Presented at the 3rd Annual Biomass Energy Systems Conference, Golden, CO, June 5-7, 1979.

LBL-9192 c.2

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 6782

RECEIVED
LAWRENCE
BERKELEY LABORATORY

JUL 9 1979

LIBRARY AND
DOCUMENTS SECTION

Energy and Environment Division

Economic Feasibility Assessment of Biomass Liquefaction

Sabri Ergun

June 1979

Lawrence Berkeley Laboratory University of California/Berkeley

Prepared for the U.S. Department of Energy under Contract No. W-7405-ENG-48

LBL-9192 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

ECONOMIC FEASIBILITY ASSESSMENT OF BIOMASS LIQUEFACTION

Sabri Ergun
Energy & Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California

Abstract

Several assessments have been made of the economic feasibility of liquefaction of organic municipal waste and/or biomass since 1972, placing the breakeven cost of liquefying from about $16.00/dry ton to over $58.00/dry ton cellulosic material processed, exclusive of the cost of biomass, in plants processing roughly 2,500 dry tons biomass daily.

LBL studied the cost assessments in order to trace the origins of disparities and to identify the unit operations or unit processes that are costly so that the R & D effort could be diverted to find solutions to the costly steps. The major causes of the disparity (corrected for inflationary trends) were traced to the differences in the interpretation of process chemistry. The LBL analysis indicated that the economic feasibility of biomass liquefaction approaches that of coal liquefaction in spite of the fact that the biomass liquefaction plants have to be smaller by an order of magnitude.

This economic feasibility assessment concerns the Bureau of Mines process for which the Albany facility was designed and built and which is now being evaluated. On the basis of bench scale experiments, Lawrence Berkeley Laboratory (LBL) conceptualized three optional biomass liquefaction processes, one of which has already been tested at Albany, Oregon and found to be chemically and technically feasible. The other two process options are scheduled to be tested at Albany during July 1979. The cost assessment made in this report pertains to the Bureau of Mines process.

In 1973, Dravo Corporation was commissioned by the Bureau of Mines to make a technical and economic feasibility study of biomass liquefaction by a process conceptualized at the Bureau of Mines and to provide the conceptual design of a process development unit (PDU) that would permit the development of the process should the process economics approach economic feasibility. The Dravo study placed the breakeven cost of oil produced at $7.00/bbl exclusive of the cost of raw material.

Two years later, National Science Foundation commissioned Bechtel Corporation to make a technical and economic desirability study of organic waste liquefaction in order to assess the operational justification of the PDU by ERDA. The Bechtel study placed the breakeven cost at $16.13/bbl.

During the same year Battelle Pacific Northwest Laboratories (PNL) made an independent analysis of the process for ERDA as a part of a study designed to explore the best use of the facility. The Battelle study placed the breakeven cost at about $12.00/bbl.

The plant construction was completed during December of 1976 and Bechtel Corporation was contracted to commission the facility, and conduct some experimental runs. The final Bechtel report (June 1978) included a cost analysis of the process which placed the breakeven cost of oil produced at $29.00/bbl, exclusive of the raw material cost, from a plant processing 2,500 TPD dry wood. Although Bechtel strongly recommended the continuation of the development program with the stated belief that the costs can be reduced through development, the high cost caused concern and LBL was asked to review the cost estimates.

Bechtel conceptualized two integrated plants, one for liquefaction, another one for gasification to provide synthesis gas for the liquefaction plant and other heat requirements. Each plant was sized to process 1,250 dry tons daily. The cost estimates made by Bechtel included the items listed below:

1. Annualized direct costs: site and yard, civil/structural, mechanical, piping and instruments, electrical, indirect (80% 9f labor), engineering, and uncertainty (20%).

2. Owner costs: land, startup, AFDC, and miscellaneous (4% of the total construction costs).

3. Operating costs: labor and material for maintenance, operating labor, supervision, administration and overhead, supplies, local taxes and insurance, and utilities.

The cost estimates were thorough and conservative. The totals translate into a wood processing cost of $58.00/dry ton. Bechtel has assumed that 2 bbls oil (a round figure) would be produced per dry ton total wood utilized. The $39.00/bbl figure translates into $78.00/dry ton. Subtracting the cost of wood ($20.00/dry ton), the cost of processing becomes $58.00/dry ton.

