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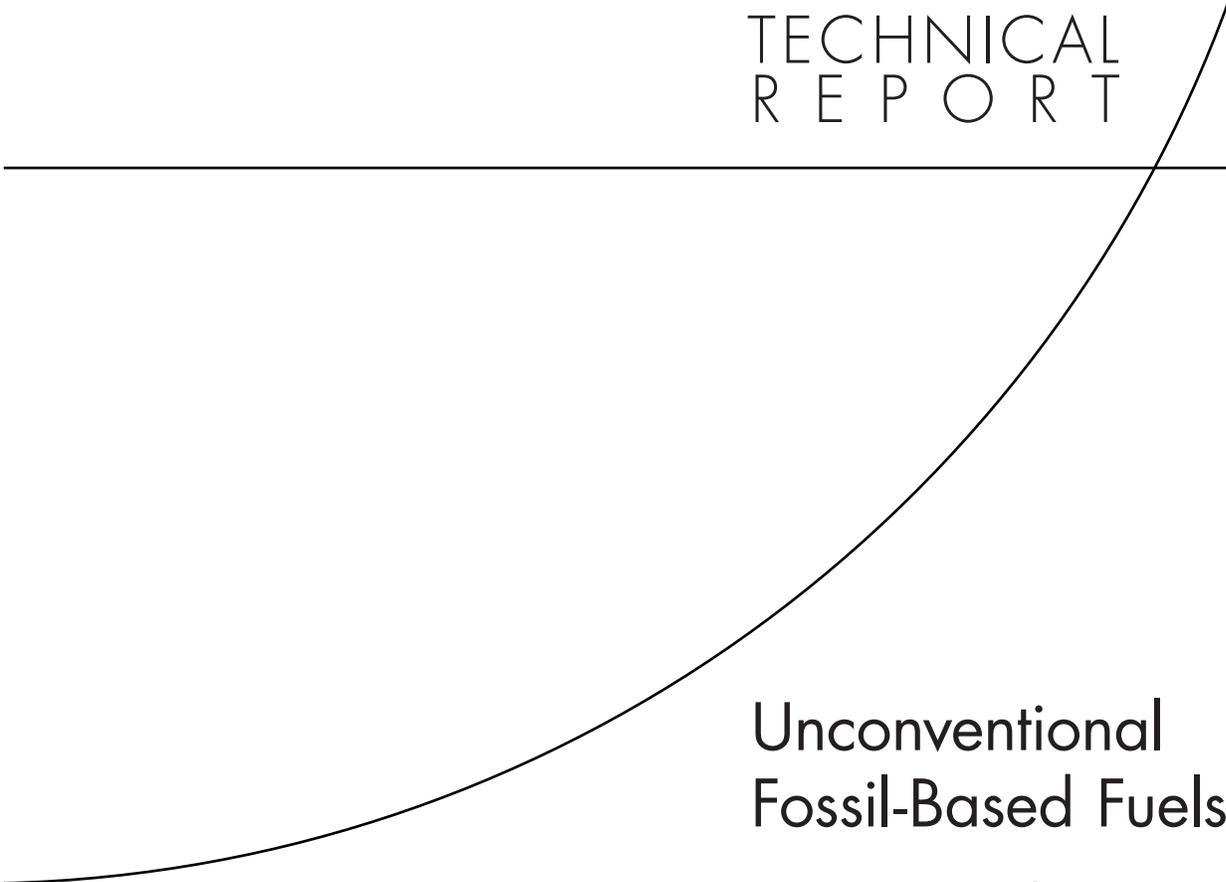
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TECHNICAL
REPORT



Unconventional Fossil-Based Fuels

Economic and Environmental Trade-Offs

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Sponsored by the National Commission on Energy Policy



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This research was sponsored by the National Commission on Energy Policy and was conducted under the auspices of the Environment, Energy, and Economic Development Program (EEED) within RAND Infrastructure, Safety, and Environment (ISE).

Library of Congress Cataloging-in-Publication Data

Unconventional fossil-based fuels : economic and environmental trade-offs / Michael Toman ... [et al.].

p. cm.

Includes bibliographical references.

