TESTIMONY

Research and Development Issues for Producing Liquid Fuels from Coal

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Subcommittee on Energy and Environment
United States House of Representatives

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Mr. Chairman and distinguished Members: Thank you for inviting me to speak on technical issues associated with the potential use of our nation's coal resources to produce liquid fuels. I am a senior policy researcher at the RAND Corporation with more than 25 years of experience in analyzing and assessing energy technology and policy issues. At RAND, I am actively involved in research directed at understanding the costs and benefits associated with alternative approaches for promoting the use of coal and other domestically abundant resources, such as oil shale and biomass, to lessen our nation's dependence on imported petroleum. Various aspects of this work are sponsored and funded by the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy, the U.S. Air Force, the Federal Aviation Administration, and the National Commission on Energy Policy.

Today, I will discuss the key problems and policy issues associated with developing a domestic coal-to-liquids industry and the approaches Congress can take to address these issues. My main conclusions are as follows. First, successfully developing a coal-to-liquids industry in the United States would bring significant economic and national security benefits by reducing energy costs and wealth transfers to oil-exporting nations. Second, the production of petroleum substitutes from coal may cause a significant increase in carbon dioxide emissions; however, relatively low-risk research opportunities exist that, if successful, could lower carbon dioxide emissions to levels well below those associated with producing and using conventional petroleum. Third, without federal assistance, sufficient private-sector investment in coal-to-liquids production plants is unlikely to occur because of uncertainties about the future of world oil prices, the costs and performance of initial commercial plants, and the viability of carbon management options. Finally, a federal program directed at reducing these uncertainties; obtaining early, but limited, commercial experience; and supporting research appears to offer the greatest strategic benefits,

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given both economic and national security benefits and the uncertainties associated with economic viability and environmental performance, most notably the control of greenhouse gas emissions.

Some of the topics I will be discussing today are supported by research that RAND has only recently completed; consequently, the results have not yet undergone the thorough internal and peer reviews that typify RAND research reports. Out of respect for this Committee and the sponsors of this research, and in compliance with RAND's core values, I will present only findings in which RAND and I have full confidence at this time.

Technical Readiness and Production Potential

As part of RAND's examination of coal-to-liquids fuels development, we have reviewed the technical, economic, and environmental viability and production potential of a range of options for producing liquid fuels from domestic resources. If we focus on unconventional fuel technologies that are *now* ready for large-scale, commercial production and that can displace at least a million barrels per day of imported oil, we find only two candidates: grain-derived ethanol and Fischer-Tropsch (F-T) coal-to-liquids. Moreover, only the F-T coal-to-liquids candidate produces a fuel that is suitable for use in heavy-duty trucks, railroad engines, commercial aircraft, or military vehicles and weapon systems.

If we expand our time horizon to consider technologies that might be ready for use in initial commercial plants within the next five years, only one or two new technologies become available: the in-situ oil shale approaches being pursued by several firms and the F-T approaches for converting biomass or a combination of coal and biomass to liquid fuels. We have also looked carefully at the development prospects for technologies that are intended to produce alcohol fuels from sources other than food crops, generally referred to as *cellulosic materials*. Our finding is that, while this is an important area for research and development, the technology base is not yet sufficiently developed to support an assessment that alcohol production from cellulosic materials will be competitive with F-T biomass-to-liquid fuels within the next 10 years, if ever.

The Strategic Benefits of Coal-to-Liquids Production

Our research is also addressing the strategic benefits of having in place a mature coal-to-liquid fuels industry producing several million barrels of oil per day. If coal-derived liquids were added to the world oil market, such additional liquid fuel supplies would cause world oil prices to be lower than they would be if these additional supplies were not produced. This effect occurs regardless

of what fuel is being considered. It holds for coal-derived liquids and for oil shale, heavy oils, tar sands, and biomass-derived liquids, as well as, for that matter, additional supplies of conventional petroleum. The price-reduction effect also occurs when oil demand is reduced through fiscal measures, such as taxes on oil, or through the introduction of advanced technologies that use less petroleum, such as higher efficiency vehicles. Moreover, this reduction in world oil prices is independent of where such additional production or energy conservation occurs, as long as the additional production is outside of OPEC and OPEC-cooperating nations.

