that the heat-mining idea has to be modular and scaleable so you start out small and you develop these connected reservoir systems in much the way that you would want to emulate what nature has given us in other parts of the world where we utilize geothermal today, but it will never be limited, and I think we make this statement clear in the report, by the acceptability or the magnitude of the resource. It is clearly going to be technology and economics which will determine how much of this we can utilize. So it could way beyond 100,000 megawatts, to finalize that, if you wanted to go to that regime, but it will be a matter of technology and cost.

LOCATIONS FOR GEOTHERMAL ENERGY PRODUCTION

Mr. INGLIS. Generally speaking, where is it available in the United States? What are the best locations?

Dr. TESTER. Well, if you use one metric as best, which would be the average gradient, the geothermal gradient, you could largely think of the western part of the United States as having the highest gradients in general. I am speaking almost from west of the Mississippi all the way to the California coast. What makes it special though is that there are other ingredients that you want besides just high temperature and shallow depths. In the conventional system, you are looking for permeability and porosity, connectivity, if you will, and the presence of fluids. In the case of EGS, we are missing one of those, and we are trying to develop technologies that would stimulate the system to a point where we could emulate these hydrothermal conditions. So if you wanted to envision a program as we tried to put it together in our thinking that this would start out something where you would work from the western part of the United States where the resources are of higher grade, shallower, less costly to develop and to demonstrate, and then move east, so reversing the migration we had to the country. So the high-grade resources I would say would be generally the western part but they are in Texas, they are in Colorado, they are in Montana. They are equally through the Pacific Northwest and in California, not just where we are producing geothermal energy right now.

GEOTHERMAL TECHNOLOGY READINESS

Mr. INGLIS. The Chairman's helpful question about the OMB's statement that it is a mature technology, could they really be saying that it is economics that will make this work? In other words, the technology is there——

Dr. TESTER. Well, I think——

Mr. INGLIS.—it is just a matter of economics?

Dr. TESTER.—eventually everything in the alternative energy field gets down to a question of economics but I think what they seem to be missing is that this is not just one number fits all geothermal systems. Very high-grade systems such as we have in parts of California and Nevada and Utah are already producing commercially competitive power right now. What we would like to do is to improve the technology to the point through this vigorous R&D program where we would bring down those costs, where we would reduce risks and encourage investment so that we could bring a larger portion of it online. So if you will, go to the lower grades, not necessarily what we might want to do in the very eastern part of the country where the gradients are very near normal but certainly to open up the west soon for a massive development of geothermal expansion.

Mr. INGLIS. Mr. Thomsen.

Mr. THOMSEN. Mr. Chairman and Mr. Inglis, you know, I think your question is a very good one in the fact that my company focuses on your typical hydrothermal applications, and those applications have been prevalent in the western United States due to the drilling depth and cost and economics of those projects. What this bill is looking at and what Mr. Greene touched on is the fact that if we can make these technologies more efficient, we can go capture this geothermal throughout the country, and I think when we look at this, if we say what we have now is good enough, then the idea of maturity can be acceptable. My company doesn't feel that that is the case. We want to continue moving eastward, going to greater depths and, you know, to break it down to its most simple point, if we can become more efficient and reduce the risk in drilling by 10 percent, 20 percent, you will see companies like ORMAT and other start-up companies going after these resources that might be slightly deeper, harder to penetrate and go find. When we drill for geothermal resources in our standard hydrothermal applications, we are drilling through the most—the hardest rock, the hottest temperatures and looking for these resources that are difficult to find. We have done that well on the West Coast due to geology and the thickness of the Earth's crust and things. We know the resources eastward and that is what we are looking to find. The 100,000-megawatt number that we talked about was from a report done in 1979. We haven't had a new report since that time. And at that time they were looking for temperatures in standard geothermal applications that were well above 300 degrees Fahrenheit. Technology has come a little ways in being able to capture lower temperatures and turn that into viable technology projects. We want to continue looking at that throughout the country.

Mr. INGLIS. Mr. Chairman, time must be up, isn't it? Thank you.

Chairman LAMPSON. Thank you, Mr. Inglis, and I apologize for our clocks not working at all. If you will glance my way every now and then, when you hit five minutes, or four and a half minutes, I will at least hold this thing up and if you get to five I will start tapping it a little bit.

I would recognize Mr. McNerney now for five minutes.

Mr. MCNERNEY. Thank you, Mr. Chairman.

I do want to thank Dr. Tester for the excellent detail and comprehensive report that was produced and for the executive summary that was actually readable, and Mr. Thomsen for your fine work with ORMAT.

GEOTHERMAL GENERATING CAPACITY

Dr. Tester, you mentioned that there were three gigawatts being produced now and that we have a potential for 100 gigawatts in 10 years. Is that what I understood you to say?

Dr. TESTER. If we proceed on the path that we proposed in our scenario, the path was to get to 100,000 megawatts in 50 years to take us from where we are now. So three gigawatts now to 100,000 megawatts in 50 years or 100 gigawatts, that is still quite an ambitious set of developments. Each geothermal site would have to be identified and developed, exploratory drilling and verification, so we are already a few years into that, as you know. But after you get to that point, particularly as you get out along the 10- to 15-year period, we feel that this will be essentially self-sustaining because you will have enough of these modular plants in place, you will have worked on both ends of the continuum, as I call it, improving the high-grade and hydrothermal technologies, and using where you can those technologies to work on EGS, and so our feeling was that the economic analysis would say that a lot of learning would go on during that period, demonstration, multiple demonstrations, improving the modularity, being able to show we can do it not only in California but in Idaho or further east if we wanted to demonstrate the ability to make reservoirs and stimulate them. So I am encouraged that you have to get on that path and what I think is particularly laudable about this bill is that it realizes that you can't just stay with the short-term aspect of geothermal. You really should be investing in both simultaneously and I think it is very balanced with respect to that.

Mr. MCNERNEY. Thank you.

GEOTHERMAL'S IMPACT ON THE ECONOMY

Mr. Thomsen, you represent industry and I am very intrigued by your comment about jobs and the impact on the economy. Of course, we are all worried about global warming and our dependence on oil and the peak oil and so on but the actual impact on the economy is where it really is going to come—that is where the pedal is going to hit the metal. For some fixed quantity of electrical production, how does job creation compare both in the construction part and in the production part to oil or natural gas, which is our leading form of electrical production today?

Mr. THOMSEN. Mr. McNerney, geothermal production is an incredibly capital-intensive project up front. My company recognizes that for each megawatt of energy we bring online, it requires a capital investment of ours of $3 million, so if we bring on 100 megawatts, that is a $300 million investment. When we go to construct a project, 40 percent of our construction costs come from the local economy. We utilize local contractors for the small electric motors and things we use. We contract all that out to the local economy. So we have a very large impact. When it comes to jobs during the construction phase, I think the Geothermal Energy Association (GEA) can better speak to those exact numbers but I believe it is approximately 10 to one in the amount of jobs required during the construction phase compared to combined cycle gas, but we can be sure to get you those numbers. And the point that we would like to point out there is because this is a domestic resource, that money stays within the state that our project is being built and within this country, and that is hugely important for us.

Mr. MCNERNEY. You said $3 million per megawatt. Do you see that number going down?

Mr. THOMSEN. Three million dollars per megawatt. That is correct.

Mr. MCNERNEY. Do you see that number going down as the technology improves? I mean, it seems like when you go to EGS you are going deeper, you are going to have to do reservoir stimulation, rock stimulation and so on, so it doesn't seem like it is going to go down with time.

Mr. THOMSEN. It is—you have asked kind of a twofold question and I would like to answer that. As we look—if we use the technology that we are currently using today to look for harder, more difficult resources at greater depth, that cost will not go down. If we go to look for that resource using the same drilling techniques, the same efficiency and production techniques that we use today, you are absolutely correct. If we can make the technology on the surface, this suite of technologies that can take that heat and produce electricity more efficiently, that cost might come down. But without a robust R&D budget and the use of our great men and women at our national laboratories and universities to develop that, I think you are absolutely right. We don't foresee the cost of that coming down greatly any time soon.

Dr. TESTER. I could make one other small addendum to that. In our analysis, if you look at the supply curves that we developed in there, you will see that the early development of EGS, which is what Paul was referring to, would be much higher cost. It would be somewhere in the vicinity of perhaps twice the current energy cost we have now for electricity. But as you move out this yearly development and get out to the point where you have incorporated technology improvements, learning by drilling and improving the drilling technology, our estimates would be that after about 12 to 15 years you would reach this break-even condition where EGS, which requires these additional attributes, as you have mentioned, would be competitive. But you can't just assume that will happen. I think it really takes engagement now in terms of getting the demonstrations out there.

Mr. MCNERNEY. Thank you.

Chairman LAMPSON. Thank you, Mr. McNerney.

The Chair now recognizes Mr. Diaz-Balart.

