TESTIMONY

Research Priorities for Fossil Fuels

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United States Senate

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Mr. Chairman and distinguished Members: Thank you for once again inviting me to testify before this committee, on this occasion to address critical research and development (R&D) needs and opportunities associated with fossil energy. I am a Senior Policy Researcher at the RAND Corporation and specialize in energy technology and policy issues. My doctoral degree is in chemical physics, granted by MIT.

When I joined the U.S. Department of Energy 31 years ago, the challenge was energy security. Although energy security remains an important problem, we now also have a compelling need to reduce greenhouse gas emissions. Each year, the United States releases the greenhouse gas equivalent of over 7 billion metric tons of carbon dioxide. And almost 90 percent of these emissions are associated with the production and use of petroleum, coal, and natural gas, in order of decreasing contribution. So, of course, there is a clear need for research on technologies that allow us to use less of these three fossil fuels, as well as research on other energy sources, such as solar and nuclear energy, that lessen our dependence on fossil fuels. We all hope for a future in which we will depend much less on fossil fuels while simultaneously maintaining our goals for national security and economic well-being. My goal today is to make the case that the path to that future crucially depends on enhanced federal support to research and technology development directed at how we produce and use fossil fuels.

Currently, over 77 percent of the nation's electric generating capacity is based on fossil fuels. Coal plants alone meet nearly 50 percent of our electricity demand. The good news is that we have plenty of coal, more than any other nation. We also have reasonable amounts of natural gas. From an energy security perspective, the electric power sector is today in fairly good shape. And from an economic perspective, the costs of generating power from coal and natural gas are quite attractive. But the bad news is that these fossil-fuel power plants account for almost a third of the

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greenhouse gas emissions released within the United States. If the only option available to reduce greenhouse gas emissions is to eliminate coal use and turn our backs on this energy resource, consumers in the United States will pay a heavy price. Not only will electricity rates rise higher than they would otherwise, but also the price of natural gas will rise dramatically and these higher prices will affect all users, including residential and commercial customers, and will cause industries that depend on natural gas to build plants outside the United States.

Highest Priority: Low-GHG Power Production

For these reasons, our highest priority in fossil energy R&D should be to establish a technology base so that we can use fossil fuels for power production at greatly reduced greenhouse gas emission levels. Such a program needs to be directed at four major goals:

1. **Establish the technical, environmental, and commercial viability of geologic sequestration of carbon dioxide in United States, as well as public acceptance of it.** The fundamental challenge is developing the knowledge base required to confidently select underground locations that will store large amounts of carbon dioxide for many hundreds of years. This is a daunting challenge. The U.S. Department of Energy has underway an R&D and demonstration program to capture and sequester carbon dioxide emitted by new and existing power plants. In my view, this program has been grossly underfunded at every level of research, from basic studies to demonstration. While considerable progress has been achieved, the planned tests are neither large enough nor of long enough duration sufficient to establish the viability of geologic sequestration. If this program is short-changed, either with regard to funds or staffing, there is a real possibility that the public will neither gain confidence in the technology nor trust the Department to execute sequestration projects competently. We cannot afford to have the Department's efforts in geologic sequestration of carbon dioxide follow the path the Department took with Yucca Mountain.

2. **Develop advanced power-generation technology that enables both carbon dioxide capture and highly-efficient power production from new power plants.** We have a problem with current technology, including even our advanced combined-cycle systems. Capturing carbon dioxide and preparing it for transport drains energy from the power plant, increasing coal or natural gas requirements, raising power costs, and increasing the amount of carbon dioxide requiring geologic sequestration. Expanded federal R&D efforts should be considered, especially R&D directed at high-risk, high-payoff opportunities for cost reduction and improved efficiency and environmental performance. Fruitful areas for longer term R&D include advanced high-temperature fuel cells, oxygen production at

reduced energy consumption, improved gas-gas separation technologies, higher temperature gas-purification systems, and reduced or eliminated oxygen demand during gasification.

3. **Develop carbon capture technology that can be retrofitted onto existing power plants.** About 800 GigaWatts of electric generating plants powered by fossil fuels currently operate in the United States. Representing over 77 percent of total electric generating capacity, these are the plants responsible for about a third of U.S. greenhouse gas emissions. Replacing these existing plants will require an investment of many trillions of dollars. Approaches are available for capturing the greenhouse gas emissions from these plants. The R&D challenge is to discover and bring to the market carbon dioxide capture systems that drain less power from the plant and cost less to install and operate.

