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Barriers to the Utilization of Synthetic Fuels for Transportation

Harry W. Parker and Matthew J. Reilly
The Engineering Societies Commision on Energy, Inc.

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NOTICE

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FOREWORD

Drs. Harry W. Parker and Matthew J. Reilly were Chemical Engineers
in Residence at the Engineering Societies Commission on Energy,
Inc., when this project was commissioned in July 1981. Subsequent-
ly, Dr. Parker returned to his permanent organization, Texas Tech
University in Lubbock, Texas, and Dr. Reilly became associated
with Environmental Research & Technology, Inc. in Washington, D.C.

ESCOE wishes to acknowledge the individual efforts of Dr. Lewis
D. Conta and Dr. Serge Gratch who, at the request of the American
Society of Mechanical Engineers, kindly agreed to review and to
comment on this report in the draft form.

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

The dependence of the United States upon imported petroleum has created a situation which affects virtually every element of the Nation's economy and has important implications for national security. While dependence on imports has lessened in the past two years, this is due in part to underutilization of the Nation's factories and other productive facilities. Higher import levels would recur if domestic consumption returns to historic highs, considering domestic production is operating at close to full capacity. While increasing industrial activity will cause increased demand for fuels, improved efficiencies recently obtained by the transportation and industrial sectors should offset the increased demand somewhat. However, full demand could reach previous historic highs. Thus, the Nation continues to require technological options for shifting energy reliance from foreign oil to domestic supplies of coal, oil shale and other energy resources.

The transportation sector accounts for approximately 25 percent of the Nation's total energy consumption. Almost all energy directly consumed by nonstationary sources in this sector is in the form of liquid, petroleum-based fuels. The only significant exceptions are the electrified railway systems which are more dependent on oil-fired electric generation than any other source.

Many of the synthetic fuel processes nearing the commercialization phase are capable of producing, directly or indirectly, liquid products suitable for use as transportation fuels. Therefore, there is a need to assess the potential of these processes to provide increments of transportation fuels and to identify the barriers to their utilization in order to reduce dependence on imports.

Since its establishment in 1976, the Engineering Societies Commission on Energy, Inc. (ESCOE) has examined many aspects of this question. Most recently, in Synthetic Fuels Summary (March 1981), ESCOE addressed the problem of the entry of synthetic fuels into the fuels market and found that with end-use consumption in the transportation sector approximately equal to the level of imports, this sector held the key to future penetration of the liquid fuels market. In fact, ESCOE projections of the composition of the energy market in 1990, based on Federal law and policies as of early 1980, indicate that transportation sector consumption will increase to nearly 75 percent of total marketed production of liquid fuels. With this background and experience, at the request of the National Aeronautics and Space Administration, Lewis Research Center, in conjunction with the Department of Energy, Office of Vehicle and Engine Research and Development, ESCOE undertook an assignment to identify and examine the barriers to the use of transportation synthetic fuels and approaches to overcoming them.

For ESCOE, this report represents the next step in assessing various current technical and economic issues involved in bringing domestically produced synthetic fuels into the marketplace.

In 1978 a Workshop co-sponsored by the Department of Energy and the Southwest Research Institute was held in San Antonio, Texas to identify the technical barriers to utilization of transportation fuels produced from synthetic fuels processes. Out of that Workshop emerged a consensus that there existed constraints other than those associated with technical uncertainties or unresolved questions of the chemistry of producing these fuels. These barriers which are of a financial, institutional and political nature, have been the subject of considerable discussion within the Federal government and among engine manufacturers and petroleum refiners since 1978. Passage of the Energy Security Act and the commitment of Federal support for three large synfuels projects have been pivotal events which stimulated continued interest in this question.

The purpose of this report is to identify the current issues involved in utilizing synthetic fuels for transportation, the barriers to their utilization and the approaches needed to resolve these constraints. ESCOE conducted a telephone survey of a number of individuals in government, the petroleum industry, engine manufacturers and fleet operators to gather the information upon which the bulk of this report is based. Thus, the report reflects the views and opinions primarily of individuals and organizations actively involved in process development as well as various aspects of the synfuels/engine interface problem. Those contributing to the report are listed in the Appendix.