Mr. DIAZ-BALART. Thank you very much, Mr. Chairman. I have two brief questions.

NOT IN MY BACKYARD (NIMBY) AND COST CONCERNS FOR RENEWABLES

One is to Mr. O'Neill. You mentioned the cost per kilowatt-hour for wind and wave and tidal, and just for, you know, laypeople like us, for comparison sake, how does that compare to the cost of kilowatt-hour for electricity from, you know, coal, natural gas and nuclear, which is what we currently have, number one.

For Mr. Greene, this weekend, by the way—last weekend I was at the NOAA's Southeast Fishery Science Center, which is located in Miami, and I think some of the research that you recommend, for example, understanding fish populations, would probably be more appropriately performed by an agency like NOAA that is doing that right now, rather than DOE. Now, my understanding is that currently these bills include only the Department of Energy. Don't you believe that adequately incorporating—would it not be better to expand to other agencies like NOAA and others who may be doing it and not just limiting it to DOE?

And lastly, I don't know who this question is to, Mr. Chairman, but we saw last year a very good example of NIMBY, Not In My BackYard, in the Northeast. I am not going to mention who or what but, you know, people who are seen as real forceful advocates of renewable energy, when it blocked their nice view of the ocean, all said, you know, damn these resources, you know, we don't need them in front of my yard, in front of my view, in this case. It was just because it was blocking the view a few miles out in the ocean. Have you all looked at that and figured out how to deal with that because, you know, when the rubber meets the road and reality is that, you know, this is all great but nobody wants it in their backyard or in this case, in the front of their ocean view, and I don't know, it is not really a question. It is kind of just throwing out there and you all have a thought about that.

So Mr. Chairman, those three questions and I will shut up. Thank you, sir.

Mr. O'NEILL. If I can start with your last question first because I have spent over 20 years studying the NIMBY phenomenon and worked for U.S. generating companies siting plants in 17 different states where we ran into NIMBYism in all its many forms. Very often NIMBYism comes from not a real substantive issue with a plant. You can be in a community for a year and have the town fathers telling you boy, this is the best thing since sliced bread. Then it is time to pull papers and run for office and you are the only issue in town. Very oftentimes NIMBYism comes from disenfranchisement, and with projects like ocean energy projects or even traditional power projects, the important way to approach a project, any kind of very large-scale change is going to scare people, so what you need to do is, you need to go in, you need to talk to the environmental community, you need to talk to the NRDC, you need to talk to the Sierra Club, you need to talk to the local folks and you need to listen to them, having a two-way dialog. In some cases project developers have actually made changes in the design of their projects, say, changed the coal train coming into a town to using a barge to bring coal in so that people don't have the same kind of impacts that the train would have. So making a change, actually listening to the people in the community. There have been lots of wonderful changes made to traditional power plants. In Florida they found that agricultural nutrients were going into Lake Okeechobee. The project developer built a 29-mile pipeline around the lake and took those nutrients, used them in their process water instead of letting the nutrients go in. They got that information by working with the local community and the county. So reaching out and dealing with stakeholders early in the process is the answer to your first question. Sorry for such a long answer.

To your first question in terms of the cost, traditionally, to be competitive, you want to be about three to four cents a kilowatt-hour. The cost to the consumer is actually about eight-plus cents. I think it is 8.6 cents a kilowatt-hour and that—excuse me? Oh, yeah, and it varies from region to region. But that includes the transmission and distribution costs that the utilities incur, et cetera. When you look at a 32-cent-per-kilowatt-hour feed-in tariff in Portugal compared to our 1.9, that 1.9 is probably appropriate right now for wind because of the scale that we have onshore wind projects. That brings them right into the hunt to be commercial. With ocean technologies, as I mentioned, the offshore wind was 40 cents a kilowatt-hour when it started. We are down getting into the single digits already right out of the box.

Chairman LAMPSON. Thank you very much. Your time is expired and I turn now and recognize Ms. Giffords for five minutes.

Ms. GIFFORDS. Mr. Chairman, because I know we are going to have votes called in just about five minutes, five, ten minutes actually, I was hoping to hear from the sponsor of the bill.

Chairman LAMPSON. You may yield to her if you care to.

Ms. GIFFORDS. I would yield to Representative Hooley.

Ms. HOOLEY. Thank you very much for yielding.

WAVE ENERGY TECHNOLOGY READINESS

Dr. von Jouanne, talk to me a little bit about with wave energy where we are compared to some of the other renewable energy sources.

Dr. VON JOUANNE. Very good. In wave energy, we are about 20 years behind wind energy and that is because we have just started to see dollars invested in wave energy and what we saw in wind energy is that those investment dollars enabled an acceleration toward the optimum topology that we see now. We see this horizontal axis three-blade turbine. What we are seeing in wave energy right now is several topologies being considered in very preliminary stages of development and so while companies are planning to deploy and preparing to deploy their first topologies, a great deal of research and development still needs to take place in order to really optimize those topologies to make them cost competitive, and because of the advantages of wave energy over other forms of strong renewables such as wind and solar, we really feel that the catch-up time can be accelerated with the proper research and development dollars invested, and that the cost can be very competitive with other strong technologies such as wind, and, as I emphasized, we have this issue of energy density. If we look at the density of water compared to air, the density of water is about 832 times greater, which means we can extract more power from a smaller volume at subsequent lower costs and smaller visual impact with the whole NIMBY issue being critical. We also have greater availability, that is, how often are the waves rolling, and we have greater predictability that enables a utility to determine how much power a wave park equivalent to a wind farm, a wave park would be putting onto the grid, so some substantial advantages there.

Ms. HOOLEY. Mr. O'Neill, at what point do you think that wave energy in some form would be available for to be used in this country, and what happens if we don't have the research and development dollars available?

Mr. O'NEILL. Well, if you look at Alaska right now where they are paying up to 80 cents a kilowatt-hour for diesel-generated electricity, we could go commercial and be profitable in Alaska right now. The problem is that we don't have projects in the water. We need to have actual operating projects. We need to embrace the concept of adaptive management so that we are looking at the environmental effects as well as the efficiencies of these technologies to improve them. So getting them in the water—and Dr. von Jouanne accurately portrayed the fact that wave technology is about 20 years behind wind but I see us ramping up to commercial viability within the next five to eight years, and maybe even sooner. Advances not only in wind technology but in composite materials design, looking at other offshore construction techniques, our companies—if you look at Verdant Power, which has six turbines in the East River of New York, they have been operating. They have got $2 million of sonar equipment to watch the fish and the fish are swimming around the turbines. They are not running into the turbines, just as expected. But the tips of the turbine blades go around slowly just like with wind turbines, because of the lessons from Altamont Pass. We use a monopole, another lesson from Altamont Pass. We are learning from—so it is like the technology cycle time in computers where it used to be a new computer would come out every two or three years, then it was every year and now it is every six months and three months. You can't buy a cell phone now and think that is going to be new and sexy for more than three months, and that is what is happening. It is a robust, vibrant area and we are going to get there.

Ms. HOOLEY. Thank you.

Chairman LAMPSON. I thank the gentlelady, and now we recognize Mr. Bartlett for five minutes—Dr. Bartlett.

SOLAR AUGMENTED GEOTHERMAL ENERGY (SAGE)

Mr. BARTLETT. Thank you very much. My wife suggests that a better acronym for those who are opposed to development that they are a BANANA, Build Absolutely Nothing Anywhere Near Anyone. That is where some of our people are coming from. I wonder if Dr. Tester or others might comment on a concept called SAGE, which is Solar Augmented Geothermal Energy. One of the big problems of course with solar and wind is that they are intermittent and you have got to store the energy and they have what I think is a very clever approach to doing that. They are using the excess energy at the moment of production to heat brine, which is then pumped down into exhausted oil fields. Using all the techniques you use in geothermal, they are then extracting the energy from that hot brine. But a side benefit from this is that they are loosening up some of the oil that is there and we are now able to pump additional oil from these fields. We would just like your observation on the utility of SAGE as a potential for being a bridge between fossil and renewable energy.

Dr. TESTER. Let me comment first. I am sure Mr. Thomsen will want to add something to it. One good thing about geothermal is that it is continuous, dispatchable power, having very high capacity factors that are typically now in excess of 90 percent in terms of their availability capacity factor. So to go to a hybrid concept would take—using solar would take some redesign and rethinking of how you would handle the power conversion end of it but certainly could be done. There are good examples of this across the spectrum of renewables in general where we are dealing with interruptible renewables with respect to solar. If we look at the Kramer Junction plant in California where it uses gas when the sun is not shining, that is a hybrid concept as well. So I would be very positive about considering all ways in which you could utilize a higher fraction of renewable resources if it made sense technically and economically. The idea of injecting hot water and increasing production of fluids is something that we address sort of in the inverse way, namely that through the production of oil and gas we also produce a lot of hot water, warm water just as a consequence of that, and that water, at least the thermal energy content goes largely unutilized. This is what is referred to as co-produced fluids, and I think that too could increase the effectiveness or efficiency of a utilization effort. So all of the things you are suggesting I think are appropriate to be examined and analyzed. I don't think there are any picking winners and losers at this stage. It is perhaps a little premature.

