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Project Summary

Environmental and Economic Comparison of Advanced Processes for Conversion of Coal and Biomass into Clean Energy

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Biomass and coal conversion into clean energy is compared on an economic and environmental basis in three regional scenarios: (1) electric power from direct combustion of wood versus conventional coal combustion in the south central U.S., (2) synthetic pipeline gas from anaerobic digestion of wheat straw and manure versus high-Btu gasification of coal (HYGAS®) in the midwest, and (3) synthetic fuel oil from wood liquefaction versus coal liquefaction (H-Coal®) in the northeast. Conceptual commercial-scale plants are described. Capital and operating costs are presented for each of the six plants, and the biomass versus coal economics are compared. General environmental impacts of biomass and coal resource collection are assessed and compared in the scenario contexts. Plant environmental emissions were estimated where possible, and relative environmental impacts are discussed. Conclusions are given about the conversion concepts which seem the more promising routes to clean energy, and areas needing further study are identified.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction and Summary

This report presents the results of three environmental and economic comparisons of biomass and coal conversion into clean energy. The study was initiated to help develop priorities for assessing conversion technologies capable of producing clean energy from biomass and coal resources. Electric power, synthetic pipeline gas (SPG), and synthetic fuel oil were chosen as representative clean energy products which can be produced from both biomass and coal. Representative coal conversion technologies were to serve as base cases to which biomass conversion technologies were to be compared. Three regional scenarios, each with a biomass-coal plant pair, were selected from a number of possible candidates. Conceptual designs of commercial-scale plants were compared in these regional scenarios:

- A 50 MWe wood-fired power plant versus a 500 MWe coal-fired power plant in the south central U.S.

- A 7 MM SCFD (6.7 billion Btu/day) biogas plant (anaerobic digestion of wheat straw and manure) versus a 274 MM SCFD (250 billion Btu/ day) high-Btu gasification plant (steam-oxygen HYGAS®) in the midwest.

- A 1764 BPD wood-oil liquefaction plant versus a 66,856 BPD coal liquefaction plant (H-Coal®) in the northeast.

In the scenarios, biomass residue is collected locally from forestland (chipped forest residue), from farmland (wheat straw), and from feedlots (cattle manure). Coal is strip-mined in the first two scenarios and deep-mined in the third. As plant feedstocks, the biomass materials have lower sulfur and ash contents, lower heating values, and lower bulk densities (except manure) than coal.

The plant capacities chosen are representative of commercial scales being proposed for biomass residue and coal conversion. The disparity in biomass-coal plant capacities is almost inherent; hence, the higher capacity coal conversion plants have a distinct economy-of-scale advantage. The direct combustion and the liquefaction processes for biomass conversion are similar to their coal conversion counterparts. A biological conversion process, anaerobic digestion, is compared with a thermal conversion process, steam-oxygen gasification. Estimated plant thermal efficiencies (based on net product output) are compared below:

	Power	SPG	Fuel Oil
Biomass Conversion	21.6%	31.9%	42.1%
Coal Conversion	35.1%	69.1%	65.5%

It is apparent that these three biomass processes have relatively low conversion efficiencies. In the wood conversion processes, the feedstock properties are a disadvantage—low heating values (high moisture and oxygen contents) and low bulk densities mean that more material must be handled per unit of energy content than for coal. Energy consumption and losses are high. The anaerobic digestion process suffers from a low methane production rate and incomplete biomass conversion. This process does yield a digester residue that may be a valuable byproduct if it can be used as an animal feed.

Improvements in conversion efficiencies are important if these particular biomass processes are to be competitive with the coal processes. Worthwhile ideas for improving feedstock properties (preprocessing of biomass) should be given attention, as such ideas could lead to increased process conversion efficiencies.

