Title: A Novel Configuration for Coproducing Fischer-Tropsch Fuels and Electric Power from Coal and Natural Gas

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Introduction:

No rational projection of world energy use suggests that oil and gas will be plentiful enough to permit coal to be eliminated from the energy mix in the near future. Even the Energy Information Administration (EIA), which is highly optimistic about the price and availability of oil and natural gas, projects that coal use in the United States (US) will ***increase by 20 percent*** between 1996 and 2015. EIA projections for the world energy mix forecast that ***coal use will increase by almost 50 percent*** from 5,122 million tons presently to 7,495 million tons in 2015. Only 10 percent of this increase is expected to occur in the Organization for Economic and Cooperative Development (OECD) countries and the former Soviet Union (FSU). In the developing world, coal use is forecast to increase by 100 percent. The best available evidence is, therefore, that coal will remain a major part of the energy mix both in the US and worldwide for at least one or two equipment generations of about 30 years.

The challenge is to determine how to use the combination of oil, gas ***and*** coal most efficiently with the minimum environmental damage. Since coal is, by nature, a high carbon energy source, it will necessarily emit more carbon per unit of energy released than will oil or gas. ***If this inherently high carbon resource must be used to provide energy, then it becomes an environmental imperative to develop and implement technology that permits coal to be used cleanly and efficiently.*** Our national R&D effort should be targeted to assure that coal is utilized in the most efficient and environmentally acceptable manner.

The Proposed Configuration:

To this end, the U.S. Department of Energy and Mitretek have developed and evaluated a concept that combines the use of gas and coal for the highly efficient production of electric power and high quality transportation fuels. In its simplest form, this coproduction cofeed (CoCo) concept consists of diverting coal-derived synthesis gas from the combined cycle power block of an Integrated Coal Gasification Combined Cycle (IGCC) unit to a liquid synthesis reactor (see Figure 1). The unreacted synthesis gas from the liquid synthesis reactor, and imported natural gas are then combusted in the downstream combined cycle power generation unit. Combining processes in this manner accomplishes the equivalent of natural gas to liquid synthesis while eliminating the conversion losses associated with the production of synthesis gas from natural gas.

This concept of using both coal and natural gas to coproduce power and transportation fuels utilizes both feedstocks in an optimum manner. Coal cannot be combusted directly in gas turbines, it must first be converted into clean synthesis gas. Once in gaseous form, the high efficiencies associated with gas turbine performance now become accessible to coal. This is the rationale behind the IGCC concept. However, once the synthesis gas has been produced from the coal it is even more efficient to use this gas to produce liquid transportation fuels through Fischer-Tropsch (F-T) synthesis technology. Using a once-through F-T process, the inefficiencies of carbon dioxide removal and synthesis gas recycle can be avoided and the unconverted synthesis gas can be directly combusted in the gas turbines thereby benefiting from the high efficiency of gas turbine power production. For natural gas, optimum efficiency is realized by direct combustion in the gas turbines as in the concept described here. Making F-T fuels from natural gas first requires the natural gas to be reformed to synthesis gas at an efficiency penalty. Only then can this natural-gas-derived synthesis gas be used to produce fuels using F-T synthesis.

Impact on Carbon Emissions:

To quantify the advantages of this concept, it is necessary to compare it to the alternatives for producing electric power and fuels in separate facilities. First, we examine the production of F-T fuels from natural gas and power from coal in separate facilities and then compare this to coproduction in a single facility. The top part of Figure 2 shows schematics for the production of 6,083 BPD of F-T transportation fuels from 53 million cubic feet per day (MMSCFD) of natural gas feed, and production of 400 MW of power from 3,200 TPD of coal using separate facilities.

For the separate production of F-T fuels from natural gas shown in the top part of Figure 2, the natural gas is autothermally reformed with oxygen to produce the synthesis gas that is then catalytically combined over F-T catalysts to produce hydrocarbon fuels in a slurry-phase F-T reactor. The unconverted synthesis gas is then recycled to the synthesis unit to complete the conversion to fuels. The overall efficiency for this gas-to-liquids (GTL) process on a higher heating value (HHV) basis is about 60 percent. These liquid fuels consist of sulfur free naphtha and high cetane diesel. By optimizing operating parameters, production of high quality diesel fuel can be maximized. In these cases the resulting fuel mix is one third naphtha and two thirds diesel fuel. Since 836 tons per day of carbon are used to produce 31.9 billion BTUs of transport fuels, 26.2 million tons of carbon would be used to produce and utilize one quad (10^{15} BTUs) of fuels.