Mr. THOMSEN. If I could, Mr. Chairman to Mr. Bartlett, you have touched on some very good points, one being is the bridging of renewable to fossil fuels. I think the SAGE idea that you proposed is great and I think we should look at it. We are also looking at, like Dr. Tester said, the co-production of hot water from existing oil and gas wells which research has shown to us might increase the longevity of our existing oil fields. We also have technology very similar to geothermal, which captures waste heat from gas compression stations using the exact same geothermal technology and producing additional electricity with no new emissions. The solar concept has been used. ORMAT was responsible for a test project in Arizona using solar troughs that heated a working oil, kind of a solar trough collecting the sun's heat centered on a working oil that we pumped through our system and produced electricity. So the idea there is a fantastic one. What all of those projects have in common is they can all be added to the suite of technologies for geothermal and renewables but none of those yet are commercially viable, and that is what we think this bill, 2304, will help us do, take all that science and technology that isn't quite yet commercially viable and help us learn from that so we can make it commercially viable, bring down those cost points, look at the problems with interfacing a geothermal power plant with a well with a solar—you know, solar field, et cetera. So I think—I mean, that is a fantastic suggestion.

GEOTHERMAL ENERGY TRANSPORTATION

Mr. BARTLETT. If we can do this of course we have another challenge and that is how to get the energy from the site of production to the user. With oil, it is easy. You put it in a pipe. You put a gallon in the pipe; 1,000 miles away you still got a gallon. What we are producing with electricity we put on a wire and 1,000 miles away you may have nothing. So we have the challenge of how we get the energy that we produce to the ultimate user because most of these abandoned fields are not near big population densities.

Mr. THOMSEN. And one of the interesting and great attributes of geothermal energy is its ancillary services, and because it is a baseload energy source, when we produce electricity—I am not an electrician and I am sure someone on the panel can probably explain it to you better. We can actually change the oscillation of that energy from AC current to DC current, so when we put it on a line, we can actually change the characteristics of that electricity so that it can go farther and farther away. Some of our power plants in Nevada are hundreds of miles away from the residential base. We are close to transmission but far away from that residential base and we can actually change the characteristics so that we can get more power there.

Mr. BARTLETT. Thank you, Mr. Chairman.

Chairman LAMPSON. Thank you, Mr. Bartlett.

I will now recognize Ms. Woolsey for five minutes.

GEOTHERMAL PRODUCTION TAX CREDIT

Ms. WOOLSEY. Hello, and just outside of my district, Santa Rosa, California, we have some of the largest reserves of geothermal energy in the entire country, and to make this renewable energy source even more renewable, Santa Rosa, which is the largest city in my district, pumps wastewater up the geysers to keep them generating electricity for a large part of Santa Rosa. So it is a wonderful partnership and Santa Rosa does away with a lot of their wastewater while they receive electricity.

What I want to know is, are the current production tax credits adequate to stimulate exploration and development, and I also want to know, are there any offsetting problems with the natural resources that need to be mitigated or do we come up "A+" because we are actually helping the environment while we do this?

Mr. THOMSEN. Thank you, Mr. Chairman to Ms. Woolsey. Regarding the production tax credit, the geothermal industry was thrilled to finally be included in the production tax credit. The problem we have with the production tax credit is that it only tends to be renewed every two to four years. The average geothermal project takes three to five years to come online from a Greenfield project, and so we are really asking the industry sometimes to take a very short market signal from the government and make a 20-, 30-year commitment because that is how long our power plants operate. When it comes to getting financial institutions to help you with the huge upfront capital costs, the production tax credit, its amount is great but its length is not so great and we have been unable to make good use of that. There have been two projects that have qualified for the production tax credit since it was passed. They happen to both be ORMAT projects and the projects were started long before we knew the production tax credit was going to be there. We just happened to kind of fall into that later on and so what we are looking for and what would really help industry is a credible commitment for a longer period of time so that we knew when we went to investors and we went to the banks to say we are going to have this tax credit when this project comes online. Without that, it hasn't been that beneficial to the geothermal industry as of yet. The second part of your question I think Dr. Tester can answer.

GEOTHERMAL RESOURCE ASSESSMENT

Dr. TESTER. Thank you for pointing out that lovely example of what goes on at the geyser field. In fact, you are doing what we would want to do in normal geothermal practice, which is to continually reinject and resupply the system so you can more effectively mine heat, and you might note in our assessment of the enhanced geothermal system side of the story that we did talk about the need and recommended that resource assessment in general needs to be looked at much more quantitatively and in a much more specific way across the country. The last time a serious study was done was almost 30 years ago right now, a published study by the U.S. Geologic Survey. The bill addresses that but I think the importance of that and how that will affect where you go to the next generation of sites is incredibly important. We picked a few targets of opportunity, as we called them, in our study, one of which was the Clear Lake area right near the geyser site. That has been well characterized and obviously is a high-grade area but there are many others in the country that haven't had that degree of drilling and exploration that also need to be looked at in California as well as many other states. So this is a good part of the bill and I think needs to be sustained. It is something that I think nationally is important for us to do. Thank you.

ENVIRONMENTAL BENEFITS FROM GEOTHERMAL

Mr. GREENE. Congresswoman, I think, without a doubt, that geothermal can play a large role in a very environmentally positive way. Every energy technology though has some environmental impact and I think the important thing that I talked about earlier is thinking about this technology in a long-term way. We need to go from one, two, three projects to having lots of these projects if they are going to contribute in a large way. That means we need to think about their impacts cumulatively over all of those projects. I think to do that, that is an environmental challenge and issue in and of itself. The other part of getting there is addressing the sort of uncertainty that communities feel when a project comes to them and they are trying to figure out, all right, well, what does this geothermal project in our backyard mean, and so getting consensus around what the real environmental impacts are going to be is critical and I think the research and development that we are talking about here today can play a huge role in building that consensus.

Ms. WOOLSEY. Thank you.

Chairman LAMPSON. Thank you, Ms. Woolsey.

I want to thank this panel. I think that we can adjourn at this point in time. We have had everyone who wanted to ask questions, and I have a few more questions but we will do that differently.

I really appreciate all of you for appearing before the Subcommittee. We all do. Your testimony has been very helpful and I think fascinating. I believe that the legislation that we have discussed today moves us forward in our effort to develop a more diverse supply of energy.

Under the rules of our committee, the record will be held open for two weeks for Members to submit additional statements and any additional questions, as I have, that they might have for the witnesses.

Thank you all for coming. This hearing is now adjourned.

[Whereupon, at 11:25 a.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jefferson Tester, Meissner Professor of Chemical Engineering, Massachusetts Institute of Technology

Questions submitted by Chairman Nick Lampson

Q1. What is the smallest scale plant for electric power conversion that is both technologically feasible and also makes commercial sense? What is the largest? How modular or centralized can geothermal energy production be?

A1. About one to two MWe would be the smallest output for geothermal electric plant that would be practical today. There have been smaller ones in operation in the past by they have been mostly demonstrations and not in commercial service. For non-electric applications such as geothermal heat pumps much smaller outputs (e.g., 5–10 kW thermal) are commercially feasible today. Economies of scale are reached for single modular generating plants supplied by one set of production wells somewhere in the 50 to 100 MWe range. These modules can be linked together to provide central station generation capacity to meet demands for large load centers—such as mega cities or densely populated regions. A good example of this approach is The Geysers field in Northern California near Santa Rosa which is the largest geothermal plant in operation in the world. It actually has a nameplate capacity in excess of 2,000 MWe and consists of many modular plants in the size range of 50 to 100 MWe.

Q2. Can you please comment on workforce training issues relevant to geothermal energy development. Is our country currently producing technically competent workers in sufficient numbers to significantly expand work in all aspects of geothermal development?

A2. Our country is not currently producing enough engineers and scientists with specific geothermal knowledge to develop and deploy geothermal technologies at a much increased rate. Fortunately in the U.S., student interest in alternative energy careers is growing and we have the capacity in our universities in engineering and Earth sciences to teach most of the core skills and fundamentals needed. With a national R&D program in place it would not take much to redirect colleges and universities to actively engage in creating programs to educate and train the next generation of scientists and engineers needed for large scale geothermal energy system deployment and operation. It would be good to involve students and faculty with actual operating geothermal plants and field demonstrations by way of internships or co-ops when possible.

Q3. Can individual geothermal reservoirs be depleted of heat or fluid over time? If so, how long does a reservoir last? If the heat in a reservoir can be depleted, can it be recharged by allowing it to lie "fallow" for a period of time? How long? Must the power plant on the surface lie dormant during this time, or can it tap into other reservoirs?