In a 2005 analysis of the strategic benefits of oil shale development, RAND estimated that 3 million barrels per day of additional liquid-fuel production would yield a world oil price drop of between 3 and 5 percent.[3] Our ongoing research supports that estimated range and shows that the price drop increases in proportion to production increases. For instance, an increase of 6 million barrels per day would likely yield a world oil price drop of between 6 and 10 percent. This more recent research also shows that even larger price reductions may occur in situations in which oil markets are particularly tight or in which OPEC is unable to enforce a profit-optimizing response among its members.

This anticipated reduction in world oil prices yields important economic benefits. In particular, U.S. consumers would pay tens of billions of dollars less for oil or, under some future situations, hundreds of billions of dollars less for oil per year. On a per-household basis, we estimate that the average annual benefit could range from a few hundred to a few thousand dollars.

Further, this anticipated reduction in world oil prices also yields a major national security benefit. At present, OPEC revenues from oil exports are about $700 billion per year. Projections of future petroleum supply and demand published by the U.S. Department of Energy indicate that, unless measures are taken to reduce the prices of, and demand for, OPEC petroleum, such revenues will grow considerably. These high revenues raise serious national security concerns, because some OPEC member nations are governed by regimes that are not supportive of U.S. foreign policy objectives. Income from petroleum exports has been used by unfriendly nations, such as Iran and Iraq under Saddam Hussein, to support weapon purchases or to develop their own industrial base for munitions manufacture. Also, the higher prices rise, the greater the chances that oil-importing countries will pursue special relationships with oil exporters and defer joining the United States in multilateral diplomatic efforts.

[3] *Oil Shale Development in the United States: Prospects and Policy Issues*, Bartis et al, Santa Monica, Calif.: RAND Corporation, MG-414-NETL, 2005.

Our research shows that developing an unconventional fuels industry that displaces millions of barrels of petroleum per day will cause a significant decrease in OPEC revenues from oil exports. This decrease results from a combination of lower prices and a lower demand for OPEC production. The size of this reduction in OPEC revenues is determined by the volume of unconventional fuels produced and future market conditions, but our ongoing research indicates that expectations of annual reductions of hundreds of billions of dollars are not unreasonable. The significant reduction in wealth transfers to OPEC and the geopolitical consequences of reduced demand for OPEC oil represent the major national security benefits associated with the development of an unconventional liquid fuels production industry. Note that these revenue reductions would affect all petroleum exporters, both friends and foes.

These strategic benefits derive from the existence of the OPEC cartel. The favorable benefits of reduced oil prices accrue to consumers and the nation as a whole; however, the private firms that would invest in coal-to-liquids development do not capture those benefits.

The Direct Benefits of Coal-to-Liquids Production

Beyond the strategic benefits for the nation associated with coal-to-liquids production are certain direct benefits. If coal-derived liquid fuels can be produced at prices well below world oil prices, then the private firms that invest in coal-derived liquid fuels development could garner economic profits above and beyond what is considered a normal return on their investments. Through taxes on these profits and, in some cases, lease and royalty payments, we estimate that roughly 35 percent of these economic profits could go to federal, state, and local governments and, thereby, broadly benefit the public.

An auxiliary benefit of coal-to-liquids development derives from the broad regional dispersion of the U.S. coal resource base and the fact that coal-to-liquids plants are able to produce finished motor fuels that are ready for retail distribution. As such, developing a coal-to-liquids industry should increase the resiliency of the overall petroleum supply chain.

The remaining benefits of developing a coal-to-liquids production industry are local or regional, as opposed to national. In particular, coal-to-liquids industrial development offers significant opportunities for economic development and would increase employment in coal-rich states.

Greenhouse Gas Emissions

While the strategic benefits of the development of a domestic coal-to-liquids industry are compelling, no less pressing is the importance of addressing the threat of global climate change. Specifically, without measures to address carbon dioxide emissions, the use of coal-derived liquids to displace petroleum fuels for transportation will roughly double greenhouse gas emissions.

This finding is relevant to the total fuel life cycle, i.e., well-to-wheels or coal mine–to-wheels. This increase in greenhouse gas emissions is primarily attributable to the large amount of carbon dioxide emissions that come from an F-T coal-to-liquids production plant relative to a conventional oil refinery. In fact, looking solely at the combustion of F-T–derived fuel as opposed to its production, our analyses show that combustion of an F-T, coal-derived fuel would produce somewhat, although not significantly, *lower* greenhouse gas emissions than would the combustion of a gasoline or diesel motor fuel prepared by refining petroleum.

