Coal-to-liquids: A Boon or a Boondoggle?

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ABSTRACT

Crude oil is the single biggest energy resource for the transportation industry. The high cost of gasoline and instability in the Middle East has recently resulted in more attention for fuel alternatives in the United States for the existing fleet of vehicles. Biofuels such as ethanol and biodiesel have received many tax incentives. More recently, coal-to-liquids (CTL), a process by which coal is gasified and converted to liquid fuel under high temperatures is being proposed as the route to energy security. Several bills have been introduced in the Congress to amend the Energy Policy Act of 2005. Among other provisions, these bills would permit loan guarantees to certain large-scale CTL facilities, offer tax credits for investment in CTL projects, and extend the alternative fuel credit for liquid fuels derived from coal. In this article, CTL is reviewed with emphasis on the availability of the coal resource, status of technology, its role in alleviating foreign oil dependence, and its role as an enhanced emitter of greenhouse gases. Being a vast and distributed resource, additional coal technologies will make welcome contributions to our energy supply. However, given the cost and the long lead-time in building large-scale CTL plants, the coal resource required for meeting demand, and the environmental impacts of associated pollutants, coal technologies must be promoted responsibly. To achieve greater environmental credibility, nascent technologies such as carbon sequestration will have to be deployed in CTL plants. Ultimately, CTL must be viewed as one part of a program that includes other aspects such as increasing energy efficiency and promoting less carbon intensive renewable sources.

INTRODUCTION

The increasing demand for energy and its adverse impact on the environment is one of the most pressing problems of the 21st century. Petroleum, in particular, supplies nearly 40 percent of our energy demands [1]. The transportation sector is an extremely critical component of our society and relies overwhelmingly on petroleum; over 95 percent of the energy required for moving goods and passengers is provided by petroleum [2]. Mark Twain is known to have said, "Put all your eggs in one basket and… watch that basket!" [3]. In general, this would qualify as good advice as it leads to economies of scale. However, putting all eggs in the petroleum basket is unwise. Nearly 60 percent of the world's supply of oil is underground in the Middle East [4]. Clearly, depending on unstable regions of the globe to provide our basic needs is unwise. Coal, on the other hand, is more widely distributed, with the United States possessing the world's largest known reserves. Not surprisingly, attention has been drawn to extracting liquid transportation fuel from coal both in the United States and in coal-rich countries with severe energy needs.

Coal-to-liquids (CTL) is a technology that converts coal to liquid fuel under high pressures and temperatures. CTL was used to primarily meet the liquid fuel needs of Germany during World War II. Decades later, from the 1950s onwards CTL was used extensively to meet the fuel needs of South Africa. SASOL, a South African company, is a global leader in the indirect liquefaction technology, with the world's largest CTL plants at Secunda in South Africa with a capacity of 150,000 barrels per day (bbl/day) [5]. Currently, nearly 36 percent of South Africa's liquid fuel needs are met through the CTL process [6].

The conversion of coal can take place through one of two processes: In the first process, "direct liquefaction," coal undergoes a chemical reaction in the presence of hydrogen at high temperatures and produces liquid fuel. This liquid is of low quality, expensive to purify, and typically not pursued for commercial production of liquid fuel though this concept is being investigated in China. In the second and rather well-developed process termed "indirect liquefaction," coal is first converted to gas ("syngas") and then undergoes the Fischer-Tropsch reaction (named after its inventors), producing gasoline.

It is estimated that CTL is competitive with petroleum at $40/barrel. With oil prices above $70 per barrel, several CTL projects are being implemented around the world:

- With China's demand for transportation fuels being met increasingly by imports, the Chinese government is actively promoting a coal-to-liquids industry. China's first commercial coal direct liquefaction facility with a capacity of 60,000 bbl/day is expected to commence production in 2007. China has also, additionally, initiated a feasibility study with SASOL regarding the construction of two 80,000-bbl/day indirect liquefaction plants [7].