A3. As thermal energy or heat is mined from specific reservoirs they are "locally" depleted or cooled. An important feature is that the extent of the depletion is very limited—well within the active reservoir dimensions as only a portion of a rock volume near the injection wells would be cooled. Furthermore, in contrast to other mineral or fossil resources, once a particular geothermal reservoir ceases to operate it will "regenerate" on its own with heat being conducted from hotter regions of rock that surround the cooled parts and by energy being generated by radiogenic decay of contained minerals. After a period of roughly two to four times the energy extraction period rock temperatures will be restored to their initial condition. In a typical commercial operation any depleted wells could be redrilled or re-stimulated or replaced with new wells to restore fluid production temperatures. The power plant would continue to operate with high availability and capacity factors using the newly drilled, re-drilled or restimulated wells as their source of energy.

Q4. Given the enormous potential for geothermal energy development that you highlight in the MIT report, how do you explain the relative lack of interest in this resource? Why hasn't it attracted more attention in recent years?

A4. There are several reasons why I feel the potential of geothermal energy has been grossly undervalued in the U.S. (1) The "constituency" of advocated for geothermal energy is much smaller than for other renewables such as solar and wind that compete for resources and funds within the DOE. (2) There is widespread perception that geothermal is "too small and too localized" resource with only a few regions capable of providing power. This perception is based on the idea that only natural high-grade hydrothermal systems are viable, it completely ignores the idea of EGS—with human intervention to engineer systems to emulate the properties of high-grade hydrothermal reservoirs. (3) Federal R&D for geothermal has been inconsistent and to small for the last 15 years in the U.S. to mount sufficiently large field demonstrations of EGS technology.

Q5. What other countries are supporting EGS research and what are they doing? Have they made any significant advances?

A5. There are several EGS programs underway at the present time in Europe and Australia. The largest of these are at the Cooper Basin site in South Australia operated by Geodynamics with federal, State and private support and the Soultz site in France operated with the EU R&D program and at the Landau site in Germany, and the Basel site in Switzerland under private and federal sponsorship. Each of these tests has advanced EGS technology building on earlier U.S. experience.

Q6. In your written testimony you comment on the importance of international cooperation in geothermal R&D. Can you comment on what a specific provision to support such international cooperation might look like? What specific activities should it support, and with whom?

A6. Provisions for extended international travel support for our scientists and engineers to participate in ongoing field testing and evaluation of EGS systems in other countries would provide significant leveraging of our own efforts and avoid duplication. Also in some cases, it may be appropriate to have jointly funded research projects particularly on technique or instrumentation development for evaluating reservoirs and for drilling. To start, we should be collaborating with the Australians, with the Europeans involved in projects at the Soultz, Landau, and Basel sites, with the Italians at sites in northern Italy and elsewhere, and with the Icelandic researchers dealing with geothermal developments in Iceland and in other countries.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Paul A. Thomsen, Public Policy Manager, ORMAT Technologies, Inc.

Questions submitted by Chairman Nick Lampson

Q1. What is the smallest scale plant for electric power conversion that is both technologically feasible and also makes commercial sense? What is the largest? How modular or centralized can geothermal energy production be?

A1. ORMAT recognizes that there are many technologies that can be used to commercially convert typical hydrothermal resources into electricity. ORMAT utilizes the ORMAT® ENERGY CONVERTER ("OEC "), a power generation unit, which converts low, medium and high temperature heat into electrical energy, and therefore can only comment on this technology utilized by ORMAT.

The OECs are designed for the specific conditions of a wide variety of heat sources. Its main components include a vaporizer/preheater, turbo-generator, air-cooled or water-cooled condenser, feed pump and controls. The OEC is a field-proven, mature commercial product used in 71 countries worldwide. ORMAT has successfully manufactured and supplied more than 800 MW of geothermal power plants, based on its proprietary technology, logging millions of hours of operating experience.

The OEC enables geothermal developers to efficiently and economically use the full range of naturally occurring geothermal resources found throughout the world—from low temperature geothermal water to high-pressure steam.

- Full Range of Geothermal Conditions:
  - The OECs can accommodate a wide range of geothermal fluid temperatures and chemistries:
  - Steam pressure: from 1.5 bar (21.8 psig) up to 25.0 bar (362 psig)
  - Brine temperature: from 100°C to 224°C
  - Silica content: up to 1.95 silica index
  - NCG content: up to 15 percent
- Full Range of Site Specific Plant Scale:
  - Available in sizes and configurations cost-effectively matched to specific resource and project requirement, rather than imposing standardized plant sizes
- Capacity range:
  - from 250 kW to 130 MW
- Enabling 100 percent re-injection of the geothermal fluid serves to maintain reservoir pressure and sustain the life of the aquifer.
- Air-Condensers for Sustainability and Environmental Benefits
  - In addition of enabling 100 percent re-injection, air-cooled condensers minimize the environmentally negative impact of emissions and acid rain from cooling towers and eliminate the use of chemicals for water treatment
- High Availability
  - ORMAT binary cycle plants have demonstrated average plant availability of over 97 percent, with typical individual OECs demonstrating generally over 95 percent availability
- Modularity:
  - The modular approach leads to flexibility, high average plant availability, faster delivery time and the capability of incremental development of projects
- Incremental Development:
  - Use of the modular concept and cost-effective plants at modest capacities makes it feasible to develop projects in an incremental manner, which is a more economically viable and a less risky approach
- Repowering Existing Plants:

- – The use of OECs for re powering existing power plants produces more power without additional resources by:
    - Utilizing excess inlet steam pressure through unique "topping" turbines
    - Utilizing unused heat of brine discharged from a separator
- Small/Medium Scale Projects:
  - – OEC technology is also commercially applicable for small-scale projects where the resources are limited, the power demand small and/or where the conventional technology is not economically viable
  - – The OEC's high reliability, pre-assembled units, ease of operation and maintenance, and convenience in transportation and installation are expanding the use of small scale projects

Q2. Can you please comment on workforce training issues relevant to geothermal energy development? Is our country currently producing technically competent workers in sufficient numbers to significantly expand work in all aspects of geothermal development?

A2. Currently, ORMAT sees a lack of engineers and personnel with applicable vocational skills in this county. With the expanded growth of the industry coupled with a lack of confidence in the continuation of DOE funding the geothermal industry is bracing for a substantial dearth of qualified and interested individuals.

In the GEA's Handbook on the Externalities, Employment, and Economics of Geothermal Energy Alyssa Kagel points out that a geothermal power plant provides significantly more jobs than a comparative natural gas fired power plant, according to the Department of Energy (DOE).[1] Geothermal jobs are quality, long-term, and diverse. According to the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for the proposed Telephone Flat geothermal development project located in the Glass Mountain Known Geothermal Resource Area (KGRA) in California, the average wage at the facility will be more than double the average wage in the surrounding counties. GEA's employment survey found that the overwhelming majority of geothermal jobs (95 percent) are permanent, and most are also full-time. In 2004 the geothermal industry supplied about 4,583 direct power plant related jobs.

The total direct, indirect, and induced employment impact of the industry in 2004 was 11,460 full-time jobs.[2] Looking to the future, geothermal employment should expand significantly. In 2005 alone, GEA has verified over 2,000 MW of geothermal projects under development, which would increase geothermal capacity, and subsequently geothermal employment, by over 70 percent. Within the next ten years, the Western Governors' Association (WGA) estimates that over 5,600 MW could be produced in eleven U.S. states, the economic effect of which is detailed in the table below.

[1] U.S. DOE (Jan. 2006). Employment Benefits of Using Geothermal Energy, Geothermal Technologies Program. Retrieved March 17, 2006 from *http://www1.eere.energy.gov/geothermal/employ_benefits.html*

[2] Geothermal Energy Association (GEA) (September 7, 2005). Expanding Geothermal Power Could Create 100,000 New Jobs. Press Release. Retrieved June 16, 2006 from *www.geo-energy.org*

Summary of Western States' Near-Term Geothermal Potential and Resulting Employment and Economic Contribution

	New Power Capacity (MWs)	Direct and Indirect and Induced Employment (Power Plant Jobs/Construction & Manufacturing Employment)**	30 Year Economic Output (nominal)+
California	2,400	10,200 ft jobs/38,400 person*yrs	$36 billion
Nevada	1,500	6,375 ft jobs/24,000 person*yrs	$22.5 billion
Oregon	380	1,615 ft jobs/6,080 person*yrs	$5.7 billion
Washington	50	212 ft jobs/800 person*yrs	$749 million
Alaska	25	106 ft jobs/400 person*yrs	$375 million
Arizona	20	85 ft jobs/320 person*yrs	$300 million
Colorado	20	85 ft jobs/320 person*yrs	$300 million
Hawaii	70	298 ft jobs/1,120 person*yrs	$1 billion
Idaho	860	3,655 ft jobs/13,760 person*yrs	$12.9 billion
New Mexico	80	340 ft jobs/1,280 person*yrs	$1.2 billion
Utah	230	978 ft jobs/3,680 person*yrs	$3.4 billion
Wyoming, Montana, Texas, Kansas, Nebraska, South Dakota, North Dakota	Potential Exists; Resource not studied in WGA Report	Not Studied	Not Studied
Total Western States (additional to current)	**5,635 MW**	**23,949 fulltime jobs/90,160 person*years of construction and manufacturing employment**	**84,410,046,000.00** **Almost 85 billion dollars to the U.S. economy over 30 years**

