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Mitigating the Oil Crisis:

Coal-to-Liquid Technology for American Energy Independence

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Executive Summary

The ballooning price of oil and increasing dependence on foreign imports has led to an American liquid fuels crisis. Although clean fuels and alternative energy sources hold great promise for the future, they are not yet ready for large scale integration. A solution must be found that can buy time for the development and implementation of future renewable technologies while reducing America's reliance of foreign oil. Coal-to-liquid (CTL) technology is a promising possibility. CTL has the advantage of being a mature technology that relies on America's most abundant energy resource, coal. Unfortunately, the implementation of CTL has been prevented by the volatility of oil prices and the expense of first adoption. We advocate federal policies to promote initial installations that will develop both the technology and economics of CTL: a sliding-scale federal tax subsidy for CTL fuel, federal loan guarantees for plant construction and federal grants for research bridging CTL technology to renewable replacements.

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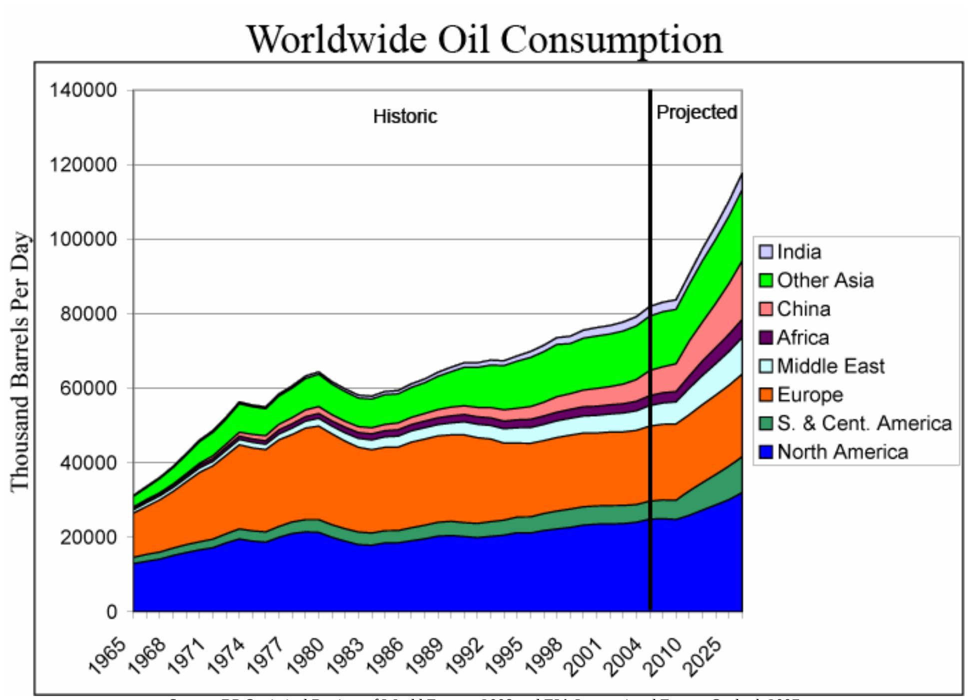
America consumes 21 million barrels of oil per day. 66% of that is supplied by imports.

Demand for oil in China has increased by 89% in the past decade

The peak production of oil has passed in America and is imminent worldwide

The Liquid Fuels Crisis

In 2008, the worldwide price of crude oil topped $140 a barrel, while the price of gasoline at the pump now averages over $4 a gallon nationwide. The last time petroleum prices reached these heights in real dollars was after the peaking of domestic oil production in the 1970's. Since that time, the shortfall in domestic oil production has been made up by increased oil imports. Currently, the United States consumes 21 million barrels per day, 24% of the worldwide oil production. A striking 66% of American oil consumption is supplied by imports, as the US holds only 2.5% of the worldwide proven oil reserves. Meanwhile, domestic energy resources such as coal have been largely rerouted to electricity production.