ISBN 978-0-8330-4564-5 (pbk. : alk. paper)

1. Petroleum engineering. 2. Heavy oil. 3. Oil sands. 4. Coal liquefaction. I. Toman, Michael A.

II. RAND Corporation.

TN871.U49 2008

333.79'68—dc22

2008036873

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Published 2008 by the RAND Corporation
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Summary

Background

Both the price of petroleum motor fuels and concerns regarding emissions of carbon dioxide (CO₂) are driving attention to possible substitutes. In 2008, the world price of oil reached record highs after being adjusted for inflation, continuing a pattern of price increases over several years. Petroleum products derived from conventional crude oil constitute more than 50 percent of end-use energy deliveries in the United States and more than 95 percent of all energy used in the U.S. transportation sector. Emissions from the consumption of petroleum account for 44 percent of the nation's CO₂ emissions, with approximately 33 percent of national CO₂ emissions resulting from transportation-fuel use (EIA, 2007a). Commonly considered alternative transportation-fuel options for the near and medium terms (roughly 10–20 years) include both biomass-based fuels (e.g., ethanol, biodiesel) and unconventional fossil-based liquid fuels derived from such sources as heavy oils, oil sands, oil shale, and coal liquefaction.

In this report, RAND researchers assess the potential future production levels, production costs, greenhouse gases (GHGs), and other environmental implications of synthetic crude oil (SCO) produced from oil sands and transportation fuels produced via coal liquefaction (often referred to as *coal-to-liquids* [CTL]). Production of liquid fuels from a combination of coal and biomass is also considered. Although oil shale is also an important potential unconventional fossil resource, we do not address it in this report because fundamental uncertainty remains about the technology that could ultimately be used for large-scale extraction, as well as about its cost and environmental implications. The omission from this report of renewable fuel options and other propulsion technologies should not be interpreted as a conclusion that the fossil-based options are superior to others.¹

Policy Context

Concerns about high oil prices reflect not only the hardships endured by many energy users but also the large transfer of national wealth to foreign oil producers (particularly members of the Organization of the Petroleum Exporting Countries [OPEC]) that are widely perceived to elevate prices above competitive market levels by restricting output. Such artificially elevated oil prices provide a rationale for policy intervention to support the production of alternative fuels, because increased competition from alternative sources limits petroleum exporters' abil-

¹ For further information about renewable options, see Toman, Griffin, and Lempert (2008); Bartis, LaTourrette, et al. (2005) provided a detailed analysis of oil shale.

ity to influence the market. In addition, sudden oil-price spikes are widely seen to have adverse effects on national employment and output levels. Alternative fuels may reduce the instability of oil prices by lowering the potential size and likelihood of sudden reductions in crude-oil supply. However, the magnitude of the effect on short-term market instability is likely to be small so long as the alternative fuels make up only a relatively small increment in world fuel production. Accordingly, we focus in this report on the longer-term price effects.

There also are increasing concerns about the adverse impacts of climate change from rising global emissions of GHGs. CO₂ is the most important GHG in terms of total volume and impact on the climate, and most CO₂ emissions result from fossil-fuel use. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), increased accumulation of CO₂ and other heat-trapping gases in the earth's atmosphere is likely (albeit with varying degrees of quantitative uncertainty) to change the climate in a variety of ways, with a variety of adverse effects. While the U.S. share of global emissions (currently about one-quarter) will decline as energy use in the developing world continues to grow rapidly over the next few decades, the Energy Information Administration (EIA) projects that U.S. emissions will rise by about one-third between 2007 and 2030, with emissions from transportation maintaining their roughly one-third share of this larger total (EIA, 2007a).

Within this broader context of concern for energy cost and security and CO₂ emissions, the possibility for increasing use of liquid fuels derived from oil sands and coal raises several specific questions. One set of questions concerns the potential production volumes of these alternative fuels (since this will affect the size of benefits from increased competition with crude oil) and the potential production costs of these fuels (since this will influence their competitiveness in the market and thus their ability to provide such competition for conventional crude oil-based products). Another set of questions concerns the potential life-cycle emissions of CO₂ from these substitutes relative to conventional fuels and the relative costs of mitigating increased emissions from transportation fuels. These sets of economic and environmental questions are linked by the fact that the future unit costs of alternative fuels in the market will depend on advances in their technologies and the costs of addressing their CO₂ emissions; the competitiveness of the alternative fuels will depend on the potential future price of crude oil and the cost of addressing CO₂ emissions from conventional fuels.

Technical Approach

For both SCO and CTL, we provide a bottom-up assessment of potential future production, potential costs, and potential environmental and other barriers to capacity expansion. The environmental barriers addressed include CO₂ emissions and more local and regional concerns related to water and land. Our primary focus is on the longer term, although we also discuss the issues that arise in ramping up capacity over the intervening period. Production of SCO is already occurring on a significant scale in Canada, using several technologies. CTL, on the other hand, is produced only to a limited extent on a commercial scale in South Africa, so its analysis is based on studies of how modern technology might perform if deployed in the United States. In addition, we discuss the use of capture and geological storage of CO₂ emissions resulting from the production of the two alternative energy sources. Carbon capture and storage (CCS) consists of separating out CO₂ emissions then transporting them to sites where they can be injected deep underground for long-term storage. The added cost of CCS is the cost, including return on investment, for capture, transportation, and storage.