The authors gratefully acknowledge and appreciate the contributions made by these individuals. The authors have chosen to minimize direct citations, however, because the expedited schedule for this study necessitated primary emphasis upon oral communications. As a result, there was insufficient time to give the information sources an opportunity to review and to comment on the draft report.

2.0 BACKGROUND

2.1 ENGINES FOR TRANSPORTATION APPLICATIONS

A wide range of engine sizes, designs, and configurations are in common use in the United States for transportation applications. In fact, engine variability is as great as the variability in applications, ranging over automobiles and other light duty vehicles; heavy duty trucks, construction equipment, and earth-moving vehicles; railroad locomotives, aircraft, ships, barges and marine applications. These many different engines and applications, however, have several things in common. For most of the applications there are only a few fundamentally different engine types: the spark ignition (SI) internal combustion (Otto cycle), the diesel (Diesel cycle), and the gas turbine (Brayton cycle). Each type is the end product of decades of engine testing, development and refinement. The fuels used are almost exclusively liquid products refined from petroleum.

The combination of today's transportation engines and today's transportation fuels represents over 80 years of experience and advancement. Over that period, engine manufacturing and petroleum refining have evolved from very small scale activities into two of the Nation's major industries. An enormous investment has been made in the stock of engines, petroleum refineries, and engine manufacturing facilities. In addition to these capital assets, the engine and the fuels industries possess enormous technological know-how. This knowledge base, which is partly theoretical and partly empirical, is adequate to answer most technical or economic questions about current engines with a high degree of confidence.

Some, but not all, of the existing capital investment and fundamental knowledge base can be applied to the development of new or modified engines, including engines for use with synfuels. The empirical portion of the knowledge base can be extrapolated only with caution to different fuels and engines. The vast majority of automotive and fuels experts stress that the development of new or modified engines for use with synfuels must include significant engine testing and long-term full-scale demonstrations.

Several types of engines have been suggested for use with synfuels. They include:

- Spark ignition (SI) engines, adapted for methanol or synfuels as fuel

- Stratified charge, spark ignition (SI) engines adapted for methanol or a variety of synfuels

- Diesel engines, adapted for synfuels or methanol

- Stirling engines (external combustion)

3

- Rankine (steam) engines (external combustion)
- Gas turbines

Although some of these engines can be considered new to current transportation applications, most of them are old as measured by the date of their invention. At one time, the steam engine enjoyed widespread use in transportation, but was displaced by the diesel and SI engines because of lower operating costs and greater fuel efficiency. There is little or no continuing development of steam engines for transportation usage primarily because of their relatively low thermal efficiency. The Stirling engine often has been proposed for land transportation, but has not yet achieved a lasting position. The ceramic gas turbine and Stirling engine have engineering design and materials problems for which solutions allowing reliable use in transportation vehicles have not been demonstrated. Although gas turbines, Stirling engines, and Rankine engines are relatively tolerant of certain fuel properties, such as octane or cetane ratings, their uses in ground transportation do not appear likely to grow much in the near future. Gas turbines are expected to continue to be used almost exclusively in aircraft applications. Consequently, the balance of this report will focus on methanol, synfuels for the SI engine, the stratified charge SI engine, and the diesel engine.

The stratified charge engine has a good potential for commercial acceptance. Development of this engine began over 40 years ago with the goal of achieving both improved efficiency and engine compactness without requiring a high octane fuel. When crude oil was cheap, the low octane fuel requirements for the stratified charge engine were not a sufficient advantage to offset the complexity of the stratified charge engine technology. Recent increases in the price of petroleum and uncertainties about its availability are causing renewed interest in the stratified charge engine.

One variation of this engine employs the concept to permit utilization of compression ratios in excess of the compression ratios allowable with a homogeneous charge engine. In this way the increased efficiency resulting from a high compression engine is attained without excessive octane number requirements for its fuel. This approach effectively utilizes gasoline as currently marketed so it can be implemented by any engine or car manufacturer who finds it attractive to develop and market. Honda currently sells this type of engine and Ford has developed, but not yet marketed, their PROCO system.