Depending on the choice of technology used, production of 400 MW of power from coal using IGCC requires about 3,200 TPD of coal for an overall HHV efficiency of about 42 percent. The technology choice in this case is oxygen-blown Texaco coal gasification with radiant syngas cooling and conventional cold gas cleaning. The carbon use is 2,272 TPD. Considering the overall production of the power and the liquid fuels in these separate facilities, the total carbon used to produce the 400 MW and the 6,083 BPD of fuels is 3,108 TPD.

Now consider the bottom half of Figure 2. This shows the coproduction of power and fuels using the CoCo concept of cofeeding natural gas and coal in one integrated facility. In this case, the same quantity of coal is used (3,200 TPD) as in the separate case described above. The same quantity of products are produced as in the prior case (400 MW of power and 6,083 BPD of liquid fuels) but now, in the integrated facility, only 34.7 MMSCFD of natural gas is required compared to 53.2 MMSCFD in the separate case. The net carbon attributable to the liquids production in this case is, therefore, the total carbon fed to the system (2,817 TPD) minus the carbon used to produce the 400 MW of power (2,272 TPD). This is equal to the carbon associated with the natural gas; that is 545 TPD. On a quad of transportation fuels basis, this is equal to 17 million tons of carbon compared to 26.2 million for the separate case. ***This concept, therefore, represents a very significant contribution to reducing potential greenhouse gas emissions by optimizing the use of both coal and natural gas as feedstocks.***

If coal by itself were to be used to coproduce 400 MW of power and 6,083 BPD of liquid fuels, the schematic is shown in Figure 3. In this single feedstock coproduction case, 4,790 TPD of coal would be required (equivalent to 3,401 TPD of carbon) to produce fuels and power at an overall HHV efficiency of 55 percent. Approximately one third of the clean coal-derived synthesis gas bypasses the F-T unit and is sent directly to the gas turbines. The other two thirds of the synthesis gas is passed once-through the F-T reactors and the unconverted synthesis gas together with the C_1 to C_4 hydrocarbons produced in the F-T synthesis are sent to the gas turbines. The net carbon attributable to liquids production (1,129 TPD) is the total carbon feed to the system (3,401 TPD) minus the carbon used to produce the 400 MW of power (2,272 TPD). This is equal to 35 million tons of carbon per quad of fuels; over twice the net carbon per quad of fuels produced using the CoCo concept.

It can be shown that, from the perspective of the production and consumption of F-T transportation fuels, the CoCo concept produces the lowest carbon emissions, even lower than the direct transportation use of compressed natural gas (CNG)[1]. The CoCo concept achieves these low carbon emissions and produces fuels of higher quality than conventional petroleum-derived fuels that are compatible with the existing liquid fuels infrastructure. In contrast, CNG use in transportation requires expensive vehicle modifications and the introduction of a CNG-based infrastructure for distribution. At a conversion cost of $3500 per vehicle, the cost of converting enough vehicles to consume 6,083 BPD is about $550 million; approaching the capital cost of a CoCo plant. Carbon emissions from F-T fuels produced from natural gas feed are comparable to those from the direct use of CNG and petroleum-derived diesel. Carbon emissions from F-T fuels produced from all-coal feed configurations are comparable to carbon emissions from petroleum-derived gasoline.

National Implications of Deploying this Technology:

The development of clean coal technologies that allow coal to be used efficiently and cleanly to produce electric power in IGCC systems and to coproduce power, super-clean transportation fuels, and chemicals in one integrated configuration is the harbinger of a new age of coal utilization. The CoCo concept represents the opportunity to make use of these new technologies to replace conventional coal utilization technology. Figure 4 shows an example of this. In this case a conventional pulverized coal power plant is replaced by a CoCo facility. For the conventional coal power plant, 4,052 TPD of coal, equivalent to 2,877 TPD of carbon, produces 400 MW at an efficiency of 33 percent. In the CoCo plant, slightly less carbon (2,817 TPD) produces not only the 400 MW of power but also 6,083 BPD of

F-T liquid fuels. Therefore, if one conventional coal-fired power plant is replaced by a CoCo plant, the 6,083 BPD of fuels are produced for **no additional increase in carbon.**

Nationwide, if all existing conventional coal-fired plants were to be repowered or replaced by CoCo facilities to produce the amount of electricity currently produced from coal (1,671 billion kWh of electricity), this would result in the use of 6 quads of natural gas and 14 quads of coal and the coproduction of 2.89 million barrels per day of high quality transportation fuels. Production of this fuel from domestic resources would save over 3 million BPD of imported crude oil with a resulting reduction in annual carbon emissions of over 150 million tons.