4. **Develop new markets and uses for captured carbon dioxide.** If we are going to capture carbon dioxide, it would preferable to put it to some good use. One opportunity already exists, namely, using carbon dioxide to extract crude oil that remains in place after normal petroleum pumping operations cease. Considering advanced methods for enhanced oil recovery, one recent study sponsored by the Department of Energy suggests that as much as 200 billion barrels of petroleum might be recoverable while simultaneously sequestering billions of tons of carbon dioxide. A longer term option is to use captured carbon dioxide to support the production of renewable liquid fuels from sunlight. For example, carbon dioxide can be used to promote rapid growth of algae that is genetically engineered for high-yield oil production.

Increasing Natural Gas Supplies

When it comes to greenhouse gas emissions, not all fossil fuels are equal. When burned, coal yields the greatest amount of carbon dioxide per unit of energy released, while natural gas yields the least. In particular, for the same amount of energy, natural gas releases about 56 percent of the carbon dioxide that would be released using coal. Moreover, because natural gas is an ash-free fuel, it can be used at much higher energy efficiencies than coal. The bottom line: Substituting natural gas for coal generally will halve greenhouse gas emissions. But it would be shortsighted to believe that natural gas can displace coal in power generation without serious adverse economic consequences, unless technology development efforts can greatly expand the amount of natural gas supply resources that can be recovered in North America.

Under higher pressures and lower temperatures, natural gas forms a solid complex with water that is known as a methane hydrate. These conditions of pressure and temperature commonly occur offshore and in the arctic regions of North America, including Alaska. At present, we do not have a good understanding of how much natural gas is available to us in the form of these methane hydrates. But we ought to, because some of the estimates of the U.S. resource are enormous, enough to supply the United States for thousands of years.

The National Methane Research and Development Act of 2000 authorizes a federal research program to determine the potential of this resource to contribute to our energy needs. Equally important, that Act also provides the basis for research directed at the potential adverse environmental consequences of these resources. Although the intent of that Act was reconfirmed in the Energy Policy Act of 2005, this research area has never seen adequate funding. In 2007, the Federal Methane Hydrate Advisory Committee reported its findings to Congress.[3] They emphasized the "critical need for more funding" and the detrimental effects of the current level of funding (about $10 million per year) on R&D progress. I fully concur with this finding, as well as with their recommendations for program emphasis, which I quote directly:

5. **"Field testing of concepts and technologies for producing hydrates economically."** Production tests are essential for developing data required for further scientific progress. Here we have an opportunity to build on promising work occurring abroad, especially work done under the support of the government of Japan.

6. **"An accurate assessment of the economic viability of marine hydrates, which exceeds the permafrost resource by several orders of magnitude."** Present estimates are extremely speculative. Better estimates are required, especially so we can understand whether this resource can provide the United States and other Nations with a means of deeply cutting greenhouse gas emissions at much lower costs than would otherwise be the case.

7. **"A quantifiable assessment of the environmental impact of possible leakage of methane from uncontrolled hydrate decomposition."** Compared to carbon dioxide, methane has a twenty-fold greater greenhouse gas effect. Understanding mechanisms that lead to methane leakage, especially from permafrost, must be a high priority research topic, especially in light of recent observations of methane releases in Arctic regions.

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[3]Federal Methane Hydrate Advisory Committee, "Report to Congress, An Assessment of the Methane Hydrate Research Program and an Assessment of the 5-Year Research Plan of the Department of Energy," June 2007.

One of the reasons methane hydrate research has not been adequately funded in the United States is the view that any research in this area should be fully carried out and funded by the oil and gas industry. While the oil and gas industry is participating and making R&D investments in methane hydrate research, their investment levels are small, as they should be, given the high risks of success, the uncertainties of obtaining access to the resource, and the long time span required to realize profits. Methane hydrate research should not be viewed as a subsidy to fossil fuel production, but rather as an integral part of the federal strategy to reduce dramatically greenhouse gas emissions.

The Department of Energy also has underway research directed at extracting natural gas from unconventional formations. However, I have not recently had the opportunity to familiarize myself with the details of this program, and therefore suggest that the Committee turn to another expert qualified to make a recommendation about critical R&D opportunities or needs in this area.

For Energy Security: Unconventional Liquid Fuels

Over the past few years, RAND has examined opportunities for the United States to produce liquid transportation-quality fuels from abundant domestic resources, in particular oil shale and coal. If carbon dioxide sequestration can be demonstrated as commercially and environmentally viable, our findings indicate that the very large oil shale and coal resources located within the United States offer the potential to produce strategically significant amounts of liquid fuels while not increasing, and more likely decreasing, greenhouse gas emissions as compared to fuels produced from imported crude oil.