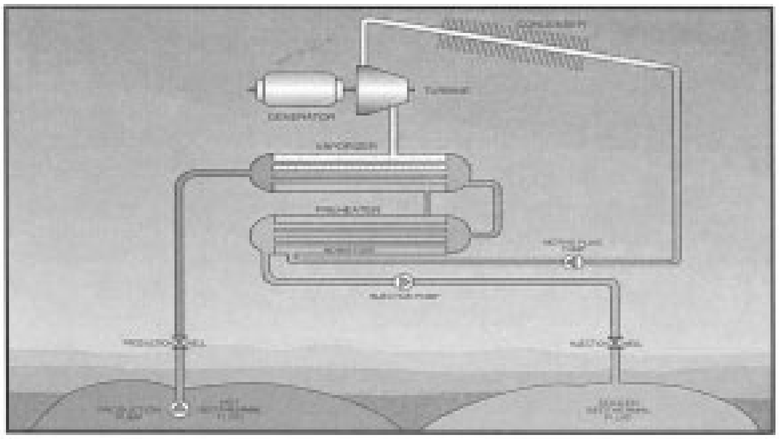
** Power plant jobs are the direct, indirect and induced full-time jobs (ft jobs) created by reaching the full power production capacity indicated. Construction and manufacturing jobs are the direct, indirect and induced jobs necessary to build and supply the power plants at the full power capacity indicated. Construction and manufacturing jobs are expressed as full-time positions for one year (person*years), however these jobs will be spread out over several years depending upon the development time frame for new projects. Direct employment results in 1.7 full time positions and 6.4 person*years per megawatt. Induced and indirect impacts were calculated assuming a 2.5% multiplier; for a total direct, indirect, and induced employment impact of 4.25 full time positions and 16 person*years per megawatt.

+Economic Output measures gross power sales over 30 years, assuming power sells at $.06/kWh and produces at a 95% capacity factor. Economic output is represented in nominal dollars, is not adjusted for inflation, and is rounded to the nearest million. Total economic output is not rounded.

Q3. Can individual geothermal reservoirs be depleted of heat or fluid over time? If so, how long does a reservoir last? If the heat in a reservoir can be depleted, can it be recharged by allowing it to lie "fallow" for a period of time? How long? Must the power plant on the surface lie dormant during this time, or can it tap into other reservoirs.

A3. The geothermal reservoir is the entire system of fractured and permeable rocks and the hot water or steam trapped in that volume of rock. Geothermal reservoir engineering is the application of the basic principles of physics and chemistry to the engineering problems associated with the production of hot water ("brine') or steam from permeable rocks within the Earth. The rock contains most of the heat energy, but the brine or steam is necessary to carry the thermal energy to the surface for economic use. The long term success and profitability of an electricity producing geothermal project depends on how well the geothermal resource is managed. Like oil and gas reservoirs, geothermal reservoirs can be overproduced if not properly managed. Overproduction of a reservoir leads to a significant shortening of its productive lifetime and a loss of income. Almost all geothermal fields require injection of the produced brine back into the reservoir to maintain pressure and productivity.

ORMAT's closed loop binary process re-injects 100 percent of all brine used in its process creating a preferable reservoir management program, allowing ORMAT to predict future changes in pressure, temperature, production rates, and chemistry of the produced geothermal fluids.



Such information is crucial for designing power plants and other facilities required for the most economic use of the resource. Reservoir engineering is of major importance in geothermal development. Any unexpected change in the characteristics of the wells or produced fluids can dramatically affect the profitability of the project. The application of reservoir engineering begins during the exploration phase of the project with the analysis of the initial geophysical measurement data that indicates a promising geothermal system, and it continues throughout the operational life of the geothermal resource. It is the reservoir engineer's task to test wells, monitor their output, design new wells, and predict the long-term performance of the reservoir and wells. This design and prediction is accomplished by studying field and operational measurement data and using computer models to project the field operation into the future. During operation of a geothermal field, the reservoir engineer will be able to compare the actual performance to the predicted performance. If necessary, the engineer can modify the management plan for the geothermal field to obtain more efficient operation. ORMAT's steamboat facility has been operating since 1985 with minimal variation to the resource temperature. Because 90 percent of the heat utilized in the geothermal process is transferred from the surrounding rock to the brine, ORMAT is unaware of any geothermal reservoir that has completely depleted its heat source. While water management can be difficult in non-closed loop systems, EGS systems may prove pivotal in assisting in reservoir management.

Q4. Does your company see major export opportunities for geothermal energy technologies?

A4. Yes, ORMAT is a vertically-integrated company whose primary business is to develop, build, own and operate geothermal and recovered energy power plants utilizing in-house designed and manufactured equipment selling the electricity to utilities under long-term power purchase agreement. Power generation resulted in 73 percent of 2006 total revenues.

ORMAT also supplies its power generating equipment or complete power plants on a turnkey—EPC (Engineering, Procurement and Construction) basis to developers, utilities and industrial users. ORMAT has installed its equipment in 71 countries on six continents. Products resulted in 27 percent of 2006 revenues.

Q5. What are the specific technological hurdles that stand in the way or geothermal power being used as a significant source of energy in the United States?

A5. ORMAT sees technological hurdles and substantial needs for improvement in technology, resource information, and efficiencies for which federal research is vital. The range of near-term needs is broad. Our knowledge and understanding of the geothermal resource base is limited and largely outdated. The technology available today to identify and characterize the resource often does not mitigate the high risk of development. Drilling in harsh geothermal environments is difficult and expensive. In locations where the resource cannot presently support commercial production, we need to evaluate the applicability of EGS techniques to achieve power generation at competitive prices.

ORMAT supports a continued geothermal research program to address these near-term needs to expand domestic energy production and the long-term need to find the additional breakthroughs in technology that could revolutionize geothermal power production and reduce this countries dependence on foreign energy sources. ORMAT believes this to include an ongoing R&D program focused on further expanding the hydrothermal resource base, developing the technologies needed to make the EGS concept commercially viable, and taking advantage of the substantial deep thermal resources associated with the petroleum formations along the Gulf Coast.

ORMAT believes cost-sharing is an appropriate and necessary component of a near-market partnership between the government and a for profit entity. For an example of what can come from this type of collaboration I turn to the fact that ORMAT has signed a cost-shared Cooperative Research and Development Agreement (CRADA) with DOE to validate the feasibility of a proven technology already used in geothermal and Recovered Energy Generation (REG).

The project will be conducted at the DOE Rocky Mountain Oil Test Center (RMOTC), near Casper, Wyoming, and will use an ORMAT Organic Rankine Cycle (ORC) power generation system to produce commercial electricity. ORMAT will supply the ORC power unit at its own expense while the DOE will install and operate the facility for a 12-month period. ORMAT and the DOE will share the total cost of the test and the study, with ORMAT bearing approximately two thirds of the less than $1M total investment. The information gathered from this project may have implications to the some 8,000 similar type wells have been identified in Texas.

Questions submitted by Representative Gabrielle Giffords

Q1. Can you comment on the use of water resources in geothermal power plants? Is a source of water essential, either for cooling or other purposes? Is geothermal technology applicable in regions, like the southwestern U.S., where water is scarce?

A1. Water use: Water cooling is not always required for geothermal power plants. Binary power plants (which will be the most commonly installed for most new geothermal facilities) can be air-cooled. However, in locations with high average ambient temperatures, water-cooling is a preferred method, even for binary plants. The water-use for these power plants is relatively low compared to fossil fuel technologies.

According to the Geothermal Energy Association, "Geothermal plants* use five gallons of freshwater per megawatt hour, while binary air-cooled plants use no fresh water. This compares with 361 gallons per megawatt hour used by natural gas facilities."[3]

* This includes binary plants and flash or steam plants.

Because geothermal plants use significantly less water than fossil fuel plants, the scarcity of water is not a concern, nor a obstacle to development. Geothermal plants currently operate in the Southwest in Southern California, Central Nevada, and Southwestern Utah. A geothermal power plant has operated in Southwestern New Mexico.

Outside of Southern California, and Central and Northern Nevada, other areas in the Southwest have been noted as containing geothermal prospects sufficient for electric production.

This includes areas in Arizona (including Southeastern Arizona)

This includes areas in Colorado (particularly Southwestern/South central Colorado)

This includes areas in New Mexico (particularly Southwestern/South central New Mexico)

[3] *A Guide to Geothermal Energy and the Environment.* Geothermal Energy Association (2007) (page ii).

