Technical and Economic Evaluation Wood to Ethanol Process

A report prepared for Solar Energy Research Institute

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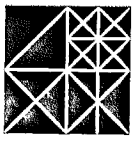

CHEM SYSTEMS

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I. SUMMARY

A. Introduction

The interest in using ethanol as an octane enhancer, fuel extender or neat liquid fuel has grown over the years. Recently there has been increased concern over the worsening situation of the environment, the national debt and the depletion of U.S. petroleum resources. The use of ethanol as a neat fuel can dramatically impact these problems and go a long way towards their resolution.

Today, 50 percent of U.S. petroleum consumption comes from oil imports. Not only do these oil imports make a serious contribution to the balance of payments deficit (between 30-40 percent) they also affect the strategic independence of U.S. government policy. The very fact that half the transportation fuels of the country are imported puts the country in very vulnerable position. In addition to the strategic aspect, the economic impact highlighted by the recent OPEC decision to raise oil prices by 15 percent will only cause the U.S. balance of payments deficit to increase.

Furthermore, there is increased concern over air quality standards in the nation stemming from the fact that half of all Americans live in areas that fail to meet Federal clean air standards. The combustion of conventional hydrocarbon transportation fuels is a major cause of the nation's ground level air pollution. It also contributes about 27 percent of the CO_2 released into the atmosphere in the United States each year. It is believed by many experts that the accumulation of CO_2 and other gases will lead to the warming of the earth thus having severe climatic, environmental and socio-economic consequences.

Using ethanol as a transportation fuel on a widespread basis will significantly improve the U.S. balance of payments by reducing oil imports and reducing the smog levels in cities because pure ethanol has a high combustion efficiency and together with ETBE, an oxygenated fuel additive, will reduce carbon monoxide emissions.

The Solar Energy Research Institute (SERI) has proposed the use of lignocellulosic materials (such as wood) to produce ethanol because of their low cost and their huge potential availability. Using a renewable feedstock source such as wood is a long term solution to the problem of dwindling petroleum reserves. It can also be argued that by using ethanol from lignocellulose there will be no net contribution of CO_2 to the atmosphere. This is because the CO_2 released during ethanol production and combustion will be absorbed during the growth of new biomass materials replacing those utilized during production.

Until now, the barrier to widespread ethanol use has been the lack of appropriate technology that would reduce the cost of ethanol to a reasonable level. Over the last five years, SERI has made significant improvements in the ethanol from lignocellulosic wood process and has developed a new process that incorporates these recent developments. The current process is a snapshot in time of the development work done to date.

As part of its ongoing program, SERI has developed a process design for large scale plant, based primarily on experimental data, to determine the economic feasibility of such a plant.

Accordingly, SERI has retained Chem Systems to provide an independent technical and economic evaluation of its plant design. Chem Systems' analysis is based on its extensive experience with commercial alcohol plants as well as familiarity with earlier work and ongoing developments in biomass to ethanol technology.

In addition, Chem Systems' awareness of the technology allowed for discussions with appropriate equipment manufacturers regarding equipment feasibility and current costs. A review of each process section of the SERI plant design is discussed below along with Chem Systems' detailed economic analysis.

B. Conclusions

Following the review of SERI's process design Chem Systems has concluded the following:

- The overall process concept appears to feasible and is generally supported by SERI and related laboratory data as well reasonable engineering judgement.

- The next step in the process development and scale-up program needs to be the construction of a pilot scale plant with all process steps integrated to verify data assumptions especially for a commercial scale plant.

- Vendor laboratory experiments are necessary to verify large scale equipment feasibility (e.g., disc refiner, impregnator, prehydrolysis reactor, etc.).

- Based on the current design, the economics for the production of the ethanol are much improved over previous (mid-1980s) designs. At the base case wood feed rate (1920 short tpd) and base case yield (68 percent), the price of ethanol is $1.27 per gallon including 20 percent capital charges.

- Initial laboratory results make it appear that improved overall yields are feasible. Many possibilities for yield improvements have been proposed. Assuming that the necessary research and development efforts will continue and that these yield improvements are proven, it could significantly reduce the cost of ethanol production from wood. For example, if carbohydrate yield can approach 90 percent, at this point the price of ethanol can be reduced to 96.5 cents per gallon at the 1920 tpd wood feed case. This assumes constant investment and wood cost, including 20 percent capital charges.

- If an analysis is made for a large plant (5 times the base case wood feed capacity) then the ethanol price is estimated to be 102.0 cents per gallon. If one

assumes the same yield improvements as above, then the ethanol price is reduced to 78.1 cents per gallon. Both values include 20 percent capital charges.