Economic comparisons of the biomass and coal conversion concepts are presented in Figures 1, 2, and 3 for utility and private financial methods, using the ERDA-AGA Cost Guidelines. These figures illustrate that the biomass-derived energy products are about 50 percent (power) to 300 percent (SPG) more expensive to produce than the corresponding coal-derived products from much larger conversion plants. Synthetic fuel oil from wood liquefaction is about 2.5 times more costly than oil from the H-Coal® process. In these scenarios at least, the economic disparities result from a combination of less desirable feedstock properties, smaller biomass plant capacities, and lower process conversion efficiencies. In many economic situations, both direct-fired plants would produce electric power more cheaply than it could be produced in conventional power plants firing any of the four synthetic fuels.

Figure 1 shows that the cost of electricity from a wood-fired plant is not competitive with that from a large coal-fired generating station if wood and coal prices are about the same on a $/MM Btu basis. For a high coal cost/low wood cost scenario, a small wood-fired plant could be economic as evidenced by existing power boilers burning wood wastes in many pulp and paper mills in the northeast.

The biomass-derived synthetic gas and oil are just not close to being competitive with the coal derived synthetic fuels, as Figures 2 and 3 illustrate.

Pollution control costs will be high for the large coal conversion plants, probably 5 to 10 percent of the total plant capital costs. These large expenditures, however, do not shift the economic advantage to biomass conversion, as the foregoing figures show.

Environmental impacts of plant construction and operation were considered separately from impacts of resource collection. Resources consumed by the plants and emissions of conventional pollutants were esti-

