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# SYNTHETIC LIQUID FUELS DEVELOPMENT:

## ASSESSMENT OF CRITICAL FACTORS

## VOLUME IV ENERGY/ECONOMIC COMPARISON OF COAL-BASED AUTOMOTIVE ENERGY SUPPLY SYSTEMS

*Prepared for:*

TRANSPORTATION ENERGY CONSERVATION DIVISION
OFFICE OF CONSERVATION
U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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SYNTHETIC LIQUID FUELS DEVELOPMENT
ASSESSMENT OF CRITICAL FACTORS — VOLUME IV

ENERGY/ECONOMIC COMPARISON OF COAL-BASED AUTOMOTIVE ENERGY SUPPLY SYSTEMS

# EXECUTIVE SUMMARY

**Is energy analysis needed to select energy supply choices that conserve resources?**

As the nation strives to reduce its dependence on foreign petroleum sources, technologies for converting coal and oil shale to liquid and gaseous fuels become increasingly important. These new synfuel systems must be analyzed for their economic and technical feasibility, environmental impact, and socioeconomic effects. But an additional factor — the analysis of energy resources required to produce and deliver useful forms of energy — may also prove important because the nation must choose judiciously among alternative supply options to conserve resources.

**Traditional economists say "No." Energy analysts say "Yes."**

The relative merits of energy analysis versus traditional economic analysis have been debated at length in recent years. Some economists assert that energy analysis adds no new information to that already contained in economic analysis. Some energy analysts, on the other hand, claim that the explicit consideration of energy flows is necessary for a complete understanding of the implications of energy supply and use. Furthermore, these energy analysts argue that the market has not been able to serve its appropriate role as an allocator of energy resources because of government regulation and the influence of the OPEC cartel. Therefore, so the argument goes, energy analysis provides a valuable service in illuminating the effect that the many energy supply and conservation choices facing the nation will have on energy resource consumption.

**One way to find out is to compare the two approaches**

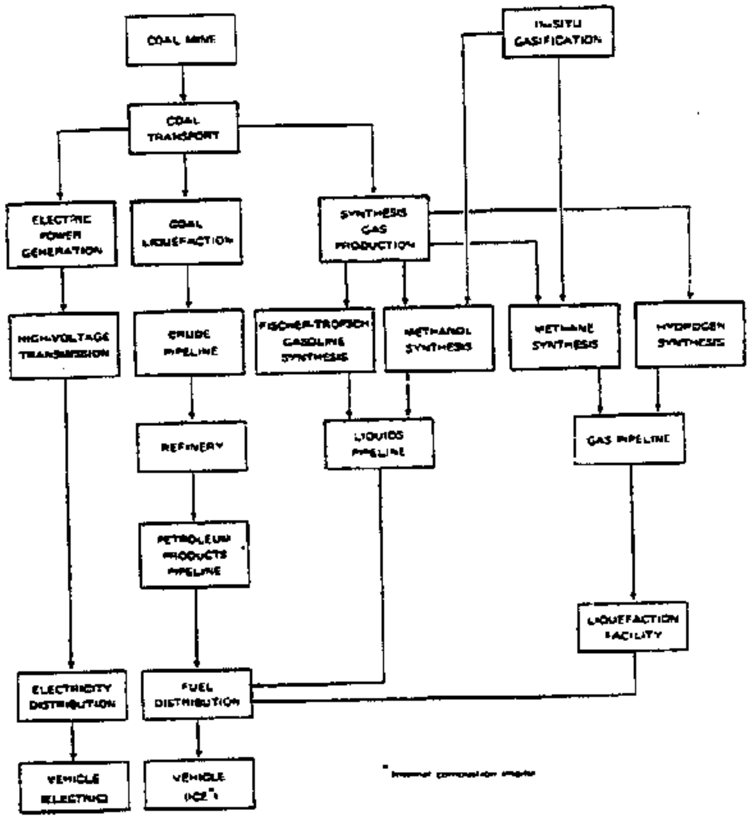
The objective of the study reported here was to compare the choices that result from a traditional economic analysis of energy supply systems with those obtained from an energy analysis to see if similar or divergent options emerge. This issue has particular significance to those who must make decisions in the field of energy conservation because it is desirable that those options that are the most energy conservative also be low cost. Energy conservative but high cost options present difficult tradeoffs.