Source: BP Statistical Review of World Energy, 2008 and EIA International Energy Outlook 2007

America's demand for liquid fuel is predicted to increase by 10% in the next decade, primarily due to use in the transportation sector where a viable replacement is not readily available. The rising demand for oil in America is further complicated by the rise of consumption in developing nations. Oil use in China increased 89% in the past decade, rising to 9% of the world total. Similar trends are occurring in India, with consumption rising 51% in a decade to 3.1% of the world total

With rising consumption and dwindling supply worldwide, it appears unlikely that we will be able to meet domestic demand by simply importing more foreign oil. Current estimates of worldwide reserves predict that there is enough oil for 41 years at current production levels. However, the majority of this oil lies in "unfriendly" countries, with 68% of proven reserves in the Middle East and Venezuela. Furthermore, the dynamics of oil extraction imply that the peak of worldwide production capacity may occur within the next twenty years, with some studies finding that the peak has already been reached. In addition to the shortfall in supply, the increasing difficulty in extraction will further raise oil prices. We simply will not be able to bring enough oil out of the ground to satisfy worldwide demand.

Possible Technological Solutions

Any near term replacement for foreign oil must be compatible with current infrastructure

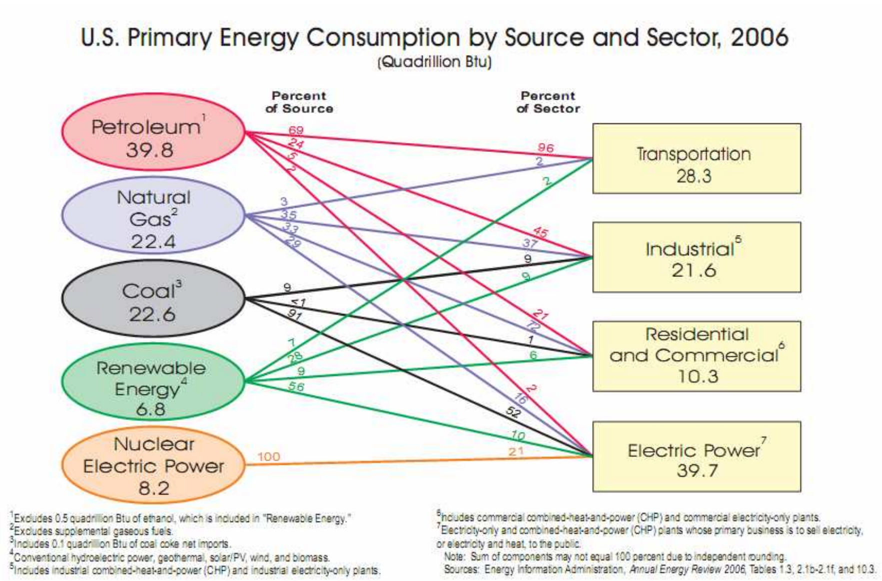
Any possible near-term replacement for petroleum-based liquid fuels must meet several requirements:

1. Rapid implementation
2. Minimal collateral resource effects
3. Minimal environmental impact
4. Security of Supply
5. Economic Feasibility

The first criterion requires that the solution rely on proven technology. Although experimental solutions may become applicable in the long term, they cannot mitigate the current American dependence on foreign oil. Ideally, the technology should rely on existing infrastructure to promote prompt integration.

The second criterion prevents a "shell game" scenario where one energy resource is swapped for liquid fuels thereby creating a shortfall and resulting crisis in another energy sector.

An oil replacement must have enough supply to avoid a shortage



The third criterion limits the environmental impact of the petroleum replacement. Burning of petroleum fuels causes significant environmental damage in the form of pollution and green house gas emissions. Any alternative technology should be at least as clean as the petroleum fuel it replaces and would ideally be cleaner.

The fourth criterion requires that the replacement fuel not be subject to the supply concerns that have hindered petroleum in the past. This concern relates to both the sufficiency of quantity and access to supply. Ideally, the supply would be located within the United States.