- In the U.S., the National Energy Technology Laboratory has issued a feasibility study on a commercial 50,000 barrels per day (which is 0.25 percent of the daily U.S consumption of liquid fuels) coal-to-liquids facility in the Illinois coal basin [8]. Spurred on by tax incentives, several companies in the United States have devised plans to build CTL plans. Some examples include:
  — Rentech, Inc. [9] is building the first large-scale application of the Fischer-Tropsch process with a capacity of 1,800 bbl/day. Rentech, Inc. has also entered into an agreement with Peabody Energy, a producer of coal, to build two mine-mouth CTL plants with a capacity of 10,000 and 30,000 bbl/day.
  — DKRW Energy's CTL facility [10] in Medicine Bow, Wyoming, is expected to produce 11,000 bbl/day with the possibility of expanding the capacity to produce as much as 40,000 bbl/day of fuels.

- The third-largest producer of coal, India, is currently in talks with SASOL to build CTL plants in India.

These are but a few examples. Countries worldwide are joining in on the CTL jamboree. But should countries pursue this path? Is CTL a boon or a boondoggle?

THE OPPORTUNITY

Historical oil usage in the United States is shown in Figure 1 [11]. Over the last two decades, consumption has increased by nearly 30 percent to approximately 20 million barrels per day (MBPD) in 2006.

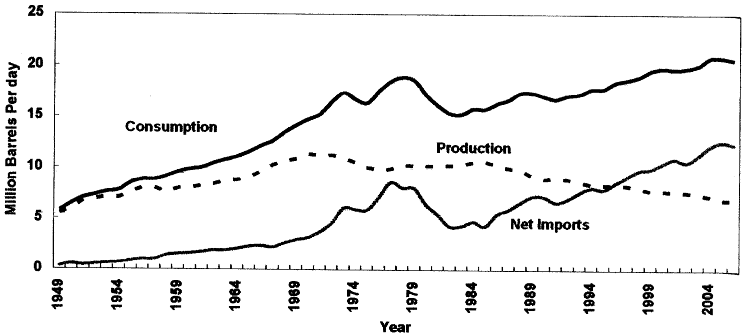

Figure 1. Trends in oil production, consumption and imports for the United States. Source: [11]

With oil production on the decline in the United States, the increasing demand is being met by imports, which have more than doubled during the same period. Finding a domestic oil substitute is clearly one route to greater energy security.

Clear advantages exist for CTL:

- The technology is well developed: The Fischer-Tropsch process was developed in early 19th century by German chemists and supplied nearly 90 percent of Germany's aviation fuel during WWII.

- No modification of existing infrastructure for transporting fuel or the internal combustion engine technology is required to exploit this technology.

- CTL is estimated to be competitive with oil at $40/barrel of oil. With oil trading over $70 per barrel, the economics favor this technology.

- Vast reserves of coal exist; the known reserves of a trillion tons of "king coal" are expected to last over 200 years at the current rate of usage. Coal reserves are also widely distributed (Figure 2), with world's largest reserves of coal in the United States. "The Saudi Arabia of coal," as the United States is called, has nearly 270 billion tons of coal, which is 27 percent of the world's known reserves [12]. Countries like China and India, with severe energy needs, also have significant coal reserves. CTL technologies in these countries will significantly reduce import pressures for oil.

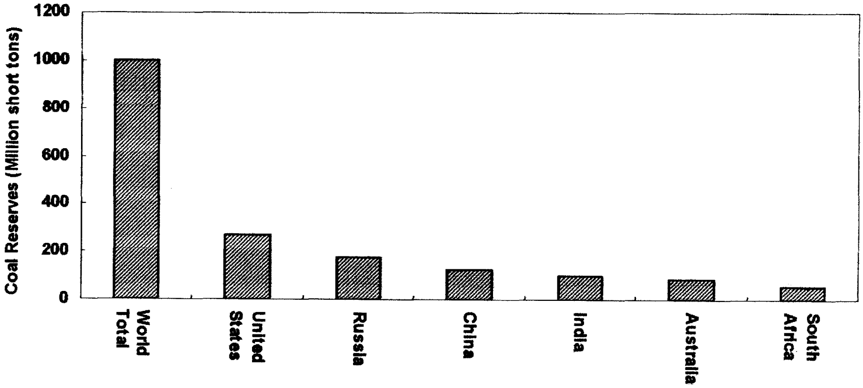

Figure2. World recoverable coal reserves. Source: [12].