**Six coal-based automotive energy forms were analyzed for cost and energy consumption.**

Our comparison of options was focused on energy supply systems that could provide automotive energy. Six coal-based energy forms (Figure I) — gasoline refined from synthetic crude oil (syncrude), methanol, gasoline produced by Fischer-Tropsch synthesis, liquid hydrogen, liquid methane, and electricity — were analyzed in terms of cost and energy consumption.

**The six were:**

- **Syncrude/gasoline**
- **Methanol**
- **Fischer-Tropsch gasoline**
- **Liquid hydrogen**
- **Liquid methane**
- **Electricity**




1 COAL-BASED AUTOMOTIVE ENERGY SUPPLY SYSTEMS

Using only coal-based energy forms promoted consistency in the comparison of options. The five synthetic liquid fuels could be used in conventional or modified internal combustion engines, while electricity was assumed for use in powering electric cars that employ an advanced battery such as lithium-sulfur. Included in the energy supply systems were coal mining, coal transport, coal conversion, product transport, refining (for syncrude only), and product distribution.

**A range of costs for each energy supply system was determined**

The cost analysis was based on the Coal Resource Depletion Model presented in a related study.* The output of this model provides coal conversion costs for plants in various regions of the country. Additional costs are assigned to product transport and distribution for all possible market areas for each conversion plant location. Thus, a range of costs representing the effects of varying coal types, conversion plant locations, and market locations was determined for each energy supply option. The percentage differences between minimum and maximum costs of delivered energy for the six options, as influenced by the factors cited above, are as follows: syncrude/gasoline, 24%; Fischer-Tropsch gasoline, 9%; methanol, 10%; liquid hydrogen, 16%; liquid methane, 14%; and electricity, 43%.

*E. M. Dickson, et al., "Synthetic Liquid Fuels Development: Assessment of Critical Factors — Volume III, Regionalized Industry, Social Impact, Coal Resource Depletion," Division of Transportation Energy Conservation, U.S. Energy Research and Development Administration, ERDA 76-129/3 (1977).

**Results showed that syncrude/gasoline is the cheapest option**

The results of the cost analysis showed that syncrude/gasoline is the least costly option, followed by methanol, methane, Fischer-Tropsch gasoline, hydrogen, and electricity. In addition, the costs of methane and methanol produced through in-situ gasification of coal were analyzed and found to be lower than all options except syncrude/gasoline.

**But, for propelling an automobile, electricity is cheapest**

When the efficiency of converting various fuels to motive power in an automobile is considered, the relative cost picture changes. Using nominal internal combustion engine efficiencies (subcompact car) for the five liquid fuels, and the electricity consumption for an advanced electric car, we found that electricity is the lowest cost option on a cents per mile basis, followed by syncrude/gasoline, methanol, methane, hydrogen, and Fischer-Tropsch gasoline.*

**Energy consumed to produce each energy form was then calculated**

Energy consumption of the six energy supply systems was analyzed in a manner analogous to the cost analysis. Energy accounting techniques described in our previous work† were used to assign an ancillary energy requirement to each component in the energy supply systems. The energy "cost" of each component was then computed as the sum of the ancillary energy requirement and the energy loss from each component, as determined by its overall energy efficiency. Using the same model approach employed in the cost calculations, the component energy consumption figures were added to obtain the total energy consumed in delivering $10^6$ Btu of each energy form. As in the cost calculations, the variations in energy consumption among coal types, conversion plant locations, and market locations were determined.

**Results showed that Fischer-Tropsch gasoline consumes the most energy, with electricity next highest, and syncrude/gasoline the lowest**

The results of the energy analysis showed that the energy consumed (converted to waste heat or nonfuel products) in delivering $10^6$ Btu of automotive fuel or electricity can range from a low of $0.8 \times 10^6$ Btu for syncrude/gasoline to a high of $2.5 \times 10^6$ Btu for Fischer-Tropsch gasoline. Between these two extremes lie methane, methanol, hydrogen, and electricity — in order of increasing energy consumption. Methane and methanol derived from in-situ gasification of coal are slightly higher than syncrude/gasoline.

**But, again, electricity is lowest in energy use when automotive efficiency is considered**

As in the cost analysis, the consideration of automotive energy efficiency results in a different picture for the relative attractiveness of each option in terms of energy consumption. Due to the high expected efficiency of advanced batteries, the electricity option has the lowest total energy requirement — 5000 Btu/mi. Fischer-Tropsch gasoline has by far the highest at 14,300 Btu/mi. Methanol, methane, and hydrogen are in the 9000 to 10,000 Btu/mi range, while syncrude/gasoline is 7500 Btu/mi — 50% higher than electricity.