Economic Considerations:

The capital cost of a grass-roots CoCo plant of the size described above is about $670 million. However, in many cases, it would be possible to reduce this by retrofitting or repowering existing coal-fired power plants rather than completely replacing them. The Wabash River CCT project, for example, uses much of the existing coal-fired plant in the IGCC configuration including the steam turbines.

The required selling price for liquid fuels from a CoCo plant is highly dependent on the value of the coproduced power. In this analysis, it is assumed that the power must be sold at a price competitive with power from a natural gas combined cycle plant; that is, about 24 mills per kWh when gas is $2 per MMBTU rising to 37 mills when gas is $4. Preliminary economic analysis of the CoCo plant has estimated that, at current oil and gas prices ($2.50 per MMBTU for natural gas and $18 per barrel for crude oil), F-T fuels could be produced for about $26 per barrel of equivalent crude oil[1]. This means that to be competitive with the current oil price an incentive, worth $8 per barrel, would be needed to realize a 15 percent return on investment. This is equivalent to about $62 per ton of carbon saved. Such a financial incentive could, for example, be provided by the government from revenues obtained from a carbon tax, or from exemption of state or federal fuel excise taxes. However, future prices for oil and natural gas are uncertain, and any increase in both has a substantial affect on the resulting cost of carbon reduction. For example, if natural gas were $3 per million BTU and crude $22 per barrel, then the cost of carbon saved would be zero. It is not only the price of oil and natural gas that influences the resulting cost of carbon saved, the capital cost of the technology has a significant impact. If continued R&D results in the deployment of advanced technologies that can reduce the cost of IGCC technology to be about $1,100 per kW, then the resulting cost of the carbon savings would also be zero. These economics are based on the cost of new facilities and do not take into account the savings that would be realized by repowering existing coal-fired facilities.

Acknowledgment:

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References:

1) David Gray and Glen Tomlinson, Efficient and Environmentally Sound Use of our Domestic Coal and Natural Gas Resources, Energeia, Published by University of Kentucky, CAER, Vol 8, No 4, 1997.