The Texaco stratified charge engine eliminates octane and cetane requirements by increased complexity. The fuel is not mixed with intake air, but it is injected when needed in the engine cycle. A spark is provided for ignition of the charge eliminating cetane requirements. In this manner the current expenditures of money

4

and process energy to produce large quantities of high octane gasoline could be reduced and future concerns about diesel fuels of adequate cetane number avoided. To take full advantage of these opportunities refinery configuration and engine modifications must be optimized simultaneously.

Another advantage of the Texaco system is that it offers high efficiency operation during part load operation or while idling since engine power is controlled by the quantity of fuel injected, not by throttling the air intake as with conventional SI engines.

Emissions from stratified charge engines depend on many variables — fuel quality, engine geometry, and sophistication of the spark and injection systems. Published information has not explored all of these variables systematically to identify preferred combinations. The United Parcel Service test program indicates emission control problems are "moderate," a term they also use to describe emissions from diesel and gasoline engines as shown in Table I. Investigators at International Harvester, and others, have found it very difficult to control hydrocarbon emissions under light loads.

United Parcel Service has an extensive testing program in progress employing GM-292 engines modified to utilize the Texaco stratified charge concepts. This investigation has included operations on test-stands and in a typical truck. This investigation has been reported favorably, as summarized in Table 1. The program is being expanded to a ten engine investigation, and there are plans for a 500 engine demonstration. (Lewis and Tierney, 1980).

2.2 CONVENTIONAL TRANSPORTATION FUELS

Conventional transportation fuels include various grades of gasoline, diesel fuel, and aviation fuel. These fuels are refined from a wide variety of crude oils. The refining steps are custom tailored for each blend of crude oils to yield a product with the desired properties and meeting certain specifications. Also, refining operations are tailored to the market so that full use is made of the entire crude oil feedstock. Among the properties of interest are octane number, cetane number, front end volatility, distillation range and distribution (boiling point curve), cleanliness, stability, sulfur and nitrogen contents, pour point, cloud point, viscosity, and corrosiveness.

Current fuel specifications and related test and measurement techniques were developed empirically over a period of many years, during which crude oil costs were relatively low. The energy efficiency of the refining process and the fuel efficiency of vehicles employing the finished fuels were relatively less important when the specifications were written than they are today. Consequently, modification of fuel specifications has been proposed frequently.

5

TABLE 1

Engine Comparison

Item	Gasoline Engine	Diesel Engine	UPS 292 SC
Fuel Economy	Fair	Excellent	Excellent On All Fuels
Fuel Requirement	Octane	Cetane	No Octane Or Cetane
Initial Cost	Low	High	Moderate
Performance	Good	Fair	Equal to Gas Engine Better Than Diesel Engine
Noise Level	Low	High	Higher Than Gas Engine
Vibration	Minor	Heavy	Minor
Exhaust Odor	Low	High	Low on Gas & Broad Cut High on Diesel
Starting Problems	None	Cold Weather	None
Retrofitability	—	Difficult	Easy
Emission Control	Moderate	Moderate	Moderate
Projected Maintenance Cost	Moderate	High	Low

(Lewis and Tierney, 1980)

One author divided the specifications into two groups — potential trade-off properties and non-trade-off properties as illustrated in Table 2.

The greatest potential for increasing refining efficiency and decreasing costs in most existing and older refineries without substantial additional investment is by relaxing the octane or cetane ratings. With efficient, modern facilities, octane numbers can be increased four or five numbers above current practice. The additional consumption of refining energy is small compared with the energy savings made possible by the higher efficiencies of the engines designed to use higher octane fuels. (Gratch, 1981). However, the qualitative aspects of these characteristics are tightly tied to the needs of the corresponding engine design.

The distillation ranges for transportation fuels are established to meet several needs, only some of which apply directly to engine performance. Safety considerations (flash point), evaporation losses, and problems of vapor lock limit the quantities of light materials which may be included in fuels. The presence of high boiling materials is limited by restrictions on smoke, and/ or particulates, and hydrocarbon emissions, and by the need to avoid dilution of the crankcase oil. Too many high boiling materials also may result in fuels having high viscosities, or insufficiently low cloud and pour points. Changing the boiling range specifications for current fuels would require balancing a small gain in refinery efficiency against a loss in performance and/or environmental compliance.