**High-cost automotive energy system components are also high energy users**

In comparing the cost and energy consumption figures for the various automotive energy options, certain parallels are evident. Those system components that have the highest costs also require high

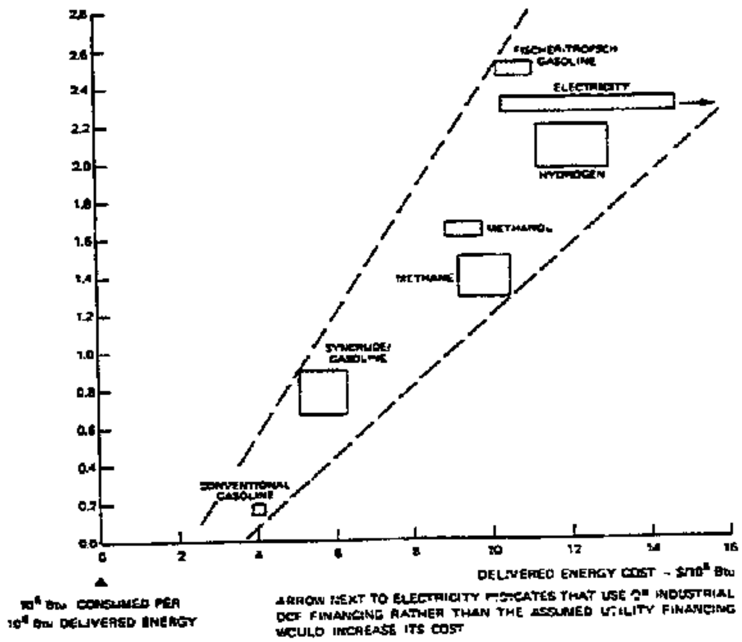
*To account for changes resulting from rapidly escalating costs, as well as errors due to the speculative nature of many of the cost estimates, a sensitivity analysis is given for each energy supply option (Appendix C).

†E. M. Dickson, et al., "Synthetic Liquid Fuels Development: Assessment of Critical Factors," U.S. Energy Research and Development Administration, ERDA 76-129/2 (1976).

levels of energy consumption. This is generally due to the severity of the processing conditions required to convert one energy form (e.g., coal) to another (e.g., methanol). These conditions require the use of capital-intensive equipment as well as the consumption of large amounts of energy. For some components that have relatively high costs but low energy requirements (e.g., fuel distribution), the costs are due to the many handling and transfer requirements, which are often labor-intensive and can also involve expensive equipment. However, such handling and transfer steps do not consume large amounts of energy.

**These results are peculiar to capital- and energy-intensive systems**

Overall, the capital- and energy-intensive energy conversion processes dominate the systems examined. Consequently, a comparison of cost with energy consumption for all of the energy forms considered showed a definite trend — increasing costs imply increasing energy consumption (Figure II).




II ENERGY CONSUMPTION VS COST FOR AUTOMOTIVE ENERGY SUPPLY SYSTEMS

Thus, decision makers concerned with promoting energy conservative supply options can feel confident that they are also promoting the least costly energy conversion options.

**Less energy- and capital-intensive energy supply systems may show a different trend**

However, we caution against extrapolating these results to other systems because systems that do not have the same kinds of capital- and energy-intensive components as those considered here may exhibit different trends.

## PREFACE

The analysis reported in this volume is a continuation of an SRI study concerned with the impacts that would attend the deployment of a large-scale synthetic fuels industry. The study was begun under the sponsorship of the Environmental Protection Agency and continued under the sponsorship of the Energy Research and Development Administration.* Throughout, the lead project officer, first at EPA, then at ERDA, has been Mr. F. Jerome Hinkle. The SRI project leader has been Dr. Edward M. Dickson.

The study team responsible for this volume consisted of Drs. Robert V. Steele and Kishandutt J. Sharma.

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*The first two volumes in this series were originally published by EPA under the title "Impacts of Synthetic Liquid Fuel Development--Automotive Market," (EPA-600/7-76-004 a,b). ERDA reissued the same report under the title, "Synthetic Liquid Fuels Development: Assessment of Critical Factors," (ERDA 76-129/1 and 76-129/2).

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