This includes areas in Utah (including Southwestern Utah)

Appendix 2:

Additional Material for the Record

I

110TH CONGRESS
1ST SESSION

H. R. 2304

To direct the Secretary of Energy to conduct a program of research, development, demonstration, and commercial application for geothermal energy, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

MAY 14, 2007

Mr. MCNERNEY (for himself, Mr. GORDON of Tennessee, and Mr. LAMPSON) introduced the following bill; which was referred to the Committee on Science and Technology

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A BILL

To direct the Secretary of Energy to conduct a program of research, development, demonstration, and commercial application for geothermal energy, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the ''Advanced Geothermal Energy Research and Development Act of 2007''.

SEC. 2. FINDINGS.

The Congress finds the following:

(1) The United States has a critical national interest in developing clean, domestic, renewable sources of energy in order to mitigate the causes of climate change, reduce other environmental impacts of energy production, increase national security, improve public health, and bolster economic stability.

(2) Geothermal energy is a renewable energy resource.

(3) Geothermal energy is unusual among renewable energy sources because of its ability to provide an uninterrupted supply of baseload electricity.

(4) Recently published assessments by reputable experts, including the Massachusetts Institute of Technology, the Western Governors Association, and the National Renewable Energy Laboratory, indicate that the Nation's geothermal resources are widely distributed, vast in size, and barely tapped.

(5) Sustained and expanded research, development, demonstration, and commercial application programs are needed to locate and characterize geothermal resources, and to develop the technologies that will enable their widespread commercial development.

(6) Federal support is critical to reduce the financial risk associated with developing new geo-

thermal technologies, thereby encouraging the private sector investment necessary to make geothermal resources commercially viable as a source of electric power and for other applications.

SEC. 3. DEFINITIONS.

For purposes of this Act:

(1) ENHANCED GEOTHERMAL SYSTEMS.—The term "enhanced geothermal systems" means geothermal reservoir systems that are engineered, as opposed to occurring naturally.

(2) GEOFLUID.—The term "geofluid" means any fluid used to extract thermal energy from the Earth which is transported to the surface for direct use or electric power generation, except that such term shall not include oil or natural gas.

(3) GEOTHERMAL.—The term "geothermal" refers to heat energy stored in the Earth's crust that can be accessed for direct use or electric power generation.

(4) HYDROTHERMAL.—The term "hydrothermal" refers to naturally occurring subsurface reservoirs of hot water or steam.

(5) SECRETARY.—The term "Secretary" means the Secretary of Energy.

(6) SYSTEMS APPROACH.—The term "systems approach" means an approach to solving problems or designing systems that considers the entire system, rather than a particular component of the system.

SEC. 4. HYDROTHERMAL RESEARCH AND DEVELOPMENT.

(a) IN GENERAL.—The Secretary shall support programs of research, development, demonstration, and commercial application to expand the use of geothermal energy production from hydrothermal systems, including the programs described in subsection (b).

(b) PROGRAMS.—

(1) ADVANCED HYDROTHERMAL RESOURCE TOOLS.—The Secretary, in consultation with other appropriate agencies, shall support a program to develop advanced geophysical, geochemical, and geologic tools to assist in locating hidden hydrothermal resources, and to increase the reliability of site characterization before, during, and after initial drilling. The program shall develop new prospecting techniques to assist in prioritization of targets for characterization. The program shall include a field component.

(2) INDUSTRY COUPLED EXPLORATORY DRILLING.—The Secretary shall support a program of

cost-shared field demonstration programs, to be pursued, simultaneously and independently, in collaboration with industry partners, for the demonstration of technologies and techniques of exploratory drilling for undiscovered resources in a variety of geologic settings. The program shall include incentives to encourage the use of advanced technologies and techniques.

SEC. 5. GENERAL GEOTHERMAL SYSTEMS RESEARCH AND DEVELOPMENT.

(a) SUBSURFACE COMPONENTS AND SYSTEMS.—The Secretary shall support a program of research, development, demonstration, and commercial application of components and systems capable of withstanding extreme geothermal environments and necessary to cost-effectively develop, produce, and monitor geothermal reservoirs and produce geothermal energy. These components and systems shall include advanced casing systems (expandable tubular casing, low-clearance casing designs, and others), high-temperature cements, high-temperature submersible pumps, and high-temperature packers, as well as technologies for under-reaming, multilateral completions, high-temperature logging, and logging while drilling.

(b) RESERVOIR PERFORMANCE MODELING.—The Secretary shall support a program of research, development, demonstration, and commercial application of models of geothermal reservoir performance, with an emphasis on accurately modeling performance over time. Models shall be developed to assist both in the development of geothermal reservoirs and to more accurately account for stress-related effects in stimulated hydrothermal and enhanced geothermal systems production environments.

SEC. 6. ENHANCED GEOTHERMAL SYSTEMS RESEARCH AND DEVELOPMENT.

(a) IN GENERAL.—The Secretary shall support a program of research, development, demonstration, and commercial application for enhanced geothermal systems, including the programs described in subsection (b).

(b) PROGRAMS.—

(1) ENHANCED GEOTHERMAL SYSTEMS TECHNOLOGIES.—The Secretary shall support a program of research, development, demonstration, and commercial application of the technologies and knowledge necessary for enhanced geothermal systems to advance to a state of commercial readiness, including advances in—

(A) reservoir stimulation;

(B) reservoir characterization, monitoring, and modeling;

(C) stress mapping;

(D) tracer development;

(E) three-dimensional tomography; and

(F) understanding seismic effects of deep drilling and reservoir engineering.

(2) ENHANCED GEOTHERMAL SYSTEMS RESERVOIR STIMULATION.—

(A) PROGRAM.—In collaboration with industry partners, the Secretary shall support a program of research, development, and demonstration of enhanced geothermal systems reservoir stimulation technologies and techniques. A minimum of 5 sites shall be selected in locations that show particular promise for enhanced geothermal systems development. Each site shall—

(i) represent subsurface geological conditions; and

(ii) take advantage of an existing site where subsurface characterization has been conducted or existing drill holes can be utilized, if possible.

(B) CONSIDERATION OF EXISTING SITES.—The following 2 sites, where Department of Energy and industry cooperative enhanced geothermal systems projects are already underway, may be considered for inclusion among the sites selected under subparagraph (A):

(i) Desert Peak, Nevada.

(ii) Coso, California.

SEC. 7. COST SHARING.

(a) APPLICABILITY.—In carrying out the research, development, demonstration, and commercial application programs under this Act, the Secretary shall require cost-sharing as follows:

(1) IN GENERAL.—For the programs described in sections 4(b)(1), 5(a), 5(b), and 6(b)(1), except as provided in paragraph (2) of this subsection, the Secretary shall require that not less than 20 percent of the cost of an activity be provided by non-Federal sources. For the programs described in sections 4(b)(2) and 6(b)(2), except as provided in paragraph (2) of this subsection, the Secretary shall require that not less than 50 percent of the cost of an activity be provided by non-Federal sources.

(2) REDUCTION OF NON-FEDERAL SHARE.—The Secretary may reduce or eliminate the requirement of paragraph (1) for an activity if the Secretary determines that the reduction is necessary and appropriate.

(b) NON-FEDERAL CONTRIBUTIONS.—Non-Federal contributions required under subsection (a)—

(1) may include—

(A) personnel costs;

(B) the value of a service, other resource, or third party in-kind contribution; and

(C) indirect costs or facilities and administrative costs; and

(2) shall not include—

(A) revenues or royalties from the prospective operation of an activity beyond the duration of the award; or

(B) proceeds from the prospective sale of an asset of an activity.

(c) REPAYMENT OF FEDERAL SHARE.—The Secretary shall not require repayment of the Federal share of a cost-shared activity under this section as a condition of making an award.

(d) ORGANIZATION AND ADMINISTRATION OF PROGRAMS.—Programs under this Act shall incorporate the following organizational and administrative elements:

(1) Non-Federal participants shall be chosen through a competitive selection process.

(2) The request for proposals for each program shall stipulate, at a minimum, the following:

(A) The non-Federal funding requirements for projects.

(B) The funding mechanism to be used (i.e. grants, contracts, or cooperative agreements).

(C) Milestones and a schedule for completion.

(D) Criteria for evaluating proposals.

(3) In evaluating proposals, the Secretary shall give priority to proposals that draw on relevant expertise from industry, academia, and the national laboratories, as appropriate.

(4) In evaluating proposals, the Secretary shall consult with relevant experts from industry, academia, and the national laboratories, as appropriate.

(5) In evaluating proposals, the Secretary shall give priority to proposals that demonstrate clear evidence of employing a systems approach.

(6) Data collected by the Secretary as a result of any project supported with funds provided under this Act shall be made available to the public, except to the extent that they contain information that is protected from disclosure under section 552(b) of title 5, United States Code.