BARRIERS TO SUCCESSFUL CTL USAGE

While the advantages for CTL usage are clear, the barriers to successful deployment of this technology are significant. Associated pollutants from the production and usage of coal can adversely affect the environment and negate these advantages. Technological solutions for barriers such as compromised plant performance and increased carbon dioxide emission will likely take years to implement. In the following section, each of these issues is discussed in greater detail.

- Increased coal production: The increase in coal usage for the required conversion to liquid fuel can be simply estimated: Each ton of coal is estimated to yield 2 barrels of oil [13]. Substituting, say, 10 percent of the daily U.S. oil usage, corresponding to 2 MBPD of oil, will require approximately a million tons of coal per day. With annual coal production of 1.16 billion tons in 2006 [14], this increase in coal usage is nearly 30 percent of the annual coal production. A significant increase in coal production will, at best, lead to a small substitution of oil. Moreover, the environmental implications of such a tremendous increase in coal production can be significant. Coal mining can adversely affect landscape and habitat for wildlife. Minimizing related environmental stresses is necessary so that CTL may be a significant part of our energy mix.
- Impact of increased coal use on climate change: It was in 1904 that the Swedish chemist Arrhenius postulated the effect of increasing

industrialization and carbon dioxide emission on atmospheric warming [15]. More recently, the Intergovernmental Panel on Climate Change has stated that, "most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations" [16]. World carbon dioxide emissions in 2004 amount to nearly 27 billion tons annually, with nearly 50 percent of these emissions arising from the use of coal [17]. Atmospheric levels of carbon dioxide are about 25 percent higher than during the times of Arrhenius with temperatures about 0.5°C higher. Global carbon emissions are expected to grow over the next few decades. The effect of the increased carbon, in the form of increased global temperatures and related environmental changes such as the melting of the polar ice-sheets, loss of habitat, and severe climate changes is expected to last for many centuries [18]. Clearly, it would be unwise to additionally use coal, the largest source of greenhouse gases. Indeed, by some estimates, the total life-cycle greenhouse gas emissions or "well-to-wheel" emissions for coal-based "synfuels" are nearly twice as high as their petroleum-based equivalent [19].

However, a technological solution does exist to prevent additional carbon dioxide emission into the atmosphere. Carbon capture and storage (CCS) requires the capture of carbon dioxide where it is produced. This carbon is stored in its liquid form in underground aquifers [20]. Regarded as a Faustian bargain by some [21], CCS will allow the continued use of fossil fuels without the associated carbon dioxide emission into the atmosphere. Given the urgency of mitigating climate change, it will be critical to deploy this technology in every CTL plant that is commissioned. However, carbon capture is a nascent technology, unproven on the scale required to curtail carbon emissions. The energy required for capturing and storing carbon is expected to reduce plant output anywhere between 10 and 30 percent depending on the technology used [22]. Pipeline infrastructure to transport the carbon to the site needs to be developed. The largest carbon capture and storage project, the Sleipner oil field in the North Sea, appears to be successfully storing only about a million tons of carbon dioxide per year with few diagnostics on the storage capabilities of the oil field [22]. While potential types of geologic storage sites have been identified, continuous monitoring of the underground aquifers will be required to detect leaks.

Catalyzing the commercialization of CCS technology will require well thought-out and specific policies. Current debate in the United States is focused on placing a price on carbon dioxide emission, either through a carbon-tax emitted per ton or through a cap-and-trade system similar to those already used in Europe and established by the Kyoto Protocol. The details of either of these policies can significantly influence the commercialization of the CCS technology. CCS might be promoted extensively if it is viewed as less expensive than the regulated cost on carbon dioxide. The challenge for policy makers is to use a price on carbon emissions as a tool for containing carbon, while restraining the cost of doing business.

- Market risk and uncertainty in world oil prices: CTL is estimated to be competitive with oil when oil prices are above $40 per barrel. Historical oil prices are shown in Figure 3 [23]. In the United States, several demonstration CTL projects were started during the energy crisis of the 1970s, only to be abandoned when oil prices fell. Uncertainty in future oil prices makes the outlook for CTL projects highly uncertain.

