



TESTIMONY

THE ARTS
CHILD POLICY
CIVIL JUSTICE
EDUCATION
ENERGY AND ENVIRONMENT
HEALTH AND HEALTH CARE
INTERNATIONAL AFFAIRS
NATIONAL SECURITY
POPULATION AND AGING
PUBLIC SAFETY
SCIENCE AND TECHNOLOGY
SUBSTANCE ABUSE
TERRORISM AND
HOMELAND SECURITY
TRANSPORTATION AND
INFRASTRUCTURE
WORKFORCE AND WORKPLACE

This PDF document was made available from www.rand.org as a public service of the RAND Corporation.

[Jump down to document](#) ▼

The RAND Corporation is a nonprofit research organization providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world.

Support RAND

[Browse Books & Publications](#)

[Make a charitable contribution](#)

For More Information

Visit RAND at www.rand.org

Explore [RAND Testimony](#)

View [document details](#)

Limited Electronic Distribution Rights

This document and trademark(s) contained herein are protected by law as indicated in a notice appearing later in this work. This electronic representation of RAND intellectual property is provided for non-commercial use only. Permission is required from RAND to reproduce, or reuse in another form, any of our research documents for commercial use.

TESTIMONY

Policy Issues for Coal-to-Liquid Development

JAMES T. BARTIS

CT-281

May 2007

Testimony presented before the Senate Energy and Natural Resources Committee on May 24, 2007

This product is part of the RAND Corporation testimony series. RAND testimonies record testimony presented by RAND associates to federal, state, or local legislative committees; government-appointed commissions and panels; and private review and oversight bodies. The RAND Corporation is a nonprofit research organization providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors. **RAND®** is a registered trademark.



Published 2007 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
4570 Fifth Avenue, Suite 600, Pittsburgh, PA 15213

RAND URL: <http://www.rand.org/>

To order RAND documents or to obtain additional information, contact
Distribution Services: Telephone: (310) 451-7002;
Fax: (310) 451-6915; Email: order@rand.org

James T. Bartis¹
The RAND Corporation

Policy Issues for Coal-to-Liquid Development²

**Before the Committee on Energy and Natural Resources
United States Senate**

May 24, 2007

Chairman and distinguished Members: Thank you for inviting me to speak on the potential use of our nation's coal resources to produce liquid fuels. I am a Senior Policy Researcher at the RAND Corporation with over 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 United States 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 key 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 wealth transfers to oil-exporting nations. Second, the production of petroleum substitutes from coal may cause a significant increase in carbon dioxide emissions; however, technical approaches exist that could lower carbon dioxide emissions to levels well below those associated with producing and using conventional petroleum. Third, without federal assistance, 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 and obtaining early, but limited, commercial experience appears to offer the greatest strategic benefits, given both economic and national security benefits and the uncertainties associated with

¹ The opinions and conclusions expressed in this testimony are the author's alone and should not be interpreted as representing those of RAND or any of the sponsors of its research. This product is part of the RAND Corporation testimony series. RAND testimonies record testimony presented by RAND associates to federal, state, or local legislative committees; government-appointed commissions and panels; and private review and oversight bodies. The RAND Corporation is a nonprofit research organization providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

² This testimony is available for free download at <http://www.rand.org/pubs/testimonies/CT281>.

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 only present findings in which RAND and I have full confidence at this time.

Coal Gasification and Liquid Fuels Production

There are two major approaches for using coal to produce liquid transportation fuels: direct liquefaction and the Fischer-Tropsch (F-T) processes. Both processes were developed in pre-World War II Germany and both were used, but on fairly small scales, to meet Germany's and Japan's wartime needs for fuel. In the direct liquefaction approach, hydrogen is added directly to the organic structure of coal at high pressures and temperatures. At present, a large first-of-a-kind commercial plant based on direct liquefaction is being built in China. Pending the completion and successful operation of that plant, we do not anticipate that there will be industrial interest in the direct liquefaction approach within the United States. For this reason, I will confine my remarks to the F-T process, which is the focus of considerable industrial interest in the United States.

In the F-T approach, coal is first gasified to produce a mixture that consists mostly of three gases: carbon monoxide, hydrogen, and carbon dioxide. This gas mixture is further processed to remove carbon dioxide, as well as trace contaminants, and the resulting mixture of clean hydrogen and carbon monoxide is sent to a chemical reactor where the gaseous mixture is catalytically converted to liquid products. After a moderate amount of fuel processing that would be performed on-site, a commercial F-T plant would produce a near-zero sulfur, high-performance diesel fuel for automotive applications and a near-zero sulfur jet fuel that can be used for commercial aviation applications or in military weapon systems. Between a third and one half of the product of commercial F-T coal-to-liquid plants would be a mixture of liquids that can be used to manufacture motor gasoline, either at the F-T plant site or at nearby refineries.

