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Quarterly Progress Report

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Section 1: Introduction and Background

The Federal Energy Technology Center (FETC) at Pittsburgh contracted with the MITRE Corporation to perform Research Guidance Studies that will assist the Center and other relevant offices in the Department of Energy in evaluating and prioritizing research in the areas of coal and natural gas conversion. MITRE was reorganized in December 1995, which resulted in the formation of Mitretek Systems Inc. Mitretek has been performing this work on MITRE's behalf awaiting completion of contract novation to Mitretek. The contract was novated in February 1998 to Mitretek Systems.

The overall objectives of this contract are to provide support to DOE in the following areas: (1) technical and economic analyses of current and future coal-based energy conversion technologies and other similar emerging technologies such as coal-waste coprocessing, natural gas conversion, and biomass conversion technologies for the production of fuels, chemicals and electric power, (2) monitor progress in these technologies with respect to technical, economic, and environmental impact (including climate change), (3) conduct specific and generic project economic and technical feasibility studies based on these technologies, (4) identify long-range R&D areas that have the greatest potential for process improvements, and (5) investigate optimum configurations and associated costs for production of high quality energy products via refining and their performance in end-use applications.

Mitretek has been performing work to achieve several of these above objectives for DOE since 1980. As a result Mitretek has developed specialized and unique databases and spreadsheet simulation models that are quickly and reliably used to evaluate new and emerging fossil energy technologies. More recently, Mitretek has worked closely with other DOE contractors to screen process alternatives and provide preliminary data and information required to set the basis for doing more detailed process studies using commercial process development techniques and software such as Linear Programming (LP) and Aspen Plus. Such preliminary screening saves significant time and money in accomplishing the subsequent, more expensive, detailed process studies. The Mitretek databases and spreadsheet models are continuously checked and updated, as required, with results obtained from the detailed process studies to maintain the validity of the spreadsheet models. In addition to simulating direct and indirect liquefaction systems, these models also include detailed refinery models based on bench-scale upgrading data of coal derived liquid fuels to specification transportation fuels. In addition to the simulation models of actual conversion system configurations, Mitretek is able to simulate innovative process configurations for coal and gas conversion to fuels, power, and chemicals.

To supplement these system models and to provide a context to investigate expected energy use scenarios when alternate coal and natural gas based fuels will be

needed, Mitretek's staff has also developed world and country by country energy supply and demand models, including resource limitation considerations. The work to be performed in the current contract will be accomplished by using the existing models where appropriate and by extending and modifying the system models where necessary.

During the prior reporting period (January to March 1998), the contract was modified to include two additional tasks. These were: Task 4 entitled "Advanced Power Systems, Integrated Gasification Combined Cycle (IGCC)" , and Task 5 entitled " Gas-to Liquids (GTL) Technology Assessment".

The format for this quarterly describes the activities for this period by task as far as is possible, but there is an effort within Fossil Energy to integrate the three programs of coal fuels, IGCC, and GTL. This integration is perfectly logical because of the overlap of several of the enabling technologies within the three programs. For example, advanced synthesis gas preparation is the common element in all three programs. In coal fuels and IGCC, the feed is coal, in the GTL program the feed is natural gas. Also, advanced synthesis gas conversion is common to the coal fuels and GTL programs. In those instances where the activities describe these integrated program efforts, the activity write up is found in either one of the integrated task areas.

Section 2 Project Activity Summary

2.1) Task 1, Research Guidance Studies-Coal-Fuels, Overview of Technical Activities:

During this quarter, work was performed in two areas of Task 1. In the first of these, an analysis of the potential employment generated as a result of deployment of a synfuels from coal industry was conducted. In the second study under task 1, Mitretek investigated the potential impact of alternative liquid fuel sources on the world oil price (WOP). This study is part of a larger study to develop a strategic plan for the Coal Fuels program. As part of this strategic plan, a convincing and credible rationale has to be developed that clearly shows the necessity of a program whose goal is to provide alternative transportation fuels from domestic coal resources.

Summarizing the results of the employment potential analysis, Figure 1 shows a ramp-up profile for the deployment of synthetic fuels plants. It is assumed that deployment results by first constructing three pioneer plants each of 10,000 BPD capacity. The first pioneer plant comes on-line in 2006 followed by the second in 2007 and the third in 2008. The first entrance plant of 20,000 BPD starts operation in 2009, followed by a second entrance plant of 20,000 BPD in 2010. Deployment of commercial plants follow with five (5) 50,000 BPD plants coming on-line in the consecutive years from 2011 to 2015. In 2016 a commercial plant of 80,000 BPD begins operation followed by 6 larger

100,000 BPD plants coming on-line from 2017 to 2020. The total production of synthetics from these 17 plants is 1 million BPD by 2020.