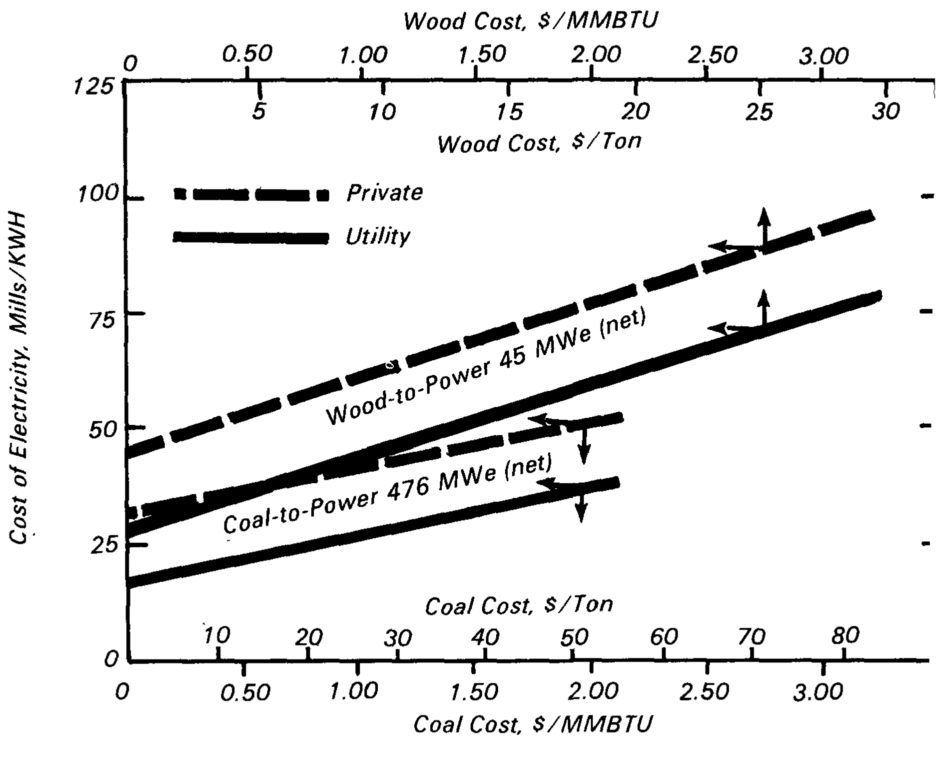


Figure 1. *Economic comparisons of wood and coal to power.*

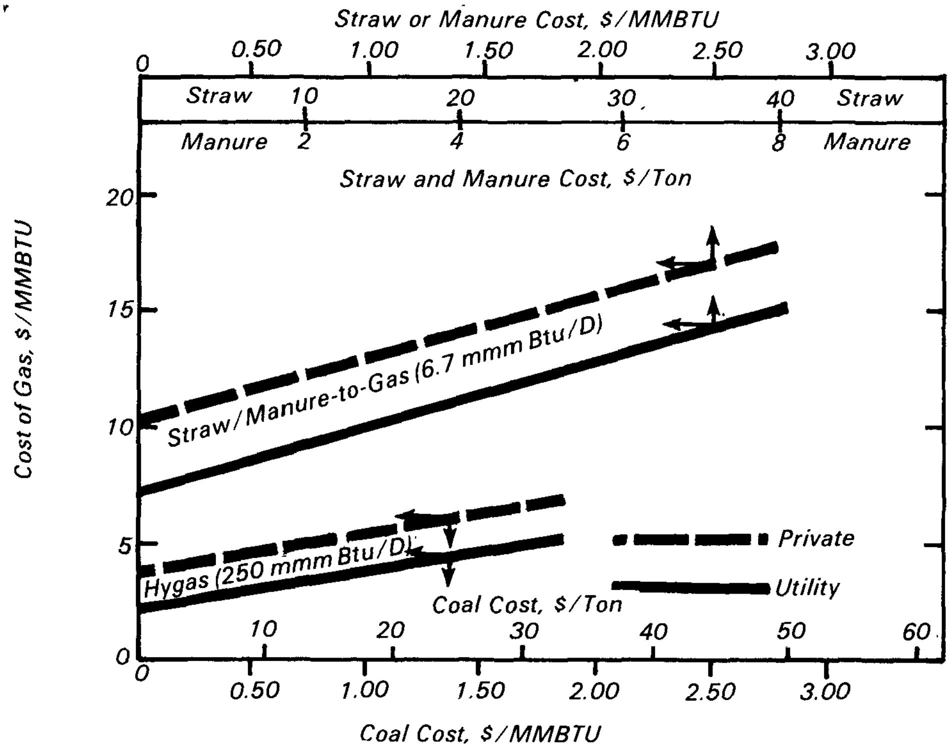
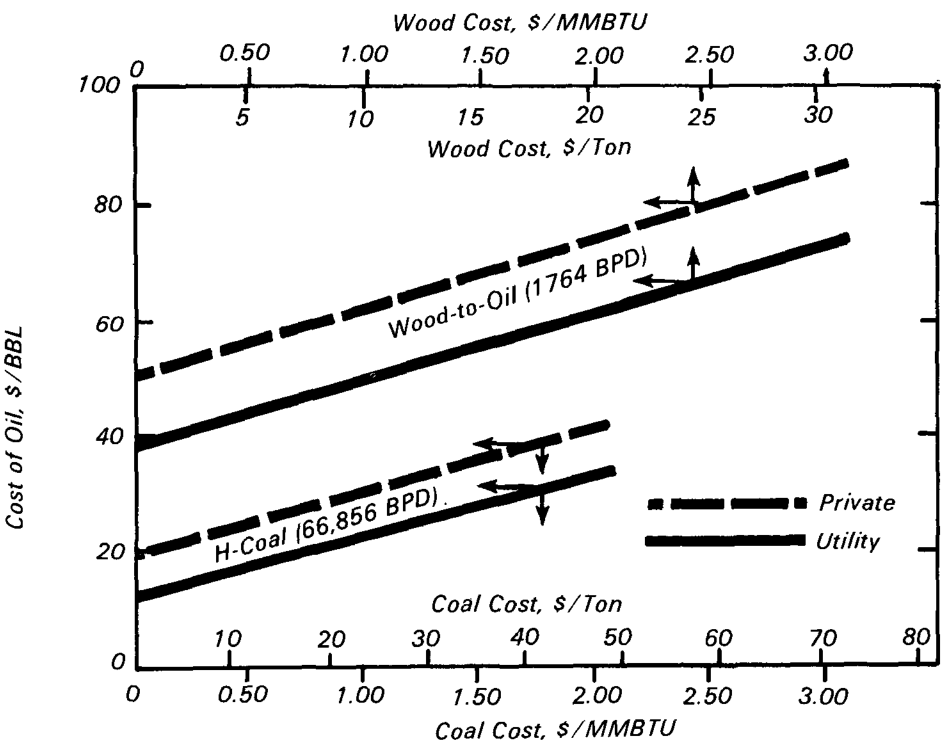


