INCENTIVES FOR THE COMMERCIALIZATION OF COAL LIQUEFACTION TECHNOLOGIES

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The World Oil Situation:

Petroleum use worldwide is about 65 million barrels per day (MMBPD) and the Energy Information Administration (EIA) predicts that by 2015, worldwide demand will increase to between 89 and 99 MMBPD[1]. Over 55 percent of world petroleum is used in the transportation sector. Liquid hydrocarbon fuels are ideal for transportation since they are convenient, have high energy density, and a vast infrastructure for production, distribution, and end use is already in place. The estimated ultimate world resource of oil and natural gas liquids (NGL) is 2.5 trillion barrels; the sum of 1.2 trillion barrels for OPEC and 1.3 trillion barrels for non-OPEC[1]. Estimates of proven reserves of oil vary over time because more of the oil *resource* moves into the *reserve* category as a result of variations in the world oil price (WOP) and available technologies. However, the estimated ultimately recoverable world conventional oil resource (EUR) has been remarkably similar for the last 25 years. James MacKenzie of the World Resources Institute[2] cites an analysis of 40 estimates of ultimately recoverable oil, for the years 1975 to 1993, conducted by David Woodward of the Abu Dhabi Oil company. In this analysis, Woodward concluded that " there is a fair degree of consistency among the estimates with the average being 2,000 billion barrels (BBO) and 70 percent falling in the range of 2,000 to 2,400 BBO."

Figure 1 shows the production history for world oil from 1960 to the present and EIA projections of world oil demand from the present to the year 2015. For the high WOP case (the dark circles), the projected world oil demand in 2015 is 89 million barrels per day (MMBPD). In the low WOP case, the EIA projects world oil demand to be as high as 99 MMBPD in 2015. After 2015, bell-shaped distribution curves are drawn so that the total integral is equal to the ultimate resource estimate of 2.5 trillion barrels.

When this projected oil demand is plotted on the ultimate resource curve, as has been done in Figure 1, it becomes clear that conventional world oil production is likely to peak in a timeframe from about 2015 to 2020 and then irreversibly decline because of resource limitations.

There are two estimates for the U.S. oil resource used in this paper. One, by Masters et al[3] estimate that the U.S. ultimate oil resource is 256 BBO. If NGLs are added to this resource the total becomes 305 BBO. The other estimate, by the Oil Resources Panel (ORP)[4] for existing technology at $20 per barrel is 263 BBO. For advanced technology at $27 per barrel ORP estimates that an additional quantity of 105 billion barrels is available.

The Impact on the U.S. Transportation Sector:

Since oil is the primary fuel for the transportation sector, the potential impact of the above world oil supply scenario on the U.S. transportation sector has been examined. Specifically, this analysis has examined the following parameters relevant to this impact. These are: the percentage of oil used in transportation, future trends in transportation oil use, future improvements in transportation efficiency, and market penetration of non-liquid-hydrocarbon fuel (alternative fuel) vehicles.

Figure 2 shows the results of this analysis for certain assumptions for the above parameters. Curve A is the percent of oil used in the transportation sector. This shows this percentage rising from about 58 percent in 1980 to 67 percent in 1995; this percentage is assumed to remain constant until 2040. Curve B shows total petroleum, NGL, and refined product demand in the U.S. The demand until 2015 is that projected by EIA. Beyond 2015, the demand is calculated from the assumption that 67 percent of the total is used in transportation. Curve C is the transportation trend estimate assuming no improvements in current efficiency. Curve D is the transportation demand assuming efficiency gains projected by EIA until 2015 and continuing beyond until 2040. These efficiency improvements result in the transportation oil demand dropping from about 23 MMBPD, in the no improvement case, to 17 MMBPD. Currently the U.S. uses 12 MMBPD in the transportation sector of which 7 MM is gasoline, 3 MM is diesel and about 2 MM is jet fuel. Curve E shows the market penetration of alternative fuels, essentiallyalcohols, CNG and electric vehicles to the year 2040. By 2040, there will be 107 million alternative vehicles in the nationwide pool. This aggressive penetration schedule results in a reduction in petroleum use of about 4 MMBPD compared to the efficiency gain scenario for all petroleum fueled vehicles. Although this is a significant reduction in transportation petroleum demand, it is by no means a panacea to completely eliminate the U.S. transportation petroleum demand by the year 2040. Furthermore, even with this rapid penetration schedule, the penetration of alternate vehicles has practically no effect on petroleum demand until after 2020. This will not be in time to prevent a domestic petroleum shortfall.