- The effect of wood cost on ethanol price for various cases is illustrated in Figure I-B-1. Using the case of a large plant at 90 percent yield and a wood cost of $34/dry ton, which according to SERI is the production goal of Oak Ridge National Laboratory for energy crops, the ethanol price is reduced to 71.4 cents per gallon.

- Figure I-B-2 shows the effect of improved yield on ethanol price for the base case wood feed rate and the large plant including a capital investment sensitivity. With wood at $42/dry ton and yield at 90 percent, assuming a large plant with 15 percent investment reduction, the ethanol price would be 73.2 cents per gallon.

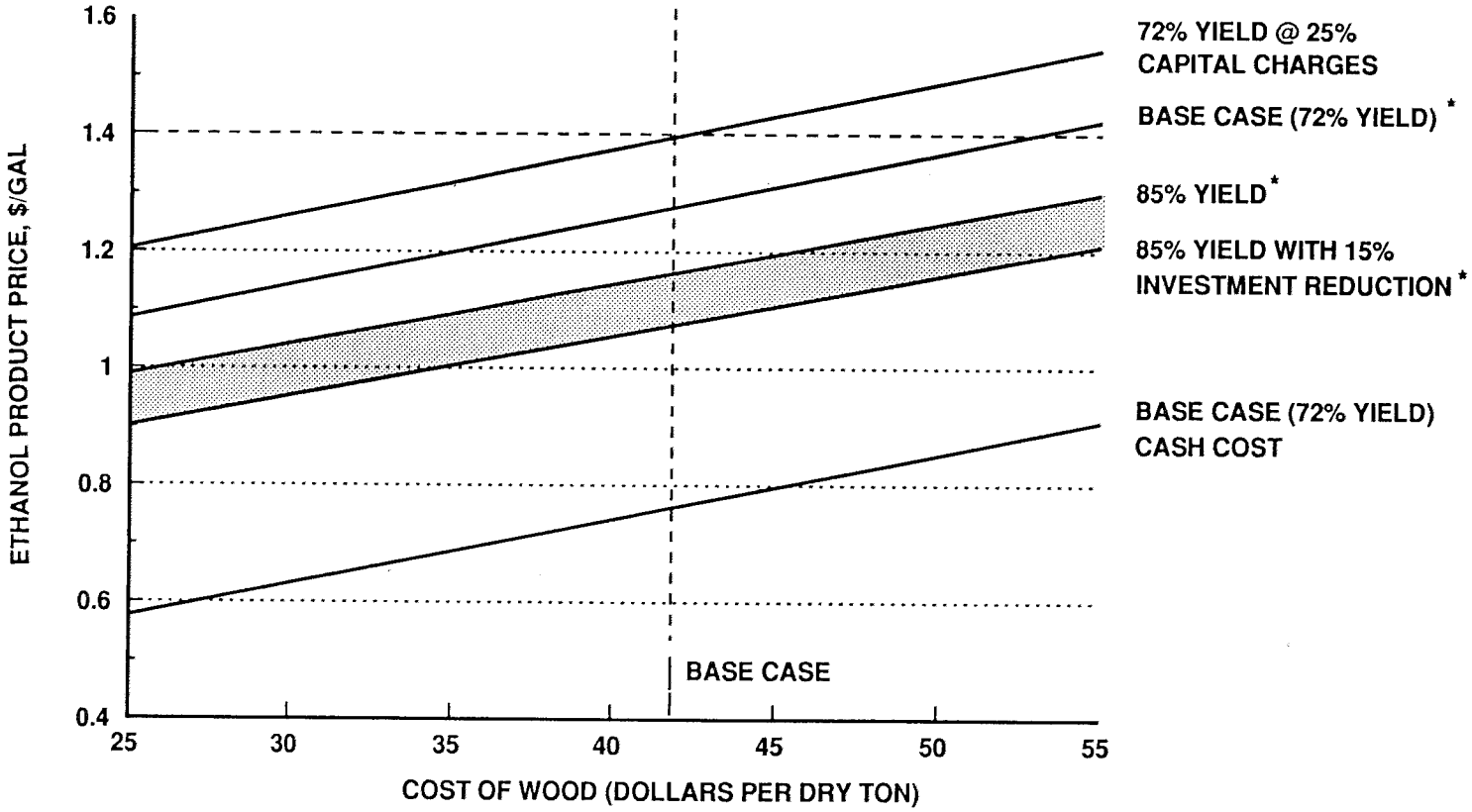
- If, in addition to the above improvements (yield, plant size, capital reduction and feedstock cost) efforts are made to reduce power consumption, optimize other aspects of the process, and increase the carbohydrate content of the feedstock, one could expect the ethanol price to be reduced even further.