Figure 2. *Economic comparison of straw/manure and coal to SPG.*



igure 3. *Economic comparison of wood and coal to fuel oil.*

mated for each biomass and coal conversion plant, and then comparisons were made on a relative (energy output) basis. None of the three biomass conversion plants appears to have an overall environmental advantage over its coal conversion plant counterpart on the relative comparison basis. This environmental standoff is partly due to the extensive pollution controls used in the coal conversion plants which reduce conventional pollutant emissions to about the same overall levels as those from biomass conversion. The potential for generation and release of toxic or hazardous substances (priority pollutants) cannot be assessed adequately at this time because much of the information has not been developed yet.

Biomass residue collection should entail considerably fewer adverse consequences on the environment than deep-mining or strip-mining coal resources. Forest residue or wheat straw collection activities will affect much more land area than coal mining, but little environmental damage should occur if collection activities are managed properly. Unlike coal, the biomass resources are renewable and some environmental credit is deserved for their utilization. If the plant impacts and the collection impacts are considered together, biomass conversion in these scenarios may be preferable from an overall environmental impact viewpoint.

Major conclusions reached from these three biomass-coal comparisons are:

- The coal conversion plants have considerably higher thermal efficiencies than their biomass counterparts.
- The biomass residues have the advantage of low sulfur and ash contents, but their low bulk densities and low energy contents are distinct disadvantages with respect to coal as a plant feedstock.
- Biomass-derived electric power, SPG, and synthetic fuel oil are more expensive to produce than the corresponding coal-derived clean energy products from the large-scale conversion plants.
- Pollution control costs for the conversion plants are high, but have little impact on the relative economics of coal versus biomass conversion.

- The anaerobic digestion and wood liquefaction processes are not promising routes to low cost synthetic fuels in view of the superior HYGAS® and H-Coal® process economics.

- In certain localities, power generation from wood may be economically competitive with power generation from coal if the coal/wood price ratio is high enough.

- The small biomass conversion plants do not appear to have an overall environmental advantage over their coal conversion plant counterparts on a relative basis; however, more and better quantitative emission data need to be developed in order to better assess the probable impacts of both the biomass and coal conversion technologies.

- Managed properly, biomass residue collection should have less severe environmental impacts than coal mining, even though much more land area would be affected by residue collection.

From these comparisons, it is evident that the coal conversion processes are more likely to become major routes to clean fuels than these biomass conversion processes, primarily because of better economics. Other biomass feedstock/conversion process/energy product scenarios could prove to be more favorable in this type of biomass-coal comparison. A combination of three factors is desirable:

- a relatively low-priced biomass feed material,

- a process that has a relatively high conversion efficiency, and

- a higher-priced product than fuel oil or fuel gas.

Steam and power production from low-cost residues and co-firing of wood and fossil fuels appear to be promising ways of using biomass resources in a number of localities in the U.S. Biomass conversion into more valuable products (chemicals, fertilizers, animal feeds) should also be a promising area of study.

Both biomass and coal conversion would have adverse environmental impacts, and there is continuing need to better define the likely impacts of resource collection, conversion, and product usage.

The coal conversion plants need to be large in order to produce competitively priced clean energy. If the coal conversion plants could be scaled-down to the same low capacities as their biomass plant counterparts, it is likely that the coal-derived energy products would be more costly than the respective biomass-derived products. In some localized scenarios, biomass conversion could have an economic advantage over coal conversion on a small scale.

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The complete report, entitled "Environmental and Economic Comparison of Advanced Processes for Conversion of Coal and Biomass into Clean Energy," (Order No. PB 81-234 239; Cost: $29.00, subject to change) will be available only from:
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