A TECHNO-ECONOMIC ASSESSMENT OF INTEGRATING A WASTE/COAL COPROCESSING FACILITY WITH AN EXISTING REFINERY

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INTRODUCTION

About 97 million tons of waste plastics, paper, oils, and tires are generated annually in the United States. The vast majority of this waste is paper, accounting for more than 73 million tons, and the second most abundant waste is plastic, accounting for more than 16 million tons. The number of waste passenger tire equivalents generated in the United States is about 300 million; considerably more than the population. On a rubber basis, this is approximately equal to 1.6 million tons: For waste oils, the average rate of annual generation is about 4.8 million tons, equivalent to about 32 million barrels(1). This rate of waste generation constitutes a major waste management problem with respect to land availability for landfills and public health and pollution concerns. Mandatory recycling of waste paper and plastics is in effect in several states, but the rate of generation of these wastes exceeds existing demand.

Solutions to the problem of excess waste are being put into effect nationwide. Paper can be recycled to a certain extent. Waste oils can be cleaned and re-refined. Plastics that are not recycled can be combusted for thermal value, and tires can either be burned whole in cement kilns, or shredded and used as a supplementary fuel for utility boilers, the so called tire derived fuel or TDF(2). Another potential solution to the waste problem is coprocessing of the wastes either with heavy oils or with coal to produce hydrocarbon liquids that can be refined like petroleum to give transportation fuels. This paper addresses the technical and economic feasibility of this coprocessing approach by examining the potential for co-siting a waste/coal coprocessing facility adjacent to an existing oil refinery.

METHODOLOGY

The conceptual waste/coal coprocessing facility is assumed to be sited at a refinery close to the greater Philadelphia metropolitan area. In this area it has been estimated that approximately 3100 tons per day of waste plastics is generated, 250 tons of tire rubber, and about 9000 barrels per day of used oil(1). It is assumed in this analysis that about 25 percent of the waste plastics can be transported and utilized at the site , 15 of the waste oil, and 50 percent of the tires. Four cases were analyzed and these are shown in table 1. In case 1, only plastic and coal is fed to the plant on an equal weight basis. In Case 2, plastics, coal and waste oil are fed to the plant, Case 3 uses plastics, oil, tires and coal. Case 4 is a coal-only case, and is analyzed to provide a comparison by which to measure any potential economic advantages of co-feeding the wastes. In all cases, petroleum coke from the refinery is used as a gasification feed to provide hydrogen both for the refinery and for the coprocessing facility. Figure 1 is a schematic showing the coprocessing facility and how it integrates with the adjacent refinery. These integrations include: letting the refinery process purge gases from the coprocessing plant, sharing of waste water treatment facilities, refining of the raw liquids from the coprocessing plant in the refinery, selling hydrogen and fuel gas to the refinery, and utilizing the petroleum coke from the refinery in the coprocessing facility for hydrogen production.

When this techno-economic analysis was performed there was little data available from continuous units operating in a coprocessing mode with coal and plastics, rubber, and oils. Since then, Hydrocarbon Research Inc. (HRI) has demonstrated the technical feasibility of coprocessing coal with plastic and rubber in their proof-of-concept (POC) facility in New Jersey under the sponsorship of the United States Department of Energy (DOE). For this analysis, it was necessary to make various assumptions as to the performance of coal/ waste coprocessing in the HRI Catalytic Two-Stage Liquefaction (CTSL) process. These assumptions can be summarized as follows: the presence of the coprocessed waste materials do not effect the coal conversion, plastics (excluding PVC) convert to 98 percent to oils and gases, plastics produce four times the gas as coal, waste oil converts to 98 percent oil and gas, tires contain 33 percent carbon black inerts and 98 percent of the remainder converts to oil and gas. It is further assumed that coal is $25 per ton, and the acquisition costs for the waste materials at the plant gate is zero. The petroleum coke is also free at the plant gate. However, the waste feed stocks must be prepared for coprocessing. It is assumed that it costs $25 per ton to shred tires, $20 per ton to shred plastics, and $5 per ton to prepare the waste oil. The coprocessing plant can sell hydrogen to the refinery for $2/Mscf, and fuel gas for $1/MMBtu. Sulfur and ammonia by-product credit to the coprocessing facility is priced at $80 and $150 per ton respectively. For processing the fuel gases the refinery charges the coprocessing facility $6 million per annum, $5 million for waste water treatment, and $3 million to recover sulfur.

To conduct this analysis, conceptual, commercial waste/coal coprocessing plants were developed using the MITRE coal liquefaction cost model methodology based on performance data from the CTSL process. MITRE has developed commercial liquefaction simulation models and these can be used to analyze the impact of process variables on performance and the resulting required selling price of products for any desired set of economic parameters. For this analysis, the performance of the coprocessing plants was based on the known performance of the coal-based process together with the estimated performance of the waste materials from the assumptions noted above. The four cases were analyzed based on the capacity of one liquefaction train of the CTSL process. The size of the overall facility was based on the availability of the waste feedstock and this train size for CTSL is not the optimum size from an economic viewpoint. A larger CTSL train size could be utilized by feeding more coal to the facility but the impact of this was not considered in this analysis.