The nitrogen and sulfur contents of transportation fuels cannot be allowed to increase, as indicated in Table 2, because that would adversely affect engine and fuel system corrosion, fuel stability and exhaust emissions. This is not necessarily the case for some engines and/or duty cycles. In intermittent reciprocating engines, some data suggest that increasing fuel-bound nitrogen does not increase NO_x emissions.

Hydrotreating is the accepted route to remove sulfur and nitrogen, although it is costly and consumes considerable amounts of energy. Hydrotreatment procedures also can alter the boiling range and types of hydrocarbons present in the treated materials. Relatively small amounts of nitrogen in fuels contribute to a multitude of problems — catalyst poisoning during reforming, instability of fuels, gum formation and nitrogen oxides emissions.

Liquefied petroleum gases (LPG), primarily propane, can be utilized as a transportation fuel. LPG is a proven alternative to gasoline for transportation usage in certain circumstances, and can be employed in conventional engines. LPG is a by-product of natural gas processing and petroleum refining so its availability

TABLE 2

POTENTIAL TRADE-OFF PROPERTIES OF GASOLINE AND DIESEL FUELS

POTENTIAL TRADE-OFF PROPERTIES	NON-TRADE-OFF PROPERTIES
GASOLINE	
OCTANE NUMBER FRONT END VOLATILITY DISTILLATION RANGE/DISTRIBUTION	CLEANLINESS STABILITY S. N CONTENT NONCORROSIVENESS
DIESEL FUEL	
CETANE NUMBER DISTILLATION RANGE/DISTRIBUTION	CLEANLINESS STABILITY LOW TEMPERATURE HANDLING VISCOSITY RANGE S. N CONTENT NONCORROSIVENESS

(Southwest Research Institute, 1977)

from domestic sources is limited to about 1.5 million barrels per day. About 3% of all LPG is used as motor fuel. LPG has other premium uses for domestic heating, agriculture, light industry and as a petrochemical feedstock. For these reasons LPG is not considered a major national source of transportation fuels, although in some locations it may be a cost-effective option.

2.3 SYNFUELS-DERIVED AND NEW TRANSPORTATION FUELS

Synthetic fuels for transportation applications can be produced from coal, oil shale, tar sands and biomass.

Coal and oil shale have received the most public attention because their reserves are relatively large. Proven reserves of oil shale are 15 to 20 times greater than domestic petroleum reserves, and the proven reserves for coal are about 40 times our petroleum reserves. The domestic reserves of tar sands are much smaller and are found in only a few locations. Western Hemisphere reserves of tar sands are substantial.

The estimated cost of syncrude from oil shale is close to that of imported petroleum. Lack of commercial shale oil production experience prevents a more definitive statement about the cost of shale oil relative to imported crude oil. Transportation fuels based on coal are generally projected to be somewhat more costly than oil shale. Less large-scale, current information is available regarding coal liquefaction from large-scale plants than for oil shale, so the cost estimates for coal liquids are even more uncertain.

The Federal government, pursuant to the Defense Production Act, has committed itself to the support of two private shale oil projects by providing a loan guarantee to TOSCO, and a price guarantee to Union Oil. These firms have been developing their oil shale retorting technology for many years and are ready to demonstrate commercial operations. The firms have obtained nearly all of the permits necessary for their operations. For these reasons it is highly probable that significant shale oil production will be achieved in the 1984-86 period. Several other firms also have made significant oil shale development efforts, both above ground and in situ, and can be expected to launch large-scale operations.

The DOE is phasing down its coal liquefaction projects. The SRC-II demonstration project is being terminated, and the SRC-I project which provides primarily solid fuel has an uncertain future, at best. Two large direct liquefaction pilot plants, H-coal and Exxon Donor Solvent, will continue to operate into 1982, but no plans have been confirmed for operations beyond that year. These pilot plants could provide a considerable

quantity of coal liquids for further refining and testing as engine fuels.