Figure 2 shows a summary of the employment resulting from this ramp-up of synthetic plants. Four employment categories are shown. Total employment is the sum of total construction, total operation, and total mining. "Total" means the sum of the direct and indirect labor that make up the category. Direct labor is defined as those jobs created directly as a result of the activity. In construction and operation, for example, it refers to those jobs directly related to the construction and operation of the plants. In mining, it refers to jobs resulting directly from the production of the coal through mining operations. Indirect jobs are those created by a ripple effect or a multiplier effect through the rest of the economy as a result of this direct employment.

Considering the **construction** labor category. This analysis uses the Bechtel baseline study[1] to determine the construction labor man-hours per million dollars of plant capital investment. For an Nth plant, 9,650 man-hours per million dollars of investment is used based on the direct and sub-contractor capital costs used in the Bechtel study. Assuming $40,000 per daily barrel for the capital investment of the synthetics plants, construction labor peaks at about 43,000 in 2017. Indirect construction labor was estimated from an Input-Output analysis conducted by E.A. Muellar in 1993.[2] Using the Muellar ratio of 1.549, indirect employment resulting from the direct labor in construction peaks at 66,400 in 2017. Total direct and indirect employment as a result of this construction activity will peak in 2017 at about 109,000 jobs.

A similar analyses can be performed for the operating labor category. In the Bechtel baseline design report[1], direct operating labor was estimated to be 1200 people for a nominal 70,000 BPD plant. This is equivalent to 850 jobs for a 50,000 BPD plant, and smaller plants are prorated based on output. Using this assumption, direct operating labor would build up to a level maximum of 17,000 jobs by 2020. Indirect operating labor was calculated from the Muellar report using an indirect to direct ratio of 3.045. Indirect operating labor will also rise to a level maximum by 2020 of 51,700 jobs, for a total operating labor force of 68,700 jobs.

Employment in coal mining was estimated by assuming an average current productivity of 0.2 man-hours per ton of coal mined[3]. With this assumption, direct mining jobs steadily rise to a level maximum of 14,600 jobs by 2020. The ratio of indirect to direct mining jobs was assumed to be 11 times, based on a report by Rose and Frias of Penn State University[4]. Indirect mining jobs increase to a level of 161,000 by 2020. Total mining jobs peak in 2020 to 176,000 in 2020. A summary of these labor categories by year is shown in Table 1.

Deployment of a synthetics industry that produces 1 million BPD of fuels would therefore result in the creation of jobs equal to the sum of total construction, operating, and mining. This total at the peak of construction would be more than 305,000 jobs in

2018, leveling off to a total of 245,000 jobs by 2021 when plant construction is completed.

Summarizing the preliminary results of the study to assess the potential impact of an alternative fuels supply on the WOP, the elasticity of the WOP to petroleum supply was analyzed from data in the Energy Information Administration Annual Energy Outlook (EIA AEO '98). Table 2 shows EIA projections of world oil production in million barrels per day (MMBPD) and WOP in $ per barrel. Figure 3 shows the elasticity plot of supply versus WOP based on this data for the year 2015. The additional availability of 1 million BPD of oil effects the WOP by $1.12 per barrel. Similarly, a deficit of 1 million BPD increases the WOP by $1.12 per barrel. This supply/demand elasticity determines the WOP. Currently with supply of oil exceeding world demand by over 2 MMBPD, the WOP is at a very low level. When this excess supply surplus is mopped up by demand in the future, the WOP will strengthen and increase.

This elasticity relationship allows us to estimate the impact of supplying a synthetic or alternative supply of liquid fuels from the liquefaction of coal. Assuming the ramp-up of synthetics production as shown in Figure 1, we can calculate the oil cost savings to the consumer that results from this production of synthetics. This is shown in Figure 4. The cumulative oil cost savings is shown as increasing from essentially zero in the year 2010 where synthetics production is just starting to over $40 billion by the year 2020. This oil cost savings is the result of the lowering of the WOP by supplying synthetics to the market over this period. However, synthetics are never competitive with the WOP in this reference EIA scenario until after 2020 (see Table 2). Therefore a subsidy must be given to the synthetics producers so that they can produce them competitively. In this analysis, it is assumed that the cost of production for the synthetics is $27 per barrel and the subsidy is the difference between the WOP and $27 per barrel. The cumulative subsidy by 2020 is about $10 billion. Therefore the net gain to the consumers, as a result of supplying synthetics and suppressing the WOP, amounts to a positive gain of over $30 billion. This is true for even the low EIA oil price scenario. This is shown in Figure 5 where the net gains to the consumer are plotted for all three EIA WOP scenarios.

This analysis is being continued as part of the rationale and strategy document being prepared for the Coal-Fuels program.

2.2) Task 4: Advanced Power Systems, Integrated Gasification Combined Cycle:

During this quarter, work was performed in three areas of task 4. These areas were: continuation of the analysis of the IGCC baseline case and improvement options, preparation of a briefing on the benefits of coproduction of power and fuels using IGCC facilities, and development of a work outline for the IGCC market penetration study.