The final criterion relates to the economic competitiveness of the replacement. No petroleum replacement will be able to achieve large market penetration without being economically competitive. Unfortunately, meeting this criterion is largely dependent on the volatility in oil prices.

Biofuels, Batteries, and Hydrogen

Biofuels, battery, and hydrogen technology are a promising solution for the long-term replacement of oil

A popular alternative to oil is biofuels, currently consisting almost entirely of corn-based ethanol. This has had unintended consequences on the price of food and leads to land use concerns. Furthermore, ethanol is only cost competitive with oil when highly subsidized. The next generation of cellulosic ethanol promises to rectify these problems by using waste and non-food crops that can be grown on land not suitable for other uses. However, this technology is not proven and appears to be at least ten years away from demonstration. Also, ethanol is not a direct replacement for current liquid fuels in that it has a 31% lower energy density than gasoline and cannot be directly implemented into vehicles without alteration.

Alternatively, the solution to transportation needs could be a transition away from liquid fuels altogether. Currently two technologies seem applicable in this regard, electric cars and hydrogen based power. Electric cars are currently limited by battery technology and current models are only applicable in the commuter sector with no foreseeable solution for long range shipping and air travel. At the end point of use, electric power is very environmentally friendly, but from a systems point of view it is only as clean as the electrical power plant and distribution system. A well-to-wheel efficiency calculation of an electric vehicle charged by standard coal burning power plants finds that electric vehicles may be more inefficient than current high efficiency liquid fuel vehicles. Additionally, large scale use of electrical vehicles would put a significant load on the existing electricity infrastructure. This and the limitation of current battery technology will postpone the wide-spread use of electric vehicles.

Despite tremendous attention, hydrogen technology is further behind than electric technology and suffers from the additional drawback of implementing a new filling infrastructure completely different from the current liquid fuel based model.

Replacing half of the US automobile fleet would take 10-15 years

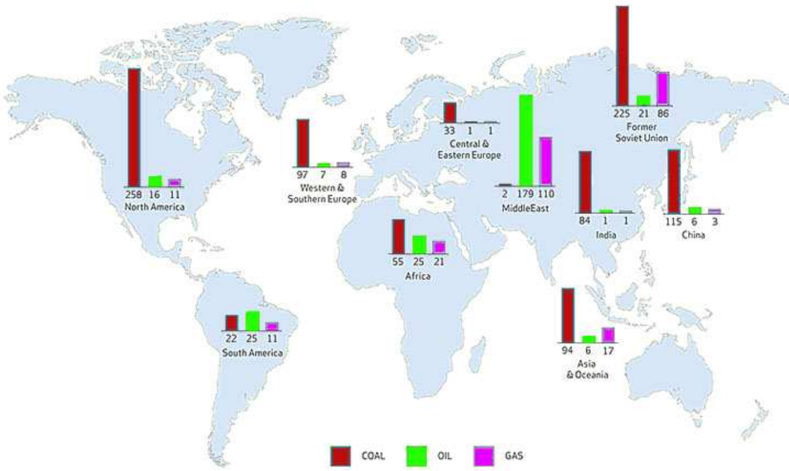
A significant drawback to any non-liquid fuels based technology is the inability to implement the technology rapidly enough to mitigate liquid fuel shortages. Currently, there are 210 million automobiles on the road with an average life span of nine years. To replace half the fleet with new technology would require 10-15 years and considerable capital investment beyond the production of the alternate power source.

Research into the development and implementation of these alternative fuels should continue and will hopefully bear fruit in the future, contributing to the long term solution. However, a solution to the liquid fuel crisis that can be quickly implemented in the current infrastructure is needed immediately.

Coal-to-Liquids

While worldwide oil reserves are estimated at only 41 years at current consumption, worldwide coal reserves are estimated to be at least 120 years. More importantly, the largest portion of those reserves, 27%, lies within the United States. The ability to convert coal to liquid fuel, CTL or coal liquefaction, could greatly mitigate reliance on foreign oil.