Oil Shale: RAND's work on oil shale was supported by the National Energy Technology Laboratory. The largest known oil shale deposits in the world are located in the Green River Formation, which covers portions of Colorado, Utah, and Wyoming. We estimate that this resource base may eventually yield between 500 billion and 1.1 trillion barrels of useful fuels. The mid-point of this range is 800 billion barrels, which is more than triple the oil reserves of Saudi Arabia.[4]

The richest and thickest oil shale deposits are on Federal lands. Protecting the public interest in these oil shale lands is important, considering both environmental issues as well as the potentially profound impact on federal revenues and energy security. Oil shale development falls squarely on the dual purview of this Committee: Energy and Natural Resources.

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[4] For further information, see James T. Bartis, Tom LaTourrette, Lloyd Dixon, D.J. Peterson, and Gary Cecchine, *Oil Shale Development in the United States: Prospects and Policy Issues*, Santa Monica, Calif.: RAND Corporation, MG-414-NETL, 2005.

Two weeks ago, the prospects for successful development of oil shale in the United States increased as a consequence of the announcement by the Department of the Interior of a second round of research, development and demonstration leases. This will allow additional small tracts of federal lands to be made available for developing and demonstrating advanced oil shale extraction technologies. The private sector is clearly willing to invest in research directed at the economic extraction of oil shale. For this reason, it is important that any government-supported R&D be directed at areas where the public stake is highest. For these reasons, our recommended priorities for federally sponsored oil shale research are as follows:

8. **Conduct research required to understand and mitigate or prevent the adverse impacts of oil shale development**. This includes research directed at better understanding of the subsurface environment, assuring safe disposal of spent shale, reducing the uncertainties associated with ecological restoration, protecting water supplies, demonstrating carbon dioxide sequestration in the vicinity of the Green River Formation, and promoting higher recovery yields.

9. **Develop the information base required for a federal leasing strategy.** This includes regional air quality monitoring, assessments of water availability and quality, and evaluation of governance mechanisms for managing federal lands and meeting infrastructure requirements in anticipation of large industrial development.

10. **Provide federal incentives for early commercial experience.** The most promising oil shale technologies are not yet ready for large-scale commercial development. Advancing any one of them will require technology development and demonstration efforts costing in the range of hundreds of millions of dollars. While the terms of accessibility to federal lands is important, there are many other instruments, such as investment tax credits for first-of-a-kind commercial plants, that the federal government should consider to encourage continued private sector investment in advanced oil shale technologies.

Oil shale development is an area where continued policy analysis is required to protect the public interest. At present, oil shale resources have little value. The key to monetizing this publicly-owned asset requires that the government put in place a federal land leasing and management framework, and possibly an investment incentive system, that assures that private firms that successfully develop commercially and environmentally viable oil shale technologies be rewarded commensurate with the considerable risk and expense of their efforts.

Coal-derived liquids: As is the case oil shale, the United States leads the world in the quality and quantity of its coal resources. Dedicating only 15 percent of recoverable coal reserves would yield roughly 100 billion barrels of liquid transportation fuels, enough to sustain three million barrels per day of fuel production for over 90 years.

A few months ago, RAND published its findings on a comprehensive examination of the prospects and policy issues associated with producing liquid fuels from coal in the United States.[5] This work was supported by the National Energy Technology Laboratory and the Air Force. The study showed that coal-to-liquid (CTL) production facilities would emit very large volumes of carbon dioxide and that the viability of a CTL industry in the United States depends crucially on the successful demonstration that carbon dioxide can be sequestered in multiple locations in the United States. Our results show that for CTL facilities, capture and sequestration of carbon dioxide does not add significantly to liquid fuel production costs.

Another important finding of RAND's work on CTL is that liquid fuels produced using a combination of coal and biomass, when combined with capture and sequestration of carbon dioxide emissions, yield lifecycle greenhouse gas emissions that are much lower than those associated with conventional petroleum-based fuels. For example, we found lifecycle greenhouse gas emissions using a transportation fuel from a production facility using 75 percent coal and 25 percent biomass (on an energy input basis) would be roughly 60 percent less than the same fuel derived from conventional petroleum.

These considerations support the following recommendations for research in coal-derived liquids:

11. **Promote early, but limited commercial operating experience.** Modern CTL technology is ready for initial use in commercial production facilities. The government should consider subsidizing early production experience from a limited number of CTL plants. These early plants should include approaches for managing greenhouse gases. Gaining early experience will facilitate post-production cost improvements, and posture the private sector for the possible rapid expansion of a more economically competitive CTL industry.

12. **Develop the technology for combined gasification of coal and biomass.** At present the design base for combined use of coal and biomass is weak. Here we are recommending a short duration (roughly, five years) engineering development program involving materials testing and the design, construction, and operation of a few test rigs.