An examination of the cost breakdown for the two plants leads to the following figures for processing costs:

1. The cost of liquefying wood is $42.00/dry ton.

2. The cost of gasifying wood is $74.00/dry ton. The average being $58.00/ton.

To translate these operating costs to a breakeven cost for the oil produced, Bechtel made the following assumptions:

1. Fifty lb dry wood will yield 35 lb oil upon liquefaction.

2. Fifty lb dry wood has to be gasified to produce the carbon monoxide needed for liquefaction and process heat requirements.

3. The oil produced has a heating value of 15,000 Btu/lb.

4. The gross thermal efficiency of the process is 66%.

Neither the conceptual design nor the operating costs are in question. However, the assumptions cited above are not acceptable.

Assumption 1 requires an oil yield of 70%! Experimental results obtained at the Bureau of Mines, PNL, and LBL indicate the yield of an oil having the composition assumed by Bechtel cannot exceed 58%. If the Bechtel cost estimate is corrected for this lower yield, the cost of oil would be $49.00/bbl instead of $30.00/bbl. This assumption is over-optimistic.

Assumption 2 is a consequence of the reaction stoichiometry assumed by Bechtel. There are no data in the literature indicating that carbon monoxide consumption is over sevenfold that determined by the Bureau of Mines. This assumption is very pessimistic.

Assumption 3 is baseless. An oil having the composition that Bechtel assumed, i.e., 23% oxygen, is likely to have a heating value of about 13,300 Btu/lb and not 15,000. This assumption is very optimistic.

Assumption 4 may not be regarded as an assumption because it is the consequence of the three preceding assumptions. However, we are not sure of this. This may have been the assumption that dictated or influenced assumptions 2 and/or 3. If corrected for lower oil yield and lower Btu value, the gross thermal efficiency of the process would be 48% instead of 66%. Even a 66% gross thermal efficiency is extremely conservative for a liquefaction process (for coal it is about 80%).

In summary, the chemical and stoichiometric bases of cost estimates are fraught with many inconsistencies and invalid assumptions.

After a careful evaluation of the results of recent research on wood liquefaction at PNL and LBL, and comparing these results with those reported by the Bureau of Mines, we arrived at the chemical bases listed below:

1. Eighty ton dry wood will yield 46.4 ton oil (58% conversion efficiency) upon liquefaction.

2. Twenty ton dry wood will be gasified to provide the carbon monoxide and heat requirements.

3. The oil produced will have a heating value of about 13,500 Btu/lb.

These bases lead to a gross thermal efficiency of about 78%, i.e., do not include the electricity used.

Using the chemical bases listed above and process costs provided by Bechtel, the breakeven cost of oil is as shown below:

$$\frac{(42 + 20)80 + (74 + 20)20}{46.4} \frac{350}{2000} = \$25.80/\text{bbl}.$$

The factor 350/2000 converts barrels to tons.

The chemical bases listed above require a larger liquefaction plant (80 vs. 50) and a smaller gasification plant (20 vs. 50) than those assumed in the Bechtel conceptual design. If we adjust the processing costs for changes in plant sizes (42 becomes 36.5 and 74 becomes 97), the cost increases by only $1.00. However, we cannot take the $97.00 figure seriously.

In summary, had Bechtel interpreted the reaction chemistry properly, they would have arrived at a breakeven cost of about $26.00/bbl and an oil yield 33% higher than they projected.

In terms of heating value of the oil produced, the latest Bechtel cost estimate places the breakeven cost of oil at $6.13/MM Btu, exclusive of the material cost ($8.25/MM Btu including the cost of the wood). The cost estimate revised by LBL places the corresponding costs at $3.86 and $5.46/MM Btu, respectively. In the Bechtel report the cost of oil produced from coal by the SRC II process is placed between $3.00 and $4.00/MM Btu including the cost of coal. If we assign $1.00/MM Btu for the cost of the coal and 80% for thermal efficiency, the cost of the SRC. II oil would be between $1.75 and $2.75/MM Btu. If the latter figures are translated into plants processing 3,000 TPD coal instead of 30,000 TPD, the cost of processing would nearly double, i.e., $3.50 to $5.50/MM Btu. Considering the fact that biomass is much more reactive than coal, liquefies at much lower temperatures (680°F vs. 860°F), does not require pure hydrogen and contains no elaborate cleanup system in the liquefaction process because it contains little or no sulfur, nitrogen, and ash, the cost figure revised in this report is very conservative. In its conceptual design Bechtel incorporated an expensive product oil recovery system and a very expensive gas cleanup system without a valid data base.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720