Methanol production and Fischer-Tropsch synthesis are the two most commercially available forms of indirect coal liquefaction. Technologies for methanol production from synthesis gas are well established, and commercial gasifiers are on the market to generate synthesis gas from coal. Fischer-Tropsch has not been utilized commercially in the U.S. but could be built under license. Methanol to gasoline conversion (Mobil M-gasoline Process) is nearing commercial readiness. Several proposals for methanol production and other coal liquefaction projects have been made to the Synthetic Fuels Corporation (SFC), but the SFC is not yet at an operational stage and has made no funding decisions.

Biomass is sometimes viewed as having a considerable resource base because it is renewable. That is not quite accurate because current agricultural practices require nonrenewable fertilizers and entail some soil depletion and erosion. Thus, biomass is not a fully renewable resource. In addition, the biomass resource base is rather small. It is not expected to make a large contribution to our domestic supply of transportation fuels. (Parker, 1980).

3.0 SYNFUELS FOR TRANSPORTATION

3.1 OPTIONS FOR USING SYNFUELS

Several options exist for using synthetic fuels from coal, oil shale, or biomass to help satisfy transportation fuel needs. In the first option, the synfuel refined is to be essentially equivalent in all major respects to a certain grade of conventional transportation fuel. It satisfies the same specifications and can be blended or used in the same engines as the conventional fuel. In fact, the user may not be aware at all that he is using a synfuel. In the second option, the synfuel product is usable in some current engines with little or no modification, but the fuel is different from conventional fuels. In the third option, the synfuel product is usable only in engines of a new or substantially modified design. A spark ignition engine adapted to run on straight methanol illustrates option three. These three options are discussed in the following sections.

3.1.1 Conventional Specifications Option

For those synfuels requiring further refining the most straightforward way to utilize synfuels is to process them to the same specifications applied to petroleum products for use in existing engines. This option requires some advancements in refining technologies. These advancements are evolutionary not revolutionary in nature; they are consistent with the current activities of the refining industry.

In many instances, the specifications for petroleum products may be adequate for products derived from coal or oil shale, but the possibility exists that additional or different specifications may be needed to ensure that refined synfuels are fully compatible with and useful in existing engines. Cooperation and coordination among fuel refiners and engine manufacturers are valuable to identify where additional specifications may be needed. Testing is required to determine the validity of applying petroleum-related, largely empirical methodology and specifications to synfuels. Refined shale oil products are being examined and tested to determine whether additional specifications are needed.

This option includes the case where synthetic crude oils from coal or shale are used as a refinery feedstock for blending with natural crude oils. In fact, a recent study by the National Academy of Sciences suggests that it is possible to improve the operation of the refining processes by processing blended feedstocks of syncrudes and natural crudes.

Blending with natural crude appears to be the most likely way of refining synfuels in the early years of synfuel production in the U.S. Blended feedstocks are consistent with the economics of refining. The relatively small amounts of early synfuels

production can be most economically utilized by feeding into existing refining processes. In fact, many oil shale and coal processes are being designed to produce a syncrude tailored for mixing with natural crude oils. The existence of surplus refining capacity also favors blended feedstocks over the construction of new facilities exclusively for refining syncrudes from oil shale or coal.

Projections of domestic oil production indicate that significant amounts of natural crude oil will be available for mixing with syncrudes. In general, 10 to 20 percent of syncrudes may be blended with crude oil without major alteration in the refineries. Of course, as the synfuel industry grows, some refiners may find it desirable to utilize large proportions of syncrude and modify their refineries as required. In doing so, however, it is necessary to effectively utilize the entire synthetic feedstock just as it is now done with petroleum crude.

Some synfuel processes may present unique opportunities for production of synfuel products, as shown by the recent example of Gulf Research and Development Company under contract to the Office of Transportation Programs of DOE. Gulf investigated preparation of octane improvers for gasoline by extracting phenols from 55 to $260^\circ C$ cut of SRC-II product, and converting these phenols to the corresponding methyl aryl ethers, (MAE). Five volume percent of MAE was blended with unleaded gasoline and tested in a variety of laboratory and automotive tests, demonstrating that MAE improves gasoline octane without degrading other gasoline properties. (Singerman, 1980).