In our judgment, the high greenhouse gas emissions of F-T coal-to-liquids plants that do not manage such emissions preclude their widespread use as a means of displacing imported petroleum. We now turn to some options for managing greenhouse gas emissions.

Options for Managing Greenhouse Gas Emissions

For managing greenhouse gas emissions for F-T coal-to-liquids plants, we have examined three options: (1) carbon capture and sequestration, (2) carbon dioxide capture and use in enhanced oil recovery, and (3) gasification of both coal and biomass followed by F-T synthesis of liquid fuels. We discuss each below in turn.

Carbon Capture and Sequestration: By carbon capture and sequestration, I refer to technical approaches being developed in the United States, primarily through funding from the U.S. Department of Energy, and abroad that are designed to capture carbon dioxide produced in coal-fired power plants and to sequester that carbon dioxide in various types of geological formations, such as deep saline aquifers. This same approach can be used to capture and sequester carbon dioxide emissions from F-T coal-to-liquids plants and from F-T plants operating on biomass or a combination of coal and biomass. When applied to F-T coal-to-liquids plants, carbon capture and sequestration should cause mine-to-wheels greenhouse gas emissions to drop to levels comparable to the well-to-wheels emissions associated with conventional, petroleum-derived motor fuels. Most importantly, our research indicates that any incentive adequate to promote

carbon capture at coal-fired power plants should be even more effective in promoting carbon capture at F-T plants producing liquid fuels.

The U.S. Department of Energy program on carbon capture and sequestration has made considerable technical progress. However, considering the continued and growing importance of coal for both power and liquids production and the potential adverse impacts of greenhouse gas emissions, we believe that current funding levels are not adequate. While we are optimistic that carbon capture and geologic sequestration can be successfully developed as a viable approach for carbon management, we also recognize that successful development constitutes a major technical challenge and that the road to success requires multiple, large-scale demonstrations that go well beyond the current U.S Department of Energy plans and budget for the efforts that are now under way.

Carbon Capture and Enhanced Oil Recovery: In coal-to-liquids plants, about 0.8 tons of carbon dioxide are produced along with each barrel of liquid fuel. For coal-to-liquids plants located near currently producing oil fields, this carbon dioxide can be used to drive additional oil recovery. We anticipate that each ton of carbon dioxide applied to enhanced oil recovery will cause the additional production of two to three barrels of oil, although this ratio depends highly on reservoir properties and oil prices. Based on recent studies sponsored by the U.S. Department of Energy, opportunities for enhanced oil recovery provide carbon management options for at least half a million barrels per year of coal-to-liquids production capacity. A favorable collateral consequence of this approach to carbon management is that half a million barrels per day of coal-to-liquids production will promote additional domestic petroleum production of roughly 1 million barrels per day.

The use of pressurized carbon dioxide for enhanced oil recovery is a well-established practice in the petroleum industry. Technology for capturing carbon dioxide at a coal-to-liquids plant is also well established, although further R&D may yield cost reductions. There are no technical risks, but questions do remain about methods to optimize the fraction of carbon dioxide that would be permanently sequestered.

Combined Gasification of Coal and Biomass: Non–food-crop biomass resources suitable as feedstocks for F-T biomass-to-liquid production plants include mixed prairie grasses, switchgrass, corn stover and other crop residues, forest residues, and crops that might be grown on dedicated energy plantations. When such biomass resources are used to produce liquids through the F-T method, our research shows that greenhouse gas emissions should be well below those associated with the use of conventional petroleum fuels. Moreover, when a combination of coal

and biomass is used, for example, a 40-60 mix, we estimate that net carbon dioxide emissions will be comparable to or, likelier, lower than well-to-wheels emissions of conventional, petroleum-derived motor fuels. Finally, we have examined liquid fuel production concepts in which carbon capture and sequestration is combined with the combined gasification of coal and biomass. Our preliminary estimate is that a 50-50 coal-biomass mix combined with carbon capture and sequestration should yield negative carbon dioxide emissions. Negative emissions imply that the net result of producing and using the fuel would be the removal of carbon dioxide from the atmosphere.