- Cost and performance of CTL plants: Related to market risks are the high capital costs, typically $3-$6 billion dollars, associated with CTL plants [24]. The significant investment risk posed by the uncertainty in the energy environment suggests that private enterprises will

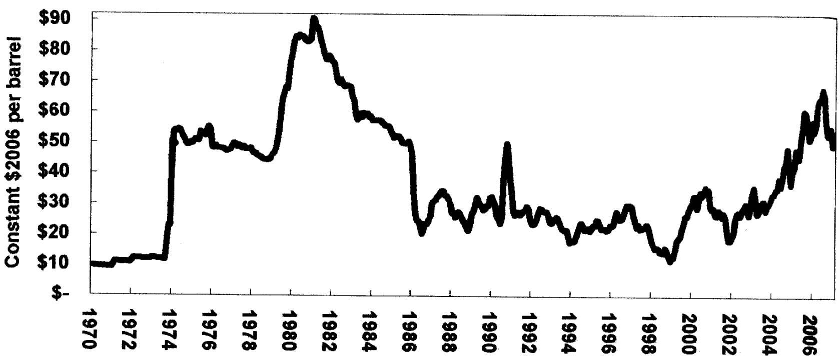

Figure3. Historical crude oil prices (in 2006 dollars). Source: [23]

undertake this project only when provided with loan guarantees and tax incentives. Indeed, several bills pending in the Congress address this issue. These bills, among other provisions, seek to amend the Energy Policy Act of 2005 to make loan guarantees to certain CTL facilities, provide income-tax credits for investment in CTL facilities, extend the alternative fuel credit for fuel derived from coal, etc. [25]. While these measures protect private industry, it may leave the taxpayer holding the bag.

- Long lead times for plants: CTL plants typically take 5-7 years to build [24]. This suggests that CTL is not a quick panacea for our energy needs.

- Public resistance to coal use: One of the primary reasons for resistance to coal use comes from the NIMBY (not in my back yard) phenomenon. Components of flue gases from coal-fired power plants include toxic materials such as mercury, sulfur, nitrogen oxides, soot, particulates, etc., and can cause considerable distress to local residents and people who live downwind from these plants. Regulations passed by the US Environmental Protection Agency require a significant reduction using existing technology of some of these chemicals over the next decade [26]. Nevertheless, the perception of coal as a dirty resource fuels the resistance to coal usage.

With a vast and distributed resource base, coal technologies will and must play an increasing role in our energy supply. However, the adverse environmental effects of coal will have to be mitigated through the use of technologies that remove associated pollutants from plant emissions. Moreover, with significant investments required for CTL plants, market uncertainty, and long lead times to build such plants, CTL is likely not a quick solution to our energy security needs.

A number of other avenues to address energy security and environmental issues have been proposed. High on the list is the improved efficiency of existing vehicle fleet. Plug-in hybrids have been identified to be less carbon intensive than CTL [27]. Given the immediacy of addressing climate change, larger cultural shifts such as the increased use of public transport, reallocating land-use, and increased use of non-motorized modes of transport, have all been proposed to address the issue of energy security, supply, and the environment. An environmentally responsible transportation program must propose an integrated solution including all of the above.

CONCLUSIONS

The road to an environmentally responsible oil substitute is unfortunately bumpy. Coal is abundant and cheap, and it's tempting to make copious use of it to address our energy needs. The major obstacle to the extensive usage of coal is from the increased greenhouse gas emissions expected from CTL plants. Given the urgency of climate change mitigation, it is critical that this carbon dioxide not reach the atmosphere. Carbon capture and storage technologies have to be researched extensively and deployed in CTL plants if coal is to be a significant part of our oil portfolio. The importance of responsible policy promoting CTL cannot be understated. Given the relatively long time scales involved in building these plants and time frame required for the maturation of the CCS technology, we should not expect that coal-to-liquids will provide a quick solution to our energy needs. While CTL and associated CCS must be pursued, gains towards energy security and positive climate change effects can also be had with other policies that promote energy efficiency and the use of less carbon-intensive renewable resources.

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