Coal has one great advantage, it is located within the US



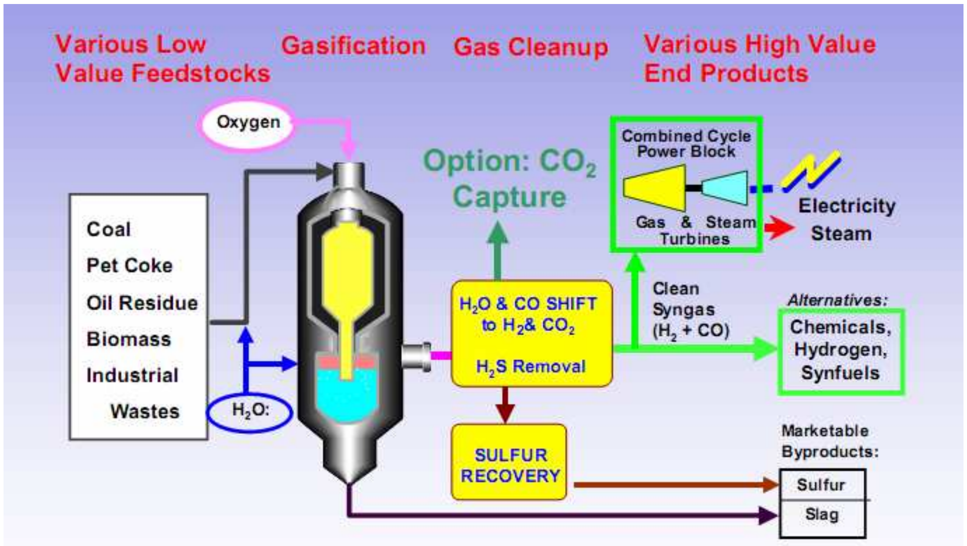
CTL can produce a variety of clean fuels

Source: Optima, Vol.51 No.1, Feb. 2005; as published in ECOAL Newsletter July 2005, World Coal Institute

Coal liquefaction is accomplished through one of two processes, direct coal liquefaction (DCL) or indirect coal liquefaction (ICL). DCL is a developing technology involving direct contact of coal with a catalyst at elevated temperatures and has the potential of higher efficiency than ICL processes. However, we will focus on ICL as it is a fully developed technology. ICL involves a two step process. First, the coal is gasified in the presence of oxygen to create a synthesis gas, or syngas, which contains hydrogen gas and carbon monoxide. In the second step, the syngas is converted to a liquid product in the presence of a catalyst. The catalyst can be appropriately chosen to produce a variety of liquids, from industrial chemicals to diesel and gasoline (so called Fischer-Tropsch Liquids, FTL). If this synthesis step is performed only once, not all of the syngas will be converted to liquids and the remainder can be used for power generation. Alternatively, the syngas can be recycled through the catalyst to increase the yield of liquid fuels.

CTL is more energy efficient than coal burning power plants

There are several important features of the coal liquefaction process. The total process is energetically efficient, currently reported as high as 60% with expectations that 75% efficiency may be possible. By comparison, standard coal power plants operate at 30-35% efficiency. The CTL process is versatile and can be adjusted to output both liquid fuel and electrical power depending on demand. Also, as mentioned, the CTL process can easily be tweaked to yield different liquid products. An additional benefit is that the input for the liquefaction process could potentially range from high quality coal to biomass or even waste. This holds great potential for future conversion of CTL plants to process renewable sources.



Source: Robert H. Williams, David Bradford Seminar, Princeton University, 5 October 2007

The greatest advantage of coal liquefaction is that it is a mature technology. The basic process, Fischer-Tropsch synthesis, was developed in Germany in the 1920s and was employed by the Germans during WWII in order to replaced lost oil supplies. South Africa continued development of CTL as a means of mitigating boycotted oil imports. In the 1970's the South African company Sasol built the Secunda plant, the world's largest synthetic fuels facility, capable of producing 150,000 barrels per day of liquid fuels. This plant alone supplies 35% of South Africa's liquid fuels, and Sasol recently announced plans to expand the facility to increase output by 20%.