Since the end of World War II, the only commercial experience in F-T coal-to-liquids production has occurred in South Africa under government subsidy. In particular, a South African plant constructed in the early 1980s currently produces fuels and chemicals that are the energy equivalent of about 160,000 barrels per day of oil.

An interesting feature of the F-T approach to liquid fuels production is that it is not limited to coal. For example, large commercial F-T plants producing liquid fuels from natural gas are operating in Malaysia, Qatar, and South Africa. Other options are to use biomass or a combination of coal and biomass as the feedstock instead of straight coal. While these options are not being used on a commercial scale, our assessment of approaches using biomass or a combination of coal and biomass is that they involve very limited, low-risk technology development. As I elaborate on below, these two approaches involving biomass offer liquid fuels production and use that entail near-zero emissions of carbon dioxide.

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 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 a number of 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 offer to produce alcohol fuels from sources other than food crops, so-called 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 ten years, if ever.

The Strategic Benefits of Coal-to-Liquids Production

As part of RAND's examination of coal-to-liquid fuels development, our research is addressing the strategic benefits of having in place a mature coal-to-liquid fuels industry producing millions of barrels of oil per day. If coal-derived liquids were added to the world oil market, such liquids would cause world oil prices to be lower than what would be the case if they 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 mileage 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 fuels 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, American 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 would range from a few hundred to a few thousand dollars.

This anticipated reduction in world oil prices associated with coal-to-liquids development also yields a major national security benefit. At present, OPEC revenues from oil exports are about \$500 billion per year. Projections of future petroleum supply and demand published by the 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 weapons 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.

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

³*Oil Shale Development in the United States: Prospects and Policy Issues*, Santa Monica, CA: RAND MG-414-NETL, 2005.

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 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.

The above-described strategic benefits derive from the existence of the OPEC cartel. The favorable benefits of reduced oil prices accrue to our nation as a whole; however, they are not captured by the private firms that would invest in coal-to-liquids development.

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.

A second direct benefit 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 fuel products 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 direct 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

Given the Committee's interest in greenhouse gas emissions, I limit my remarks to that topic and simply point out that the environmental impacts associated with certain types of coal mining and water usage requirements, especially in the West, may limit the number of locations at which F-T coal-to-liquid plants can be operated.

If no provisions are in place to manage carbon dioxide emissions, then the use of F-T coal-to-liquids fuels to displace petroleum fuels for transportation uses will roughly double greenhouse gas emissions. This finding is relevant to the total fuel lifecycle, 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 a 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 relative to 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-liquid plants, RAND 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 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. Moreover, any incentive adequate to promote carbon capture at coal-fired power plants should be equally, if not 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 appears to be well managed and 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 this program has been considerably underfunded. 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 DOE 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 2 to 3 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 a half million barrels per year of coal-to-liquids production capacity. A favorable collateral consequence of this approach to carbon management is that a half 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. 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, switch grass, 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 50-50 mix, we estimate that net carbon dioxide emissions will be comparable to or, more likely, 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 zero, and possibly negative, carbon dioxide emissions. In the case of

negative emissions, 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, 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, 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 multi-year 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;
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 a number of 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 the three uncertainties noted above 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 multi-million-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, which 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-liquid 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 only intended to provide a rough estimate 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 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 of a rapid expansion 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 noted above—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 above, is reducing uncertainties about plant costs and performance by encouraging the design, construction, and operation of a few coal-to-liquid 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.

At present, RAND is analyzing alternative incentive packages for promoting early commercial operating experience. In this analysis of incentives, we are examining not only the extent that 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 caution against the use of federal loan guarantees. Firms with the technical and management wherewithal to build and operate first-of-a-kind coal-to-liquids plants—and then move forward with subsequent plants—generally have access to needed financial resources. Loan guarantees can induce the participation of less capable firms, while isolating the project developer from the risks associated with cost overruns and shortfalls in plant performance. The public then ends up absorbing the costs if the project fails.

Given the importance of controlling greenhouse gas emissions, it is appropriate that Congress demand that the initial round of commercial plants receiving government incentives employ carbon management approaches so that net greenhouse gas emissions are at least comparable to those anticipated from refining and using motor fuels derived from conventional petroleum.

If the Federal government is prepared to promote early production experience, then expanded federal efforts in other areas would also be 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, federal support for research on F-T approaches for liquids production is minimal. A near-term technology development effort designed to establish the commercial viability of a few techniques for the combined use of coal and biomass in a F-T liquids facility could offer significant cost and environmental payoffs. 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. This research investment should also include high-risk, high-payoff opportunities for cost reduction and improved

environmental performance. Such efforts would significantly enhance the learning/cost reduction potential associated with early production experience. 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, renewables, 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.