They didn't determine the effect of yield on capital charges? This is crude analysis

Doesn't say anything

FIGURE I-B-1

EFFECT OF WOOD COST ON ETHANOL PRODUCT PRICE AT VARYING CONDITIONS (USGC-4Q 1987) 160,000 LB/HR DRY WOOD FEED



* INCLUDES 20% CAPITAL CHARGES

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FIGURE I-B-2

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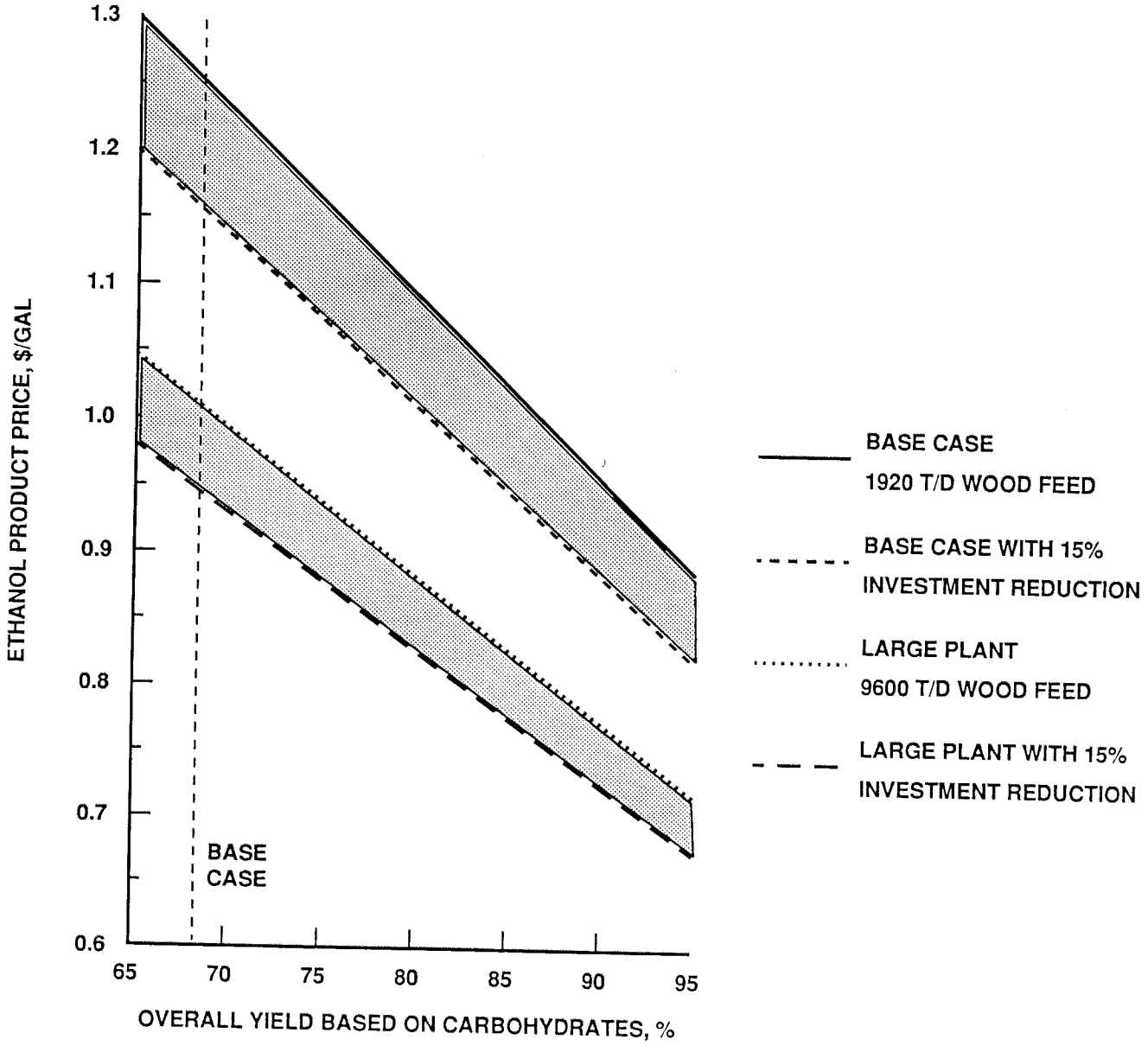
EFFECT OF OVERALL YIELD ON ETHANOL PRODUCT PRICE AT VARYING CONDITIONS (USGC-4Q 1987, $42/DRY TON OF WOOD) 20% CAPITAL CHARGES



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