RESULTS OF THE ANALYSIS

Table 2 summarizes the results of this economic analysis for the three coprocessing facilities and the coal-only plant. The components that make up the capital costs of the coprocessing facility consist of the CTSL train, gasification to produce hydrogen including air separation, and the ROSE-SR deashing process (CSD). In Case 3, the Texaco Tire dissolution process[3] is included to dissolve the tires. Total capital for these plants ranges between $330 and $350 million ($1993). Operating costs include feedstock preparation costs for the wastes, coal costs, power, and operating and maintenance costs. Netbacks is the difference between the price paid to the coprocessing facility for hydrogen, fuel gas, sulfur, and ammonia, and the service costs that the coprocessing facility pays to the refinery for sulfur recovery, waste water treatment, and acid gas processing. The required selling price (RSP) of the raw liquid products is calculated from the capital and net operating costs from a DCF analysis based on a fixed set of economic parameters. The liquid product outputs from the four cases are tabulated in Table 1.

This preliminary economic analysis indicates that waste/coal coprocessing has the potential to reduce the RSP of raw liquid products from coal liquefaction by about 30 percent if the assumptions made in this study can be verified experimentally. This conclusion is based on the comparison between the coal-only case (Case 4) where the RSP is $40 per barrel and Case 2 where coal, plastics, and waste oil are coprocessed together to yield an RSP of only $28 per barrel. The primary reasons for this significant decrease in the RSP of products from coprocessing lies in the high liquid yields obtained from the plastics and oils, and the lower hydrogen requirement compared to coal liquefaction by itself. Plastics and oils have hydrogen contents of about 14 weight percent compared to coal at only about 5 percent, therefore considerably less hydrogen is required to make liquid hydrocarbons from coprocessing a mixture of plastics and coal. Obviously, the larger the quantity of plastics in the mix the less hydrogen is required and hence the better the resulting economics. The other conclusion from this study is that siting such a coprocessing facility adjacent to an oil refinery offers opportunities for integration and hence can reduce costs. However, since this study is based on little actual continuous performance operations in a coprocessing mode, a comprehensive bench and continuous scale research and development program is needed to verify the assumptions made in this paper and to optimize coprocessing performance.

These above cases were all based on the assumption that the acquisition costs of wastes were zero at the plant gate. This implies that the costs of transporting the wastes to the plant are balanced by the savings in tipping fees. A sensitivity to this assumption has been investigated in this study, and the economic impact on the RSP of products by varying the acquisition costs has been estimated. If tipping fees are increased in the future so that the plant gate acquisition cost is negative $20 per ton, then the RSP of liquids drops to about $23 per barrel. If, on the other hand, acquisition costs are greater than zero, for example +$20 per ton, then the RSP of liquids would rise to about $32 per barrel.

The overall economic potential for this concept of coprocessing coals and waste materials to make transportation fuels does offer considerable promise. The roles that coal may play in this concept can be summarized as follows: coal allows process flexibility by acting as a feedstock flywheel to stabilize the system during periods of waste feedstock variability; the plant output can be doubled by using up to 60 percent coal and hence benefits of scale can be obtained;

there may be potential chemical synergy with coal by scavenging heavy metals in the coal ash; there may be a catalytic effect of the carbon black in tires; the hydrogen donor recycle solvent from the coal may assist the kinetics of plastics and rubber dissolution; there may be an ability to neutralize chlorine from PVC by coprocessing with low rank coals having alkaline mineral matter; coal allows several different wastes to be utilized simultaneously.

REFERENCES

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Table 1. Cases Analyzed

Feed (TPD)	Case 1	Case 2	Case 3	Case 4
Plastics	866	866	866	—
Coal (dry)	872	872	872	1,728
Petroleum Coke	1,248	1,248	1,225	1,095
Waste Oil	—	210	210	—
Tires	—	—	135	—
Total C_3^+ Products (BPSD)	8,830	10,170	10,455	7,360

Table 2. Economic Summary ($MM)

	Case 1	Case 2	Case 3	Case 4
Capital				
CTSL	110	110	110	110
Hydrogen	97	97	98	97
CSD	10	10	10	11
Other	28	28	28	28
	245	245	246	246
Tire Dissolution	0	0	15	0
Total Capital	332	332	350	338
Operating Costs				
Feedstock	7	7	7	14
Waste Prep	6	6	7	0
Power	17	17	17	17
Other	23	24	26	25
Gross O&M	53	54	57	56
Netbacks	-17	-17	-17	-8
Net Operating	36	37	40	48
RSP $/Bbl	32	28	29	40

Figure 1. Waste/Coal Coprocessing—Refinery Integration