We then investigate how three key drivers influence the future cost-competitiveness of fuels from SCO and CTL relative to fuels from conventional crude oil:

- the future price of crude oil
- changes in the unit production costs of the unconventional fossil-based fuels induced by further technical advances and experience in their production
- the implications of potential constraints on CO₂ emissions for the unit production costs of both conventional and unconventional fossil-based fuels.

The future course of each unit-cost driver is uncertain, so we compare the fuels under a number of plausible scenarios to represent the key uncertainties. EIA's 2007 *Annual Energy Outlook* (AEO) (EIA, 2007a, Table 12) has a reference-case price of light sweet crude oil in 2025 of about \$56/barrel (bbl) (in 2005 dollars), while the high-oil-price case reflects a 2025 price of about \$94/bbl. (The low-price case is about \$35/bbl.) The costs of production of the technologies also are uncertain. For oil sands, new extraction technologies are being brought forward whose future costs are uncertain. For coal liquefaction, there is not yet experience with modern plant designs implemented on a larger scale. Finally, we consider ranges of CCS costs and potential costs of fuel supply from future regulations to limit CO₂ emissions.

It is difficult to estimate future production costs for unconventional fuels. There is often a bias toward underestimating costs and overestimating performance of new fuel-production facilities and their operations. Since facilities that upgrade and refine bitumen from oil sands or produce CTL require significant levels of investment, the average cost of producing a unit of product over the facility's lifetime is sensitive to a number of assumptions regarding the time to construct the facility, the mixture of capital and debt used to finance the construction, the costs of the feedstocks, and the successful start-up and long-term capacity factor of the facility. All of these parameters are uncertain and difficult or impossible to accurately predict early in the planning process. We attempt to account for some of this uncertainty by providing ranges of cost estimates for recovering bitumen from oil sands and for coal liquefaction. There are opportunities for significant improvements in production costs as experience is gained. A first-of-a-kind plant may be subject to significant cost overruns and poor performance, but subsequent plants may resolve these issues and perform significantly better. Taking these considerations into account, for the year of interest (2025), we derived low and high cost estimates for the production of SCO and CTL.

To account for how costs associated with limiting CO₂ emissions may affect SCO and CTL competitiveness with respect to conventional petroleum or fuels, we incorporate a complete life-cycle-emission analysis of each fuel. Life-cycle emissions are those associated directly and indirectly with primary production of feedstock, processing, transporting, and, ultimately, the use of the end product, including gasoline, diesel fuel, or close unconventional substitutes for these.

We address the impacts of potential limits on CO₂ cost-competitiveness in two ways. In scenarios in which we assume that CCS does not occur, the cost of CO₂ emissions is a measure of the increased cost of supplying and using each fuel due to future regulatory constraints on CO₂ emissions from production and final use of the fuel. The life-cycle emissions per unit of fuel times the cost of CO₂ emissions released to the atmosphere is added to our estimated production cost of fuel, to arrive at a cost that includes the effects of CO₂-emission constraints. In no-CCS scenarios, we can highlight the sensitivity of cost-competitiveness to production costs,

and we establish a basis for evaluating the potential competitiveness of CCS investment. When CCS is an option, the added cost associated with potential future CO₂ constraints is the cost per unit of CO₂ captured and stored times the quantity of stored CO₂ plus the cost of CO₂ emissions (described earlier) applied to noncaptured emissions. Fuel producers will apply CCS when its unit cost is less than the cost of CO₂ emissions released to the atmosphere.

Key Findings

Basic production costs for SCO are likely to be cost-competitive with conventional petroleum fuels. Production of SCO already is a relatively mature technology, though new processes are being developed to make use of deeper formations. Taking into account both uncertainties that may lead to higher costs than estimated and cost improvements due to learning, and leaving aside for the moment the potential cost of CO₂ emissions, we find that SCO is cost-competitive with conventional petroleum unless future oil prices are well below EIA's 2007 reference-case scenario for 2025.

While basic production costs for CTL also appear to be competitive with conventional petroleum fuels across a range of crude-oil prices, CTL competitiveness is more sensitive to technology costs and to oil prices. In the absence of a CO₂-emission cost, CTL fuels appear to be competitive with conventional petroleum fuels if oil prices are above the EIA 2007 reference-case price in 2025. However, if CTL turns out to be more costly than anticipated or oil prices in the longer term are lower than this reference price, CTL may not be cost-competitive even without a CO₂-emission cost.