SEC. 8. CENTERS FOR GEOTHERMAL TECHNOLOGY TRANSFER.

(a) IN GENERAL.—The Secretary shall award grants to institutions of higher education (or consortia thereof) to establish 2 Centers for Geothermal Technology Transfer.

(b) CENTERS.—

(1) HYDROTHERMAL CENTER.—The purpose of one Technology Transfer Center shall be to serve as an information clearinghouse for the geothermal industry, collecting and disseminating information on best practices in all areas related to developing and managing hydrothermal resources, including data available for disclosure as provided under section 7(d)(6). This Center shall be based at the institution west of the Mississippi River that the Secretary considers to be best suited to the purpose. The Center shall collect and disseminate information on all subjects germane to the development of hydrothermal systems, including—

(A) resource location;

(B) reservoir characterization, monitoring, and modeling;

(C) drilling techniques; and

(D) reservoir management techniques.

(2) ENHANCED GEOTHERMAL SYSTEMS CENTER.—The purpose of a second Technology Transfer Center shall be to serve as an information clearinghouse for the geothermal industry, collecting and disseminating information on best practices in all areas related to developing and managing enhanced geothermal systems resources, including data available for disclosure as provided under section 7(d)(6). This Center shall be based at an academic institution east of the Mississippi River which, in the opinion of the Secretary is best suited to provide national leadership on enhanced geothermal systems-related issues.

(c) AWARD DURATION.—An award made by the Secretary under this section shall be for an initial period of 5 years, and may be renewed for additional 5-year periods on the basis of—

(1) satisfactory performance in meeting the goals of the research plan proposed by the Center; and

(2) other requirements as specified by the Secretary.

SEC. 9. STUDY ON ADVANCED USES OF GEOTHERMAL ENERGY.

Not later than 1 year, 3 years, and 5 years, after the date of enactment of this Act, the Secretary shall report to the Committee on Science and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate on advanced concepts and technologies to maximize the geothermal resource potential of the United States. The reports shall include—

(1) the use of carbon dioxide as an alternative geofluid with potential carbon sequestration benefits;

(2) mineral recovery from geofluids;

(3) use of geothermal energy to produce hydrogen;

(4) use of geothermal energy to produce biofuels;

(5) use of geothermal heat for oil recovery from oil shales and tar sands;

(6) coproduction of geofluids for direct use or electric power generation in conjunction with existing oil and gas extraction operations; and

(7) other advanced geothermal technologies, including advanced drilling technologies and advanced power conversion technologies.

SEC. 10. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to the Secretary to carry out this Act $80,000,000 for each of the fiscal years 2008 through 2012.

○

SECTION-BY-SECTION ANALYSIS OF
H.R. 2304, THE ADVANCED GEOTHERMAL ENERGY
RESEARCH AND DEVELOPMENT ACT OF 2007

REP. JERRY MCNERNEY (D–CA)
INTRODUCED MAY 14, 2007

Summary

H.R. 2304 directs the Secretary of Energy to support programs of research, development, demonstration, and commercial application in advanced geothermal energy technologies. It also establishes or expands several programs for technology transfer and information sharing on geothermal energy.

Section-by-Section

Section 1. Short Title

Act may be cited as the "Advanced Geothermal Energy Research and Development Act of 2007"

Section 2. Findings

Geothermal energy is a renewable resource capable of providing baseload power generation (and other applications) with minimal environmental impact. The geothermal energy potential in the United States is widely distributed and vast in size, yet it remains barely tapped. Sustained and expanded funding for research, development, demonstration, and commercial application programs is needed to improve the technologies to locate, characterize, and develop geothermal resources.

Section 3. Definitions

Provides definitions for the following terms used in the Act: 'Enhanced Geothermal Systems,' 'Geofluid,' 'Geothermal,' 'Hydrothermal,' 'Secretary,' and 'Systems Approach.'

Section. 4. Hydrothermal Research and Development

Instructs the Secretary to support research, development, demonstration, and commercial application of technologies designed to assist in locating and characterizing undiscovered hydrothermal resources. Establishes an "industry-coupled exploratory drilling" program, which is a cost-shared program with industry partners to demonstrate and apply advanced exploration technologies.

Section 5. General Geothermal Systems Research and Development

Establishes a program of research, development, demonstration, and commercial application of system components and materials capable of withstanding the extreme environment (high temperatures and corrosiveness) in geothermal wells. Also establishes a program of RDD&CA of improved models of geothermal reservoir performance.

Section 6. Enhanced Geothermal Systems (EGS) Research and Development

Instructs the Secretary to support a program of RDD&CA of technologies necessary to advance EGS to a state of commercial readiness. Also establishes a cost-shared, field based program of research, development, and demonstration of technologies to create and stimulate EGS reservoirs.

Section 7. Cost Sharing

Establishes guidelines for the ratio of federal/non-federal contributions to cost-shared programs established under this Act. Also describes certain organizational and administrative elements to be integrated into the structure of cost-shared programs.

Section 8. Centers for Geothermal Technology Transfer

Provides for the creation of two Centers of technology transfer to function as information clearinghouses for the geothermal industry, dedicated to collecting and sharing industry-relevant information. One Center, to be located in the western U.S., shall be dedicated to hydrothermal-specific development information; the other Center, located in the eastern U.S., shall be dedicated to EGS-specific development information.

Section 9. Study on Advanced Uses of Geothermal Energy

Requires the Secretary to track technological advances impacting geothermal energy development and advanced uses of geothermal energy and fluids, and report back to the Committee every other year for the next five years (a total of three times).

Section 10. Authorization of Appropriations

Authorizes appropriations of $80,000,000 for each of the fiscal years 2008 through 2012.

110TH CONGRESS
1ST SESSION

H. R. 2313

To establish research, development, demonstration, and commercial application programs for marine renewable energy technologies.

IN THE HOUSE OF REPRESENTATIVES

MAY 15, 2007

Ms. HOOLEY introduced the following bill; which was referred to the Committee on Science and Technology

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A BILL

To establish research, development, demonstration, and commercial application programs for marine renewable energy technologies.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Marine Renewable Energy Research and Development Act of 2007".

SEC. 2. FINDINGS.

The Congress finds the following:

(1) The United States has a critical national interest in developing clean, domestic, renewable sources of energy in order to reduce other environ-

mental impacts of energy production, increase national security, improve public health, and bolster economic stability.

(2) Marine renewable energy is a nonpolluting energy resource.

(3) Marine renewable energy may serve as an alternative to fossil fuels and create thousands of new jobs within the United States.

(4) Europe has already successfully delivered electricity to the grid through the deployment of wave and tidal energy devices off the coast of Scotland.

(5) Recent studies from the Electric Power Research Institute, in conjunction with the Department of Energy's National Renewable Energy Laboratory, have identified an abundance of viable sites within the United States with ample wave, tidal, and thermal resources to be harnessed by marine power technologies.

(6) Sustained and expanded research, development, demonstration, and commercial application programs are needed to locate and characterize marine renewable energy resources, and to develop the technologies that will enable their widespread commercial development.

(7) Federal support is critical to reduce the financial risk associated with developing new marine renewable energy technologies, thereby encouraging the private sector investment necessary to make marine renewable energy resources commercially viable as a source of electric power and for other applications.

SEC. 3. DEFINITIONS.

For purposes of this Act—

(1) MARINE RENEWABLE ENERGY.—The term "Marine Renewable Energy" means energy derived from one or more of the following sources:

(A) Waves.

(B) Tidal flows.

(C) Ocean currents.

(D) Ocean thermal energy conversion.

(2) SECRETARY.—The term "Secretary" means the Secretary of Energy.

SEC. 4. MARINE RENEWABLE ENERGY RESEARCH AND DEVELOPMENT.

The Secretary shall support programs of research, development, demonstration, and commercial application to expand the use of marine renewable energy production from marine renewable energy technology systems, including programs to—

(1) explore and compare existing marine renewable energy extraction technologies;

(2) research, develop, and demonstrate advanced marine renewable energy systems and technologies;

(3) reduce the manufacturing and operation costs of marine renewable energy technologies;

(4) investigate efficient and reliable integration with the utility grid and intermittency issues;

(5) advance wave forecasting technologies;

(6) conduct experimental and numerical modeling for device and marine energy conversion device array optimization;

(7) increase the reliability and survivability of marine renewable energy facilities;

(8) study the compatibility with the environment of marine renewable energy technologies and systems;

(9) establish protocols for how the ocean community best interacts with marine renewable energy devices and parks;

(10) develop marine renewable energy power measurement and identification standards; and

(11) address standards development, demonstration, and technology transfer for advanced

systems engineering and system integration methods to identify critical interfaces.

SEC. 5. NATIONAL MARINE RENEWABLE ENERGY RESEARCH, DEVELOPMENT, AND DEMONSTRATION CENTERS.