We have carefully reviewed the configurations described in the April 1998 report entitled *Texaco Gasifier IGCC Base Cases* (PED-IGC-98-001) and compared them to our own simulations of similar cases as shown in Table 3 . The results of the Texaco Radiant

Heat Recovery configuration (Case 2) and Radiant Heat Recovery and Hot Gas Cleanup (Case 3) are virtually identical to our own analysis of these configurations. Our results for the Case 2 analysis were presented in our last quarterly before the EGG results were available to us. We thus conclude that our process simulations are more than adequate for evaluation and optimizations of advanced technologies, cycle innovations, R&D goals, etc. Our estimates of construction costs are similar to the EEG analysis, but there are still differences in the manner in which the components are grouped for cost analysis.

The main problem remaining is arriving at an appropriate standard for determining the cost of power. The EEG report computes levelized costs using guidelines recommended by EPRI in 1984. Levelized costs are intimately associated with a regulated price structure, and are less useful in the coming deregulated environment. As a part of our market study, we are currently working with CONSOL and power producers to gain an understanding of the type of analysis and financial assumptions potential buyers of IGCC system would find most useful. This effort will be carefully coordinated with FETC as it evolves.

A briefing was prepared for the IGCC program manager for presentation at the Tennessee Valley Authority (TVA). A copy of the briefing slides is appended (see Appendix 1).

Mitretek is conducting an IGCC market penetration study for the IGCC program. The overall objective of this study is to provide the necessary information, rationale, and framework so that the client can develop a strategic and defensible marketing plan for commercial deployment of IGCC technologies in the U.S. and overseas. Specifically this study will attempt to estimate the market potential of IGCC between now and the year 2020 in power generation, coproduct applications, and niche markets.

In order to more produce a more credible market study, it was decided to undertake this study with direct participation with industrial companies involved in projections of the future of coal-based technologies. To this end, Mitretek, with agreement from DOE, prepared to subcontract the coal company CONSOL to assist in this study. CONSOL has already been involved in similar market assessment studies with the Coal Utilization Research Council (CURC). Also, to obtain input from companies directly working in the gasification arena, Mitretek joined the Gasification Technologies Council (GTC). We believe that a strong endorsement from industry is critical to developing a credible market analysis for IGCC technology.

The outline for the IGCC market penetration study is appended in Appendix 2.

2.3) Task 5: Gas-to-Liquids Technology Assessment:

During this quarter, DOE initiated a product team to investigate the potential for a greater degree of integration between the activities in the Coal-Fuels and Gas-to-Liquids (GTL) programs. Mitretek was part of this product team and attended several meetings in

which a strategic planning approach to this integration was developed. The summary of the strategic planning meetings is given in Appendix 3.

The technical configurational analyses of GTL plants using both oxygen and air blown reforming has been started. Several configurations are currently being analyzed in order to optimize the technical and economic performance. The results of these analyses and of configurations utilizing the Ion Transport Membrane (ITM) system will be reported in the next quarterly progress report.

Meetings and other activities:

April 14/15: Energy Frontiers International (EFI) meeting on Climate Change, Washington DC
April 22: Meeting at DOE HQ on Level II briefing of Coal-Fuels/IGCC program
April 28-31: 6th Clean Coal Technology Conference, Reno, Nevada
May 4: Meeting with IGCC product team FETC, Pittsburgh to discuss IGCC market penetration study
May 5: Meeting with CONSOL, Pittsburgh to discuss potential subcontract on market penetration study
May11/12: Meetings with David Scott of the International Energy Agency (IEA) to discuss their draft report entitled " Competitiveness of future coal-fired units in different countries" authored by David Scott and Per-Axel Nilsson. This meeting was arranged by the GTC.
June 10: Meeting of the Energy Efficiency Forum, Washington DC on Energy Efficiency and Climate Change. A summary of this meeting is provided in Appendix 4.
June 24/25: Meetings at FETC Pittsburgh to develop Coal-Fuels/GTL strategy. (see Appendix 3)

References:

1) Direct Coal Liquefaction Baseline Design and System Analysis. Final report on Baseline and Improved Baseline, Volume IV, Capital Cost and Economics for Baseline. Report prepared for the U.S. DOE by Bechtel and Amoco under contract DEAC22-90PC89857, March 1993.
2) The Analysis of Scenario Options for the Development of U.S. Coal Derived Fuels Production Capability. Report prepared for the U.S. DOE by E.A. Muellar Associates under contract DE-AC01-A8FE61661, 1993.
3) Personal communication with Dr. Francis Burke, Vice President of Research and Development, CONSOL, Pittsburgh, June 1998.
4) Rose, Adam, and Oscar Frias, The Impact of Coal on the U.S. Economy, report prepared for the National Coal Association, April 1994.