One perspective on the combined gasification of coal and biomass is that biomass *enables* F-T coal-to-liquids production, in that the combined feedstock approach provides an immediate pathway to unconventional liquids with no net increase in greenhouse gas emissions, and an ultimate vision, with carbon capture and sequestration, of zero net emissions. Another perspective is that coal *enables* F-T biomass-to-liquids production, in that the combined approach reduces overall production costs by reducing fuel delivery costs, allowing larger plants that take advantage of economies of scale, and smoothing over the inevitable fluctuations in biomass availability associated with annual and multiyear fluctuations in weather patterns, especially rainfall.

Prospects for a Commercial Coal-to-Liquids Industry

The prospects for a commercial coal-to-liquids industry in the United States remain unclear. Three major impediments block the way forward:

1. Uncertainty about the costs and performance of coal-to-liquids plants;
2. Uncertainty about the future course of world oil prices; and
3. Uncertainty about whether and how greenhouse gas emissions, especially carbon dioxide emissions, might be controlled in the United States.

As part of our ongoing work, RAND researchers have met with firms that are promoting coal-to-liquids development or that clearly have the management, financial, and technical capabilities to play a leading role in developing of a commercial industry. Our findings are that these three uncertainties are impeding and will continue to impede private-sector investment in a coal-to-liquids industry unless the government provides fairly significant financial incentives, especially incentives that mitigate the risks of a fall in world oil prices.

But just as these three uncertainties are impeding private-sector investment, they should also deter an immediate national commitment to establish rapidly a multimillion-barrel-per-day coal-to-liquids industry. However, the traditional hands-off or “research-only” approach is not commensurate with continuing adverse economic, national security, and global environmental consequences of relying on imported petroleum. For this reason, Congress should consider a middle path to developing a coal-to-liquids industry that focuses on reducing uncertainties and fostering early operating experience by promoting the construction and operation of a limited number of commercial-scale plants. We consider this approach an “insurance strategy,” in that it is an affordable approach that significantly improves the national capability to build a domestic unconventional-fuels industry as government and industry learn more about the future course of world oil prices and as the policy and technical mechanisms for carbon management become clearer.

Designing, building, and gaining early operating experience from a few coal-to-liquids plants would reduce the cost and performance uncertainties that currently impede private-sector investments. At present, the knowledge base for coal-to-liquids plant construction costs and environmental performance is very limited. Our current best estimate is that coal-to-liquids production from large, first-of-a-kind commercial plants is competitive when crude oil prices average in the range of $50 to $60 per barrel. However, this estimate is based on highly conceptual engineering design analyses that are intended only to provide rough estimates of costs. At RAND, we have learned that, when it comes to cost estimates, typically the less you know, the more attractive the costs. Details are important, and they are not yet available. For this reason, we believe that it is essential that the Department of Energy and Congress have access to the more reliable costing that is generally associated with the completion of a more comprehensive design effort, generally known as a “front-end engineering design.”

Early operating experience would promote post-production learning, leading to future plants with lower costs and improved performance. Post-production cost improvement—sometimes called the learning curve—plays a crucial role in the chemical process industry, and we anticipate that this effect will eventually result in a major reduction of the costs of coal-derived liquid fuels. Most important, by reducing cost and performance uncertainties and production costs, a small number of early plants could form the basis for a rapid expansion by the private sector of a more economically competitive coal-to-liquids industry, depending on future developments in world oil markets.

Options for Federal Action

The federal government could take several productive measures to address the three major uncertainties we have noted—production risks, market risks, and global warming—so that industry can move forward with a limited commercial production program consistent with an insurance strategy. A key step, as noted, is reducing uncertainties about plant costs and performance by encouraging the design, construction, and operation of a few coal-to-liquids plants. An engineering design adequate to obtain a confident estimate of costs, to establish environmental performance, and to support federal, state, and local permitting requirements will cost roughly $30 million. The federal government should consider cost-sharing options that would promote the development of a few site-specific designs. The information from such efforts would also provide Congress with a much stronger basis for designing broader measures to promote unconventional-fuel development.

We have analyzed alternative incentive packages for promoting early commercial operating experience. In this analysis of incentives, we have examined not only the extent to which the incentive motivates private-sector investment but also the potential impact on federal expenditures over a broad range of potential future outcomes. At this time, we are able to report that more attractive incentive packages generally involve a combination of the following three mechanisms: (1) a reduction in front-end investment costs, such as what would be offered by an investment tax credit; (2) a reduction in downside risks by a floor price guarantee; and (3) a sharing of upside benefits such as what would be offered by a profit-sharing agreement between the government and producers when oil prices are high enough to justify such sharing.