Higher oil prices or significant energy-security premiums increase the economic desirability of SCO and CTL. If longer-term oil prices are high or future energy-security policy attaches a high premium to the market price of crude oil to account for energy-security costs, then investment in both SCO and CTL production will be correspondingly more favorable. In particular, the range of CO₂-emission costs over which CTL without CCS is still economically attractive relative to conventional diesel will increase, and the economics of CTL with CCS can look attractive relative to conventional petroleum even if CCS turns out to be relatively costly. On the other hand, if oil prices end up being relatively low over the longer term, then CTL is less competitive than petroleum, even with a low CO₂-emission cost.

Even with future policy constraints on CO₂ emissions and their associated costs, SCO seems likely to be cost-competitive with conventional petroleum; the main potential constraint on SCO production is its local and regional impacts. SCO is only about 15–20 percent more CO₂-intensive on a life-cycle basis than conventional crude, even without CCS, and has essentially the same CO₂ intensity with CCS. Therefore, its potential cost advantages relative to future oil prices are maintained over a wide range of potential CO₂ emission–control costs. For oil sands, the prominent limiting factors appear to be the high water usage that would accompany a major scaling up of SCO production, attendant concerns about water quality, other environmental impacts and socioeconomic constraints, and (to a lesser extent) the availability of natural gas for bitumen extraction and upgrading.

The cost-competitiveness of CTL is more dependent than that of SCO on the costs of CO₂ emissions and CCS. If CCS can be deployed on a large scale and at a relatively low cost, then CTL with CCS appears to be economically competitive over a wide range of conventional-fuel prices and CO₂-emission costs. The picture would change only if long-term oil prices were sig-

nificantly lower than the 2007 EIA reference-case value. However, if CCS and CTL costs end up being relatively high, then CTL is cost-competitive with conventional fuels at EIA's high price for 2025, but not at the reference-case price. Other constraints on CTL production could include environmental concerns associated with increased coal mining and the availability of water for CTL plant processes.

Unconventional fossil fuels do not, in themselves, offer a path to greatly reduced CO₂ emissions, though there are additional possibilities for limiting emissions. Fuels derived from oil sands and CTL emit fossil-based CO₂ during combustion, just as conventional petroleum products do. Thus, even when employing CCS to capture and store CO₂ emitted during fuel production, life-cycle emissions of CO₂ for these alternative fuels are comparable to those of conventional fuels. Large-scale production of these unconventional fuels does not reduce emissions of CO₂. Reliance on liquefaction of a mixture of coal and biomass along with CCS does have the potential to achieve greatly reduced life-cycle emissions, but potential production of such fuels would be limited by the availability and cost of the biomass feedstock and the potential availability and cost of CCS.

Relationships among the uncertainties surrounding oil prices, energy security, CCS costs, and CO₂-control stringency have important policy and investment implications for CTL. Our analysis indicates that investment in CCS for CTL can be a very robust undertaking if CCS can be realized at an adequately large scale, if CTL and CCS costs are in the lower part of the range of costs that we have considered, and if future oil prices do not fall below reference-case levels. If CTL and CCS costs are higher, however, CCS's value to the CTL supplier as a hedge against the cost of future CO₂ controls is positive only with higher long-term (not just near-term) oil prices.

From a societal perspective, it is desirable to reduce the need for rapid and costly CO₂-emission reductions through implementing a less abrupt approach to CO₂ limits. It is also desirable to take actions that increase the availability of cost-effective alternatives to conventional petroleum. If nearer-term concerns about energy security lead to emphasis on rapid CTL investments while CO₂-control requirements are delayed or kept minimal, then energy-security and climate-protection objectives are brought into conflict.

Neither CTL investors nor policymakers have many options for reducing long-term oil-price uncertainty. As noted, moreover, there is a risk to the economic value of CTL investment just from the possibility of relatively low long-term prices. On the other hand, policymakers do have options for reducing the uncertainties surrounding CTL and CCS costs. There is a large benefit from government financing for continued research and development (R&D) for CCS *and* initial CCS investments at a commercial operating scale to further assess the technical and economic characteristics of CCS. This analysis parallels the argument in Bartis, Camm, and Ortiz (forthcoming) for active but limited public-sector support for informative initial-scale investment in modern CTL facilities. Conversely, it may be very beneficial socially to delay a significant ramp-up in CTL production until the uncertainties surrounding CCS technology and CTL-production costs can be reduced. These observations reflect the importance of the argument of the National Commission on Energy Policy (NCEP) (2004) for a broad portfolio of technology-development initiatives and a variety of policy instruments to promote energy diversity and decarbonization of fuel sources.