(a) CENTERS.—The Secretary, acting through the National Renewable Energy Laboratory, shall award grants to institutions of higher education (or consortia thereof) for the establishment of 1 or more National Marine Renewable Energy Research, Development, and Demonstration Centers. In selecting locations for Centers, the Secretary shall choose at least 1 site from among sites that host an existing marine renewable energy research and development program in coordination with a public university engineering program.

(b) PURPOSES.—The Centers shall advance research, development, demonstration, and commercial application of marine renewable energy through a number of initiatives including for the purposes described in section 4(1) through (11), and shall serve as an information clearinghouse for the marine renewable energy industry, collecting and disseminating information on best practices in all areas related to developing and managing enhanced marine renewable energy systems resources.

SEC. 6. AUTHORIZATION OF APPROPRIATIONS.

There are authorized to be appropriated to the Secretary to carry out this Act $50,000,000 for each of the fiscal years 2008 through 2012.

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SECTION-BY-SECTION ANALYSIS OF
H.R. 2313, THE MARINE RENEWABLE ENERGY
RESEARCH AND DEVELOPMENT ACT OF 2007

REP. DARLENE HOOLEY (D–OR)
INTRODUCED MAY 15, 2007

Summary

H.R. 2313 directs the Secretary of Energy to support programs of research, development, demonstration, and commercial application in marine renewable energy technologies. It also establishes National Centers for the testing of marine renewable energy technologies.

Section-by-Section

Section 1. Short Title

Act may be cited as the "Marine Renewable Energy Research and Development Act of 2007"

Section 2. Findings

Marine energy sources—including waves, tidal flows, ocean currents, and thermal gradients—are clean, renewable, domestic sources of energy that have the potential to provide significant amounts of electricity to the Nation's power grid. Technologies designed to harness marine energy sources are already providing grid power in Europe. Recent studies have identified an abundance of viable sites for marine energy production in coastal areas of the United States, but expanded R&D is necessary to further develop the related technologies and hasten their commercial application. Federal support can be instrumental in hastening the development of marine renewable energy technologies and reducing the risk of investing in these areas.

Section 3. Definitions

Provides definitions for the following terms used in the Act: 'Marine Renewable Energy' (includes usable energy derived from waves, tidal flows, ocean currents, and thermal gradients), and 'Secretary.'

Section. 4. Marine Renewable Energy Research and Development

Instructs the Secretary to support programs of research, development, demonstration, and commercial application of marine renewable energy technologies. Areas of activity shall include: studying and comparing existing technologies, developing improved technologies, reducing costs of manufacture and operation, investigating integration with power grid, improving wave forecasting technologies, optimizing placement of devices, increasing reliability and survivability, studying technology compatibility with the environment, protocols for interacting with devices, and developing power measurement standards.

Section 5. Marine Renewable Energy Research and Demonstration Centers

Calls for the establishment of one or more Centers for the research, development, and demonstration of marine renewable technologies. Such centers shall serve as permanent installations in environmentally approved areas where prototype technologies can be tested in connection with the power grid. Centers shall also serve as clearinghouses of industry relevant information. Sites for Centers shall be chosen on the basis of accessibility to appropriate marine energy resources and proximity to an existing marine renewable energy research and development program.

Section 6. Authorization of Appropriations

Authorizes appropriations of $50,000,000 for each of the fiscal years 2008 through 2012.

STATEMENT OF UTC POWER

UTC Power appreciates the opportunity to submit the following statement for the record for the House Committee on Science and Technology, Energy and Environment Subcommittee hearing on *"Developing Untapped Potential: Geothermal and Ocean Power Technologies."*

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, 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. UTC Power recently announced an agreement with Raser Technologies to provide up to 135 PureCycle® geothermal power systems totaling approximately 30 megawatts of renewable power for three Raser power plants.

Summary

Geothermal energy addresses many of our national concerns, but its potential is largely untapped. UTC Power's PureCycle® system represents an innovative advancement in geothermal energy production and is operating successfully today in Alaska as part of a demonstration effort. This geothermal energy breakthrough offers the possibility of tapping into significant U.S. geothermal reserves for a domestic, renewable, continuously available source of power to meet our growing energy demands. Congressional action is needed, however, if the United States is to translate this potential into reality. We welcome the introduction of the *"Advanced Geothermal Energy Research and Development Act of 2007"* (H.R. 2304) as a key element of the comprehensive policy framework that is necessary to advance our nation's use of geothermal energy.

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

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

Chena Hot Springs Resort Puts Geothermal on the Map in Alaska

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

The system was commissioned in August 2006 and provides power for the resort's on-site electrical needs. Our two PureCycle® 225 kW Chena units have logged 5,400 hours of experience with 98 percent availability.

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

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

Description of PureCycle® Technology

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

Innovative Features and Awards

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

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

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

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

What Is the Significance of Low Temperature Geothermal Energy?

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

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

Recommended Actions

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

We have only scratched the surface regarding our nation's geothermal energy potential. The R&D possibilities have not been exhausted and this is NOT a resource that is limited to only a few Western states. There are advances in low-temperature geothermal energy alone that prove otherwise.

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

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 and revised "placed in service" rules.*

   The 2005 *Energy Policy Act* made geothermal energy production eligible for the Sec. 45 federal Renewable Electricity Production Tax Credit (PTC). This incentive is adjusted for inflation and currently provides 2.0 cents per kWh for energy produced from geothermal resources. A taxpayer may claim credit for the 10-year period commencing with the date the qualified facility is placed in service.

   Many geothermal projects take years to develop. The PTC timeframe is too short for most geothermal projects to be completed by the current placed in service deadline. We support the Geothermal Energy Association's position that "To achieve sustained geothermal development, Congress should immediately amend the law to allow facilities under construction by the placed in service date of the law to qualify, and extend the placed in service deadline by at least five years, to January 1, 2014, before its expiration."

   Since our PureCycle® system is just now entering the marketplace, we need certainty and stability with regard to this important incentive to maximize market penetration and capitalize on the many societal benefits of geothermal power production.

2. *Robust funding for DOE's Geothermal Research Program.*

   There are a variety of geothermal research, development and demonstration needs, including cost-shared partnerships to:

   - enhance the performance of existing successful geothermal power production systems;
   - improve the efficiency of geothermal capture rates;
   - increase the size of low temperature systems to one megawatt;
   - develop systems that can operate at even lower temperatures than today; and
   - demonstrate the benefits for other applications including the oil and gas market as well as industrial reciprocating engines (jacket water and exhaust heat).

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.

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.

Comments on H.R. 2304

We applaud the leadership of Reps. McNerney (D–CA), Gordon (D–TN) and Lampson (D–TX) in introducing the *"Advanced Geothermal Energy Research and Development Act of 2007"* (H.R. 2304). This legislation addresses many of the pressing research, development, demonstration 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.

Section 4—Hydrothermal Research and Development—As noted above, there are significant opportunities for research, development and demonstration activities related to low temperature geothermal power production. We recommend that a third category of programs be included in this section that addresses the opportunities related to enhanced performance, higher efficiency, greater size, lower temperature, biomass, reciprocating engines (jacket water and exhaust heat), and oil and gas applications.

In addition, to ensure the required site characterization activities include examination of low, moderate and high temperature resources, language should be added to make this explicit. As noted above, previous assessments have not focused on low temperature geothermal resources based on the assumption that technology was not available to economically utilize these resources. As our Chena Alaska project has demonstrated, low temperature geothermal resources can be tapped for power generation and therefore it is essential that resource assessments include information on their location and key characteristics.

Section 8—Centers for Geothermal Technology Transfer—The list of subjects being addressed by these information clearinghouses should be expanded to include advances in geothermal power production technology so state of the art developments can be disseminated to interested parties.

Section 10—Study on Advanced Uses of Geothermal Energy—H.R. 2304 calls for a series of reports not later than one year, three years and five years after enactment on advanced concepts and technologies to maximize the geothermal resource potential of the United States including the co-production of geofluids for direct use or electric power generation in conjunction with existing oil and gas extraction operations. We believe the Nation could speed up its use of these strategically important resources by beginning a demonstration program at the earliest possible date to validate the technology. By supporting a demonstration effort in parallel with a more extensive and rigorous examination of the characteristics of these sites and their location, we could expedite the technical learning process and accelerate the timeframe in which we could maximize the many benefits of these resources. UTC Power would therefore recommend that in addition to the study mandated in Section 10, language be added in Section 4 authorizing a demonstration program for co-production of geofluids for direct use or electric power generation in conjunction with existing oil and gas extraction operations.

Conclusion

As UTC Power's Chena project demonstrates, far from being a mature technology with limited geographic reach, geothermal energy has the potential to satisfy a significant portion of our growing energy needs with a renewable, continuously available domestic resource. But appropriate government policies must be adopted and implemented to make this a reality. We welcome the opportunity to work with Members of the Committee and other stakeholders to refine and enhance H.R. 2304 and ensure its enactment and implementation as part of a comprehensive package of initiatives that support geothermal energy production.

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