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[5] James T. Bartis, Frank Camm, and David S. Ortiz, *Producing Liquid Fuels from Coal: Prospects and Policy Issues*, Santa Monica, Calif.: RAND Corporation, MG-754-AF/NETL, 2008.

If the United States government decides to promote early investment in CTL production, it should also consider expanding long-term R&D efforts directed at advanced technologies for producing liquids from a combination of coal and biomass. In my judgment, the most fruitful of the R&D opportunities for advancing liquids production are the very same ones that are appropriate for advanced power production, namely lower cost and more energy-efficient means of gasifying coal and biomass, as listed in my second recommendation dealing with low-GHG power production.

Leading the Transition: Hybrid Systems

For automobiles, the concept of a plug-in hybrid vehicle provides a path by which advances in electric vehicle and battery development can immediately be put to use; so also may be the case with power generation. Specifically, the combined use of fossil and solar or nuclear technologies may make for cost-effective and environmentally superior approaches.

For example, one approach to making electricity from sunlight involves building an array of parabolic troughs that heat a working fluid to about 750 degrees F. That working fluid is pumped through a heat exchanger that makes steam in the range of 650 to 700 degrees. This steam drives a steam turbine with the result being electric power. There are two problems with this system. First, the sun isn't always shining. Second, the steam cycle is inefficient because the steam temperature is too low. A possible solution is to use a combination of a solar and fossil energy. In this hybrid concept, the fossil fuel, say natural gas, would be used to raise the temperature of the steam to about 1000 degrees F, which allows much greater efficiency at possibly much lower overall costs.

Another example is nuclear energy. The Department of Energy does not know whether hybrid plants that include both nuclear and fossil technologies can lead to lower cost, more efficient power production. It doesn't know this because of the way that the Department separates and isolates its various technology development efforts. This leads to my final technical recommendation.

13. **Fossil energy R&D should include exploiting opportunities that promote renewable and nuclear power generation**. This area of research is especially appropriate as the amount of intermittent power entering the electric transmission and distribution grid increases.

Strengthening the Management of Energy Technology Development

The foundation of a successful national energy R&D program requires more than sound goals and a financial commitment from Congress. Measures need to be taken to strengthen the management of federal energy technology development efforts.

In the past, the Department of Energy has shown a tendency to downplay the scientific challenges associated with technology development efforts. Congress, the public, and the senior leadership in the Department itself are often provided with program plans with schedules that are too fast, with unrealistically low funding requirements, and with unduly optimistic technology development goals. A consequence of this tendency is that R&D funds are too often directed at large projects that are more "show and tell" than dedicated to advancing technical progress. Quick engineering fixes are attempted while the important research necessary for progress, such as materials research and applied research dedicated to truly understanding problems and developing sound solutions, is left under funded, or in many cases, unfunded.

To remedy this problem, I urge the Committee to consider steps to assure that the Department has adequate scientific and technical talent at all levels involving the management or oversight of R&D and technology development. Further, all technology development programs should be required to demonstrate that they are sufficiently addressing the fundamental research issues and materials development issues associated with their efforts.

Our energy technology managers also need to be aware of extensive R&D efforts underway in other nations. In some cases, cost-shared efforts may be highly cost effective and productive. But to bring this wealth of information back to the United States and to afford technology transfer to our firms, Department of Energy technology managers must be able to travel internationally when R&D program needs so dictate.

Strengthening the Institutional Framework for Energy Technology Development

I would like to address briefly the important role that our research universities should have in energy technology development. In my judgment, not enough of the technology development budget has supported university-based research. Moreover, much of the funding that universities do receive is through contractual instruments that undercut the main values that universities offer to the program: creativity, scientific and engineering excellence, and education.

The main reason so little funding goes to universities is that so little of the technology development program funds are devoted to fundamental research issues, as I have previously discussed. Taking care of this problem should move more funding towards our research universities. But to get the most of those funds, energy R&D program managers must take the longer view and build their relationships on grants and other flexible contractual instruments. I urge this committee to take measures so that the energy technology development programs are empowered to and expected to interact with our research universities in this more productive manner.

The central pillar is, of course, the private sector. It will be private firms that will be responsible for manufacturing, distributing, selling, and maintaining the energy systems that will emerge from our national investment in energy R&D. Their participation in the federal program has always been important, but it will be stronger and more focused the sooner the Federal government clearly signals whether or not there will be a price on emitting greenhouse gas emissions, and if so how much; and whether or not the price of automotive fuels will include costs that reflect infrastructure requirements and energy security.

In closing, I thank the committee for inviting me to testify today.