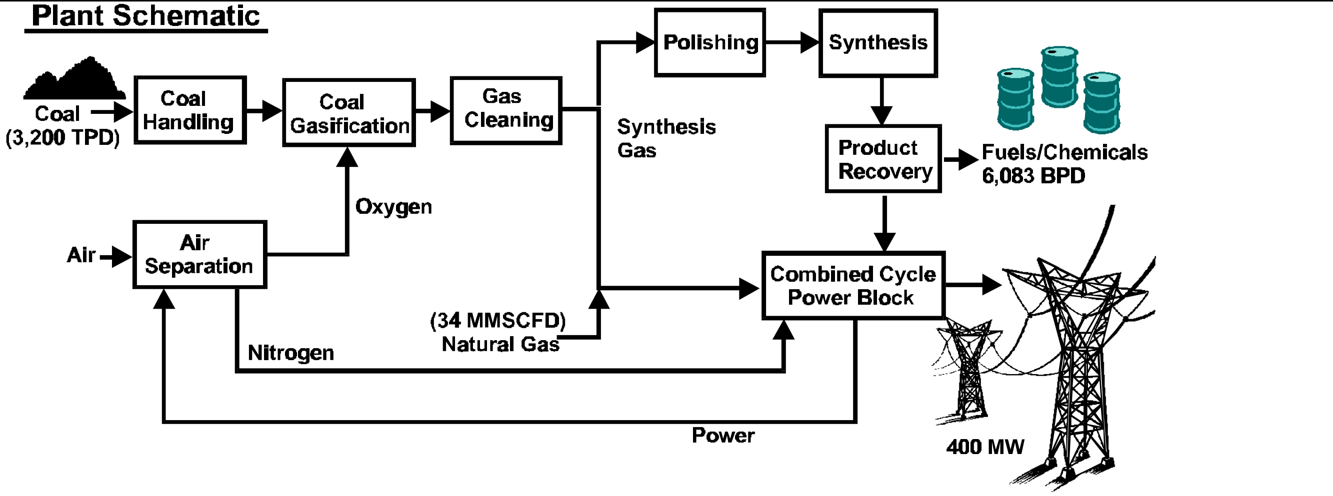

Figure 1. Coproduction Cofeed (CoCo) Configuration

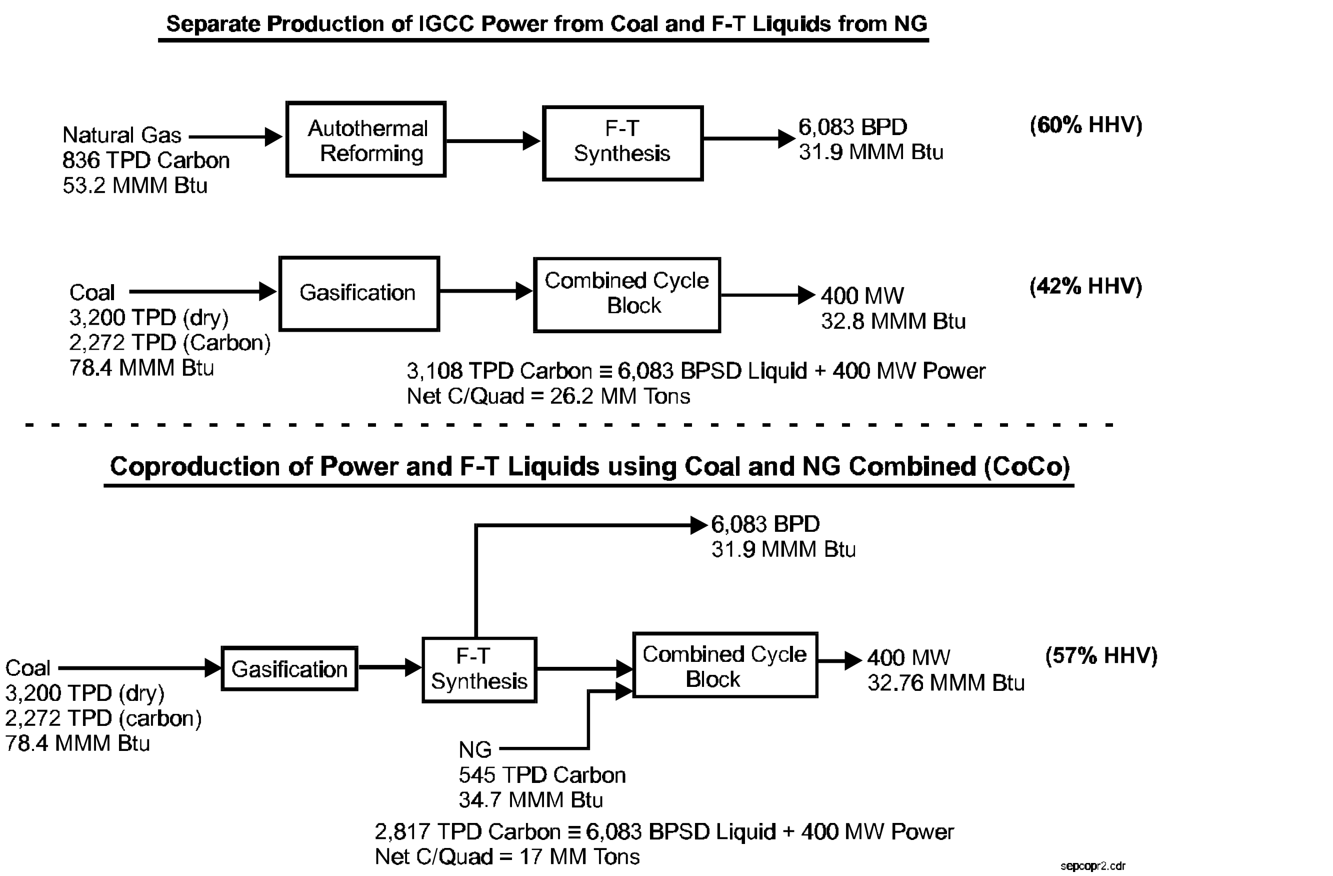

Figure 2. Separate Production vs. Coproduction of F-T Liquids and Power