What impact does this transportation petroleum demand scenario have on the overall U.S. petroleum supply situation? Figure 3 shows this overall impact. The petroleum demand curve at the top is curve B from Figure 2. Curve D represents oil imports. EIA import numbers are used until 2015 and beyond that it is assumed that the U.S. can continue to import 25 percent of total world exports. The three curves in between show the sum of imports (25 percent of world exports) and domestic production for three assumptions of the availability of domestic oil. Curve A, assumes that all of the additional 105 billion barrels of domestic oil from the ORP estimate can be produced. Under this assumption, there will be a domestic petroleum shortfall after 2020. Curve B assumes that half of the additional 105 BBO can be produced. In this scenario, a domestic petroleum shortfall would occur before 2010. Curve C assumes that only the Masters et al resource of 305 billion barrel is available. In this case, the petroleum shortfall would occur as early as 2000.

It is, therefore, essential to simultaneously pursue a number of options to mitigate the future domestic petroleum shortfall. These options are: to continue domestic exploration and production using the best technologies available, to continue to develop and deploy alternative fueled vehicles, and to continue to improve efficiencies in all sectors of transportation. Yet, even with all these efforts, this analysis indicates that the domestic demand for liquid fuels will exceed our potential sources of supply. Continuing to increase our reliance on oil imports to alleviate the shortfall is not a long term solution. Rapidly increasing oil demand worldwide will put ever increasing pressure on oil supply and the WOP will rise. The inevitable conclusion is that additional options will be necessary to insure that the U.S. will have the necessary liquid fuels supply to be able to continue its economic growth into the 21st century. One of these additional options is to produce liquid fuels from our huge domestic coal resources.

Proposed Strategy to Deploy Indirect Coal Liquefaction:

It is estimated that continued R&D in indirect coal liquefaction can reduce the cost of coal-derived fuels from $34 per barrel to about $27 per barrel for a grass-roots stand-alone coal liquefaction facility. However, there is the opportunity to deploy indirect liquefaction plants at existing facilities, for example petroleum refineries and IGCC facilities, and greatly reduce costs. These plants integrated with existing facilities are called “entrance plants” and preliminary economic analysis has shown that they can be competitive with crude at around $19-23 per barrel. This observation that “entrance plants” have the potential to be competitive with petroleum in the short term presents an opportunity for the early commercialization of coal liquefaction. They also provide a technology bridge to the eventual deployment of stand-alone coal liquefaction facilities. However, private investors and process developers are not likely to design and construct an “entrance plant” until both technical and economic risks are acceptable. Continued bench-scale and proof-of-concept testing of indirect liquefaction technology will result in sufficient data to design and construct pioneer plants. These pioneer plants are small-scale commercial plants that will demonstrate the ability to scale the integrated technologies and thus reduce both the technical and economic risks. Once these risks have been shown to be acceptable by successful operation of pioneer plants, larger “entrance plants” would be constructed and deployed. Eventually, when the most appropriate sites for “entrance plants” have been utilized and the technologies have continued to mature and improve, stand-alone, grass-roots commercial facilities will be deployed.

Pioneer plants will be necessary to reduce technical and economic risks and allow “entrance plants,” and eventually stand-alone commercial plants to be deployed. For indirect liquefaction, the pioneer plant is assumed to be located adjacent to an existing petroleum refinery and uses petroleum coke as feed to a gasification/gas cleaning plant to produce clean synthesis gas. In the simplest case, petroleum coke would probably be used as the feed but, if the plant is to be increased in size, coal can be introduced into additional gasifiers. Because the pioneer plant is located adjacent to a refinery, it is assumed that the plant will utilize some of the existing refinery facilities. In this case it is assumed that acid gas from the gas cleaning section can be processed in the existing refinery Claus unit for sulfur recovery. Also the refinery is assumed to process the waste water from the pioneer plant. The clean synthesis gas from petroleum coke gasification is passed once-through a slurry Fischer-Tropsch reactor to produce liquid fuels that are recovered in product separation, and the tail gas is sent to power generation. The pioneer plant sells electric power to the refinery and the liquid fuels are sent over the fence to the refinery for upgrading and blending. In the configuration analyzed here, 3,500 BPD of naphtha, diesel, and wax are produced together with 42 MW of power. Further additions to this pioneer plant could include pressure swing absorbers (PSA) so that hydrogen could be sold to the refinery in addition to power. The F-T unit enhances the refiner's ability and flexibility to make high value products by synthesizing high quality diesel and naphtha. The F-T diesel can be blended with FCC cycle oils to produce high cetane fuel and the naphtha can be blended in the gasoline pool or, since F-T naphtha is an excellent feed, cracked to give ethylene. The wax can be fed to a catalytic cracker to produce more high value diesel and naphtha.