3.1.2 Current Engines Option

Limited proportions of alcohols, such as methanol or ethanol, can be mixed with conventional gasoline to produce a transportation fuel that is usable in existing engines. Gasohol is an example, using 10 percent ethanol, with the remainder being gasoline. Retrofit materials compatibility issues have arisen, and some minor engine modifications may be necessary, such as adjustments or changes to the carburetor, to enhance the operation of alcohol/gasoline blends in existing engines.

This option is made complicated because alcohol/gasoline blends may not be universally substitutable in all engines where conventional petroleum products are used, primarily due to questions regarding material compatibility. Thus, testing of each individual type of engine is needed. One automotive engine manufacturer has opposed use of certain new fuels, specifically certain methanol-gasoline blends, because test data are not adequate to show that exhaust emission levels can be maintained over the engine lifetime. Thus, it appears that new engine — fuel test data are required.

Another complication is that the new fuels, although usable in existing engines, may be only marginally suited for existing applications. It would be wiser over the long run to examine how new fuels and new/modified engines can be developed as an optimal system.

3.1.3 Modified Engines Option

Several possibilities look attractive for new or modified engine designs to use synfuels. For example, methanol-fueled spark ignition engines have accumulated many years of racing experience and appear feasible and advantageous commercially. Other examples include modified combustion chambers on turbines to accept more aromatic coal-derived fuels, or stratified charge IC engines to minimize octane requirements of the fuel.

The economic feasibility of marketing new/modified engines depends upon their potential for reducing petroleum consumption in the face of future petroleum shortages and price increases. As fuel prices climb, it is economically prudent to invest in more efficient engines that can offset high fuel prices. With new fuels, economic and energy savings potentially available from minimal processing may be possible with suitable changes in engine design. Also, technological advances such as improved materials or micro-computer-aided engine operation may make engine modifications practical today that were not acceptable some years ago. For these reasons modified engine designs are opportunities for improved utilization of synfuels.

3.2 BARRIERS TO USING SYNFUELS

The barriers to using synfuels from coal, oil shale and biomass can be classified into four groups: (1) Technical Barriers, such as the uncertainty that a new engine design can satisfy the desired performance criteria; (2) Environmental Barriers, such as the risk that the engine emissions cannot meet the applicable environmental standards; (3) Economic Barriers, including the cost of using synfuels relative to conventional transportation fuels; and (4) Market Barriers, involving market penetration by offering new engines, establishing new distribution systems, and changing user expectations. Each of these barriers is discussed below.

3.2.1 Technical Barriers

Lack of sufficient technical information regarding the various options for using synthetic fuels is a major barrier. As explained in Section 2.0, although the existing information base about transportation fuels and engines is quite extensive, much of it has been gathered empirically and cannot be reliably extrapolated to synfuels. Technical uncertainties exist regarding combustion chemistry and kinetics; effects on engine materials, seals, and gaskets; start-up behavior, especially at low tempera-

tures; engine performance under extensively varied conditions of load, humidity, atmospheric pressure, and temperature; effects on engine lubricants and lubricating systems; failure mode analysis, in response to marginal specifications fuels; flame propagation, and questions of engine life-cycle maintenance and reliability.

The level of effort needed to design a new or modified engine to use synfuels is uncertain but is expected to be substantial. For example, design of a mass-production engine to take full advantage of methanol as a fuel is technically feasibile, but considerable technical effort would be required to achieve economies of scale and proven reliability. Lack of comprehensive reliable data is a very significant barrier to making effective decisions regarding new fuel — engine combinations.

Performance data for new fuel — engine combinations must be gathered systematically, and in detail, to optimize efficiencies, to comply with emissions regulations, and to estimate maintenance requirements. Comprehensive and reliable data are particularly important as a new fuel or engine nears commercialization to minimize the risk of problems in the field which are very expensive to solve. For this reason refiners, engine manufacturers, and independent laboratories have made large investments in engine test facilities and perform expensive tests on their products, including intensive actual road testing. Test fuels are difficult to procure because the pilot plants used to develop refining techniques for syncrudes are too small to produce adequate quantities of fuels for significant engine tests, while those available from existing liquefaction plants are not suitable transportation fuels without upgrading. This is a major barrier, considering an engine manufacturer cannot undertake a comprehensive program of engine development unless he is assured of adequate fuel supply. Further, it will be necessary to test a much broader range of fuels to establish design criteria for possible future fuels.