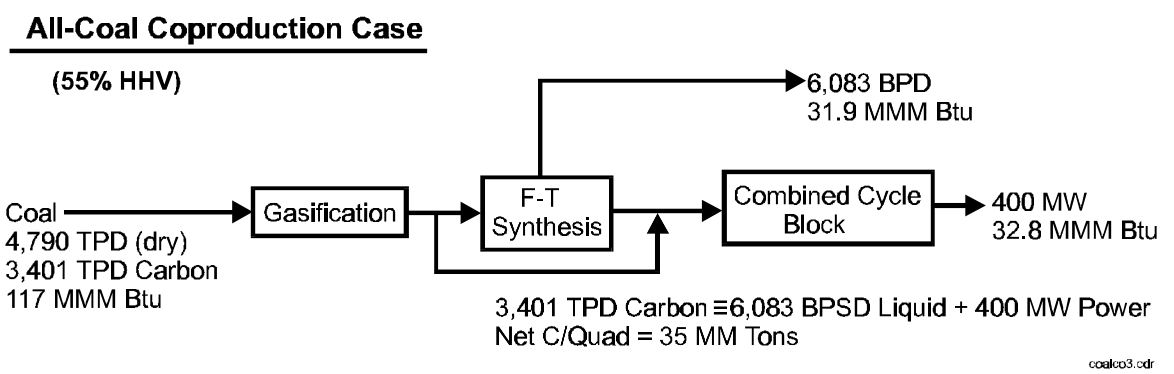

Figure 3. Coproduction Using Coal-Only as Feedstock

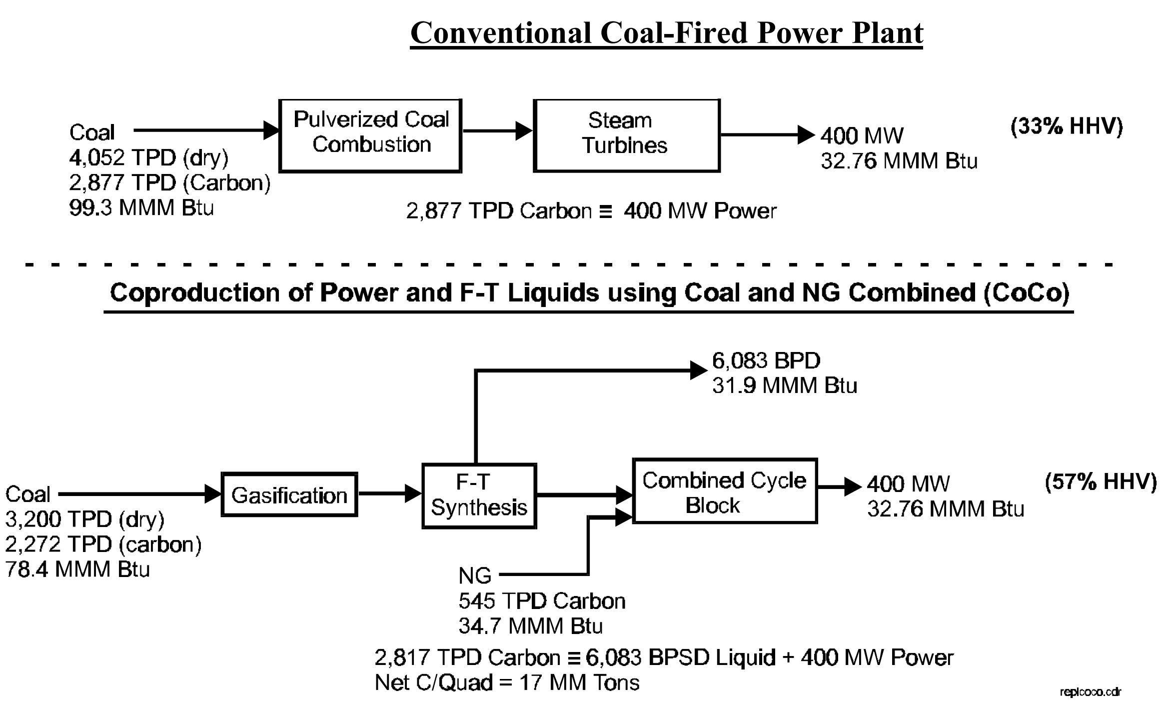

Figure 4. Replacing Conventional Coal-Fired Power Plants With the CoCo Concept