Another example of a pioneer plant configuration for indirect liquefaction is one that could be located at an existing IGCC plant. The additional units required include a polishing reactor for residual sulfur removal, the F-T reactor, product recovery, and a cracker for the wax product. In this case, the IGCC plant would coproduce about 4,200 BPD of fuels in addition to 250 MW of power. Because the synthesis gas from the coal gasifier is now being fed to the F-T unit, natural gas must be imported for combustion in the gas turbines to keep the power output at 250 MW. The synthesis gas is passed once-through the F-T reactors and the tail gas, after product separation is used in the turbines. As the future cost of natural gas increases, it would be less expensive to add additional coal gasifiers and phase out use of the natural gas.

There are both technical and economic risks associated with the design, construction, and operation of the pioneer plant configurations outlined above. The desired strategy is to minimize federal government expenditures in the deployment of these technologies. For this to happen, the private sector must feel confident enough to take the initiative in deployment. If the commercial sector is to take the lead in this deployment, both types of risk must be acceptable. The objective of the pioneer plant concept is to bring the level of risk into an acceptable regime so that commercial entities will continue deployment through future "entrance" and stand-alone facilities. The government (federal or state) must encourage the private sector to finance the design, construction, and operation of the pioneer plants by providing financial incentives that will allow the products to yield an acceptable return on the investor's capital.

For the indirect pioneer plant located adjacent to the refinery a detailed economic analysis has been performed. It is shown that adequate return on investment can be obtained for these plants if it is assumed that these high quality F-T liquids can command a premium of 20 cents per gallon ($8.40 per barrel) over conventional petroleum. If the average of the nation's state fuel tax (17 cents per gallon) is exempted, effectively making the total incentive 37 cents per gallon, then the ROE rises to over 20 percent. If both state and federal fuel taxes are exempted, then a ROE of over 25 percent would be realized from this investment. Exemption of fuel taxes would appear to result in a net loss in revenue to the government. However, although this is true for the first few years of plant operation, this is generally not so if revenues over the entire 25 year life of the plant are considered. Once the pioneer plant is constructed and operating, the objectives would be for this plant to, not only confirm proof-of-concept integrated operations so that the technical risk is reduced, but also to operate for 25 years as a commercial entity so that the investors would reap the expected ROE. Even if the WOP remains at the low level of projection ($16 per barrel) for the life of the plant, taxes accruing to the government are greater than the cost of incentives to the government. The net result is that in all of these cases the government's net revenue is positive.

Conclusion:

It is concluded that domestic coal is a viable future alternative feedstock to petroleum for the production of high quality transportation fuels that are compatible with the existing liquid fuels infrastructure. These fuels are high quality distillates that in many cases are higher quality than current petroleum fuels. It is recommended that the current program of research and development be continued and extended so that sufficient performance data can be obtained for the design of "pioneer" plants. These plants would be located adjacent to existing facilities, for example, refineries or IGCC plants, and would be operated to demonstrate the integrated technical feasibility of the configurations. These plants would be constructed with private capital and, although incentives may be provided by state or the federal government, net revenues to the government, over the life of the plant, as a result of taxes on net profits would be positive. Once technical risks have been reduced as a result of "pioneer" plant operations, the continued deployment of coal liquefaction technologies would proceed with no further government involvement based on economic feasibility under market conditions.

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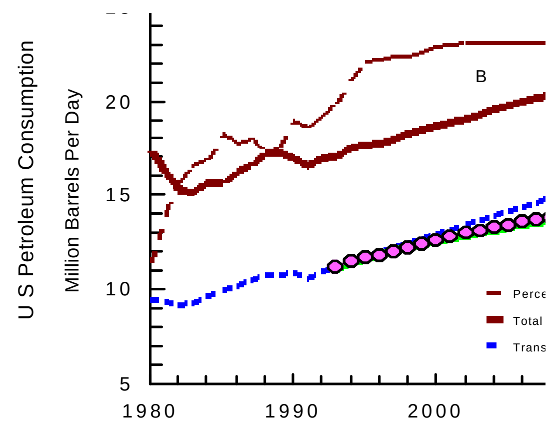

Figure 2. U.S. Transportatic

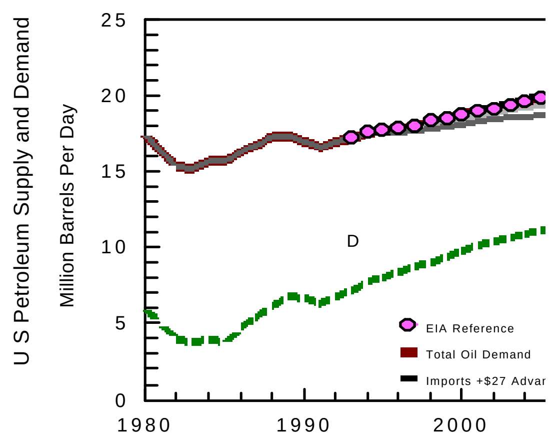

Figure 3. U S Petroleum Supply Projections