3.2.2 Environmental Barriers

A myriad of environmental standards and regulations apply to the exhaust emissions from most, if not all, engines used in transportation. These emissions are quite complex and vary according to the engine size, fuel, year of manufacture, and type of application. The pollutants currently regulated include carbon monoxide, nitrogen oxides, and unburned hydrocarbons. Diesel particulates are currently being studied. The Federal government and some states have established elaborate testing programs to certify that a new or modified engine design complies fully with the applicable environmental standards before the engine may be offered for sale. Retesting and recertification must occur if a significantly different fuel is to be used with an engine certified for some other fuel. New fuels and engines must meet the same emission standards as current fuels and engines. In addition,

14

new fuels may have additional emissions that will be regulated. An engine manufacturer would be reluctant to commit to an expensive engine development and testing program without the reasonable assurance that the new engine will be found to be environmentally acceptable. It will be necessary to make comprehensive tests and analyses of the various emitted species to be certain that there are no surprises. It also may be necessary to develop or substantiate suitable methodology and measurement techniques.

3.2.3 Economic Barriers

A variety of economic and financial barriers impede the development and production of synfuels for transportation. First, as explained in Section 2.0, the costs of producing synfuels depend upon the resource and the technology, but in all cases appear highly uncertain. Some synfuels require extensive and costly upgrading to bring them up to specifications suitable to run in today's refineries. The more favorable cost estimates indicate that shale oil can compete economically with imported crude oil at today's market price. Other types of synfuels appear initially more expensive than crude oil, but they are projected to become relatively more attractive in future years. The reasoning is that a relatively large portion of the lifetime costs of most synfuels plants are capital costs, and, once invested, are not subject to inflation. These costs, however, are tremendous and exceed the book value of all but the Nation's largest coporations. Thus, synfuel costs are expected to climb more slowly as the price of crude oil increases in the future. These uncertainties about today's and tommorrow's fuel costs present formidable barriers.

In addition, there are considerable uncertainties about the cost of developing, manufacturing and maintaining the new engines for use with synfuels. For example, N.A. Sauter, Chairman of the Alternate Fuels Committee of the Engine Manufacturer's Association, expressed reservations about the extensive testing of new fuels until their economic attractiveness had been demonstrated, including life-cycle costs of the engine while meeting emission regulations. This raises an attendant question as to the effect of diversity of outlooks and positions among industrial organizations on determining whether any fuels are tested.

Financial justification for the development of the methanol-fueled SI engine would require a detailed study by many specialists. A major difficulty in this investigation would be unequivocally establishing the cost of producing methanol from coal. A firm conclusion regarding these costs may not be possible until coal liquefaction plants have been built due to the continuing difficulty in reliably estimating the costs of synfuel production using emerging technologies. Yet, such plants are not likely to be built until a market exists which is dependent on engine development and manufacture.

A related barrier is that the benefits of a successful engine-synfuels development effort may not be returned to those who have borne the principal costs of that effort. The gains may not appear as a financial reward to those who financed the changes, but to the Nation as a whole. This circumstance makes it difficult for individuals or corporations to aggressively invest in ways to utilize synfuels in transportation.

3.2.4 Market Barriers

A major investment in new engine technology will be required in order to establish the demand for synfuels. These options highlight the very large barriers of transforming the existing industry infrastructure. The existing petroleum-engine system, including both information and physical assets, is enormous and has massive inertia which will slow the transformation.

For example, substantial distribution problems exist in broadening the product slate available at many of today's service stations. Either pumps and storage would have to be added or pumps changed to accomodate new fuels, or both. The large efforts required to justify and implement such changes nationwide are significant barriers. The present inventory of engines, fuel distribution systems, engine manufacturing facilities, and petroleum refineries represents a very large investment. This limits the rate at which changes can be accomplished. Such limitations tend to favor using new resources to make fuels that look and act like present fuels but which may be less efficient or economical than other options. This highlights the fact that the best interests of individual commercial organizations may differ from those of the Nation.