A DOE test plant in Pennsylvania will process coal waste into liquid fuel

CTL plants could reduce carbon emissions with carbon capture and sequestration when the technology becomes available

Implementation of Coal-to-Liquids

Commercial CTL plants are currently limited in number. Although Sasol has multiple plants and plans for expansion, no commercial CTL plants exist in the United States. However, Department of Energy funded test plants do exist, and in China, the Shenhua Group is working with a number of international companies to pursue a coal liquefaction plant capable of producing 70,000 barrels of liquid fuel per day.

The most ambitious current plant is the DOE National Energy and Technology Laboratory (NETL) test plant in Gilberton, Pennsylvania. This project is particularly interesting because it is working to reclaim anthracite coal waste (culm) that has been discarded by hundreds of years of coal mining in Pennsylvania. The diesel produced from this coal waste will have a higher cetane number than petroleum diesel, will contain no sulfur (sulfur is sequestered during processing of the coal) and will have lower overall tailpipe emissions. The project will process one million tons per year of coal waste, and produce 5,000 barrels per day of ultra-clean transportation fuel with 41 MWe of electrical power cogeneration. There is an estimated 200-300 million tons of coal waste in Pennsylvania and a similar amount in Illinois.

Coal liquefaction clearly satisfies our first requirement for a mitigating technology, as the products of CTL can directly satisfy current transportation needs without any vehicle alterations. The second criterion, avoiding a resources shell game, is more challenging. As almost all coal consumption in American is currently being used for electricity, implementation of CTL would require either increased coal mining or an associated change in electrical power generation. However, this impact on energy resources is the smallest possible to mitigate oil reliance with current technology, as coal is the most plentiful energy resource in this country.

The major outstanding issue with any coal processing is environmental impact. For CTL technology, the end product environmental impacts are mitigated with respect to petroleum because the high octane naphtha and high cetane ultra low sulfur diesel produced are cleaner and of higher quality than petroleum fuels. The remaining environmental impact is related to green house gas emissions. Current CTL processes emit twice the CO_2 of equivalent petroleum usage. However, the process is readily amenable to CO_2 capture and sequestration when such technologies become available.

As mentioned previously, a great advantage to processing coal is that there are large deposits of coal in the United States. Therefore, CTL is ideal for satisfying concerns of security of supply. The final concern is economic competitiveness with oil, which we address here.

Sasol Secunda Plant

Policy Analysis

From the above analysis it seems clear that CTL is the most promising technology to allay our growing demand for foreign oil in the short term. The greatest concern for CTL, or any potential oil replacement, is economic competitiveness. This provides several salient reasons why CTL has not been widely implemented in America:

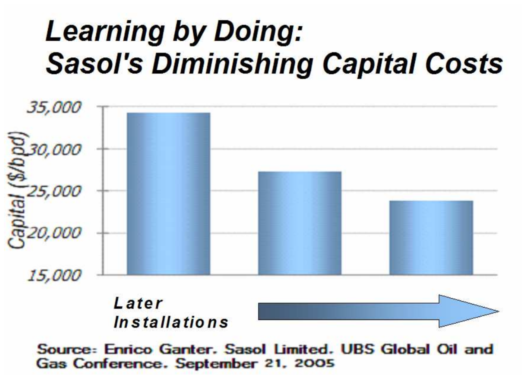
1. The volatility of oil prices makes long term predictions of economics difficult.
2. The technology is mature, but economies of scale are not yet established.
3. High startup costs for new plants mean high risk assumed by the investing companies.

The volatility of oil costs makes CTL investment uncertain

The historic volatility of oil prices is the single biggest factor affecting CTL plant economics. A permanent upward shift in oil prices from the 2000-2006 average to the 2005-2006 average would result in an increased return on investment (ROI) of ten percentage points to nearly 20% for a CTL plant, making construction highly attractive. However, there is no guarantee that prices will remain at their currently elevated levels, thereby limiting the interest of investors in CTL.