We also find that federal loan guarantees can have powerful effects, mainly because they allow the share of debt supporting the project to increase, since the government is assuming the risk of project default. For this very reason, we caution against the use of federal loan guarantees unless Congress is confident that the federal government is able to put in place a technical and financial project monitoring and control system capable of protecting the federal purse.

R&D Opportunities

A great benefit of the F-T approach to liquid fuel development is that we know it works. F-T fuels are being produced today using both coal and natural gas in South Africa and using natural gas in Malaysia and Qatar. F-T fuels or blends of F-T and conventional petroleum products are in commercial use. Their suitability for use in vehicles and commercial aviation has been

established. The R&D challenge for coal-to-liquids development is not how to use but rather how to produce these fuels in a manner that is consistent with our national environmental objectives.

If the federal government is prepared to promote early production experience, then expanded federal R&D efforts are needed. Most important, consideration should be given to accelerating the development and testing (including large-scale testing) of methods for the long-term sequestration of carbon dioxide. This could involve using one or more of the early coal-to-liquids production plants as a source of carbon dioxide for the testing of sequestration options.

At present, the federal government is supporting research on coal gasification and associated synthesis gas cleaning and treatment processes. All of this federally funded research is directed at nearer-term, lower-risk concepts for advanced power generation and the production of hydrogen, but much of it is also directly applicable to F-T coal-to-liquids production.

Missing from the federal R&D portfolio are near-term efforts to establish the commercial viability of a few techniques for the combined use of coal and biomass. Such a combination offers significant cost and environmental payoffs. The most pressing near-term research need centers on developing an integrated gasification system capable of handling both biomass and coal. The problem is to devise a system that grinds, pressurizes, and feeds a stream of biomass or a combination of biomass and coal into the gasifier with high reliability and efficiency and without damaging the gasifier. This is a fairly minor technical challenge. It is an engineering problem focusing on performance and reliability, not a science problem. To establish the design basis for such a system requires the design, construction, and operation of one or a few test rigs. These test rigs need to be fairly large so that they are handling flows close to what would be the case in a commercial plant. This is because solids are involved, and it is very difficult to predict performance and reliability of solids-handling and processing systems when the size or throughput of the system undergoes a large increase. Such large-scale testing could also be conducted during the design and construction of a full-scale plant for coal-to-liquids production, with the understanding that, if this were successfully demonstrated, the plant would convert to accept a mixture of coal and biomass.

In my judgment, the current federal portfolio on gasification systems does not give adequate support to mid- and long-term R&D directed at high-risk, high-payoff opportunities for cost reduction and improved efficiency and environmental performance. Especially fruitful areas for R&D are oxygen production at reduced energy consumption, improved gas-gas separation technology, higher-temperature gas-purification systems, and reduced or eliminated oxygen demand during gasification. I also suggest research directed at advanced F-T process concepts

that allow efficient liquid-fuels production at small scales, i.e., at a few thousand barrels per day, not tens of thousands. Very large F-T coal-to-liquids plants may be suitable for Wyoming and Montana, but east of the Mississippi, much smaller plants may be more appropriate.

In promoting the production of alcohol fuels from cellulosic feedstocks, the federal government is making major R&D investments. In our judgment, the appropriate approach to balance this fuels-production portfolio is not to lower the investment in cellulosic conversion, but rather to significantly increase the investment in F-T approaches, including coal, biomass, and combined coal and biomass gasification.

The long and mid-term research efforts that I have described would significantly enhance the learning and cost-reduction potential associated with early production experience. As a collateral benefit of this public investment, such longer-term research efforts would also support the training of specialized scientific and engineering talent required for long-term progress.

In closing, I commend the Committee for addressing the important and intertwined topics of reducing demand for crude oil and reducing greenhouse gas emissions. The United States has before it many opportunities—including coal and oil shale, renewable sources, improved energy efficiency, and fiscal and regulatory actions—that can promote greater energy security. Coal-to-liquids and, more generally, F-T gasification processes can be important parts of the portfolio as the nation responds to the realities of world energy markets, the presence of growing energy demand, and the need to protect the environment.