3.3 APPROACHES TO REMOVING THE BARRIERS

A multi-faceted approach is needed to overcome the various types of barriers discussed above. The elements include:

- A strong effort to ensure that adequate quantities of synfuels are available for testing

- Extensive studies to determine optimum engine and synfuels combinations

- A strong R&D effort to match new fuels and engines

- An engine testing program which focuses on appropriately composed synfuels

- Fleet demonstrations to verify acceptable performance under actual operating conditions

- Appropriate changes in economic, energy, tax and environmental policies

3.3.1 Engine Testing Programs

In parallel with the development of synfuels technologies, DOE, DOD, and private companies have been active in (1) determining the refining requirements to produce finished fuels and (2) testing these fuels. Primary emphasis has been on jet fuels, as they are a major need of the military. The paraffinic nature of shale oil favors the production of jet fuels from oil shale. A successful small scale test of refining shale oil and using the resulting fuels has prepared the way for larger scale testing. These tests will commence with refining of 40,000 barrels of shale oil for flight testing, and then tentative plans call for routine use of jet fuels derived from shale oil at one or two bases in 1983 or 1984.

The military is particularly aware of the necessity for adequate quantities of fuels for testing to ensure the continued reliability of weapons and support systems. Accordingly, DOD currently supports extensive fuel and engine test programs, and there exist several facilities which can extensively test engines and fuels. Limited availability of test fuels derived from coal and oil shale sources has narrowed the range of testing performed on these synfuels and has delayed some planned tests in the recent past.

DOE and DOD personnel have developed plans to increase the availability of synthetic test fuels. For example, the Bartlesville Energy Technology Center (BETC) examined the options for providing ample supplies of test fuels in a position paper. BETC noted that by modifying an existing DOE facility near Pittsburgh, PA, it would be feasible to refine 50 to 100 barrels per day of syncrude.

Private sector interest in Federal facilities for production of test fuels varies. One paper clearly calls for Federal production of synfuels for testing by the private sector. (Colucci, 1979). In August, 1980, Serge Gratch of Ford stated that the situation regarding the availability of test fuels is easing. A similar comment was made by Karl Springer of Southwest Research Institute who said that in the past some of their programs were delayed one year due to lack of test fuels, but the situation is improving. During this survey, when persons in the private sector were specifically questioned about facilities to produce engine test quantities of synthetic fuels, they often affirmed that such facilities are needed.

3.3.2 Policy Changes

Barriers which result from the need for system-wide changes in the transportation infrastructure, or the lack of financial rewards for individual development of attractive routes to more efficient use of fuels, must be mitigated at the Federal level.

17

Energy policy and regulatory decisions play major roles in influencing the choices made about alternatives for more efficient use of fuels. Federal policies can encourage or discourage petroleum imports, or they can create incentives or disincentives to conserve fuel in automobiles. Tax policies can assist certain investments. Small changes in emission regulations can favor or discourage particular engine developments which might be more fuel efficient. Perceptions of policy instability and anticipation of changes in regulations can also become barriers to development of more efficient fuel — engine combinations.

These policy barriers are quite complex, far-reaching, and often subtle. They can be diminished or removed, but to do so requires a thorough study of the full set of applicable policies, their interactions, and their influences on other national policy goals.

Appendix

The following persons were contacted during the course of this study and provided substantive information which was used in preparing this report. As this list illustrates, the information sources spanned a wide cross section of interests, including Federal program management, planners, policymakers and budget personnel.

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16. Abstract

This paper identifies the principal barriers to the use of synthetic fuels for transportation purposes and suggests several approaches which could minimize the problems of phasing synfuels into the transportation fuels mix. The principal types of engines for transportation uses are reviewed and the specifications for conventional fuels are compared with specifications for synthetic fuels. Synfuel processes nearing the commercialization phase are reviewed. The barriers to using synfuels can be classified into four groups: (1) Technical, such as the uncertainty that a new engine design can satisfy the desired performance criteria; (2) Environmental, such as the risk that the engine emissions cannot meet the applicable environmental standards; (3) Economic, including the cost of using a synfuel relative to conventional transportation fuels; and (4) Market, involving market penetration by offering new engines, establishing new distribution systems and/or changing user expectations.

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