CTL plants face large startup costs

Department of Energy analysis indicates that an initial 50,000 barrel a day CTL plant with 125 MW electricity co-generation sited in Illinois would have a total cost of $3.65 Billion. The emergent nature of the industry contributes to the initial plants' high capital costs, while later installations will benefit from economies of scale and learning-by-doing. Sasol's experience indicates that the potential gains of learning-by-doing are significant, including diminished capital costs and greatly accelerated construction schedules. As reducing dependence on oil is a public good, we therefore must develop policy to promote initial installations to jump start the industry.



Our specific policy recommendations closely follow the analysis in the DOE report "Baseline Technical and Economic Analysis of a Commercial Scale Fischer-Tropsch Liquids Facility." This report considers the impact of three independent policy initiatives on a model CTL plant with a base ROI of 19.8%.

1. **A $0.50 per gallon tax credit on FT liquid fuels**

   Subsidies remove oil price volatility risk

   This policy is modeled after 2005 Federal Transportation Bill (H. Res 109-203, Title XI, Section 11113(d)) set to expire in 2009. The benefit of a tax credit to investors would be to limit the risk that oil price volatility has on the economics of a CTL plant. Fiscal Impact: +8.9 ROI from base

2. **Federal Loan Guarantees**

   It is assumed that loan guarantees would lower the interest rate on debt financing from 8% to 6% and change the debt-to-equity ratio from 55/45 to 80/20. The use of federal loan guarantees reduces the up-front risk faced by investors by essentially transferring the risk to the federal government. Fiscal Impact: +11.3 ROI from base

3. **An Investment Tax Credit**

   A 20% tax credit on the first $650 million of plant investment claimed in the first year of operation. Fiscal Impact: +0.6 ROI from base. We disregard this suggestion as the minimal effect of the incentive is overwhelmed by the cost of implementation.

There are auxiliary effects to these policy initiatives that deserve mention. The first effect is related to the flat FT liquids tax discount. Replacing petroleum with CTL will result in significant lost tax revenue for the federal government under this scenario, $9.125 million a year for the model plant. Additionally, if oil remains at elevated levels, the rationale for the tax credit is eliminated since the return of the plant will greatly exceed the assumed base levels. The appropriate form of the subsidy should be inversely tied to the price of oil so as to maintain favorable economics for plant investors while securing federal tax revenue.

Loan guarantees lower upfront capital risk

Federal loan guarantees have an advantage over tax subsidies in that fiscal impact on the federal government only occurs if a plant fails and is forced to default on its loans. Such loan guarantees transfer the assumed risk from the private investors to the federal government, lowering the entrance barrier.

Our final policy initiative concerns the transition of CTL plants to renewable sources of energy such as biomass or waste. While, current coal reserves are estimated at 120 years, increasing consumption will only serve to deplete them faster. Any long term solution to the liquid fuels problem must rely on a renewable source of energy. The versatility of CTL input feedstock provides a bridging technology to renewable energy sources. We propose additional federal renewable energy grants to promote specifically the development of biomass-to-liquids and waste-to-liquids technology based on existing CTL technology.

Our goal is to produce policy for a short term bridging solution to the liquid fuels crisis. Therefore all policy recommendations should have a sunset clause ensuring rapid development and implementation of the technology. This phases out government intervention when the economics are clearly favorable for the technology, at which point new policies will be implemented.

Policy Recommendations

1. **A sliding gas tax subsidy of $0.50 per gallon when crude oil is below $100 per barrel decreasing to $0.00 per gallon when crude oil is above $125 per barrel , set to expire in 2020**

   Ensure favorable economics and a reasonable timeframe for plant operation while limiting the financial burden on the federal government

2. **Federal loan guarantees at 6% interest for up to 80% of CTL plant construction cost, set to expire in 2020**

   Reduce entry risk for investors with minimal fiscal impact on the federal government

3. **Direct 10% of all federal biofuel research grants to biofuel-to-liquids and waste-to-liquids conversion research and development using CTL technology**

   Enable the transition from coal-to-liquid to renewable liquid fuels for long term energy stability

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