STANFORD RESEARCH INSTITUTE
Menlo Park, California 94025 · U.S.A.

Management Report No. 17

SRI Project EGU-4810

TECHNOLOGY ASSESSMENT OF ALTERNATIVE
TRANSPORTATION FUELS

Report Prepared for:

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June 10, 1977

To AM&R 8.1

Contract 115/103 ✓

ATO 3-760550115

MASTER

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A. Research Program

SRI International is performing a study entitled "Technology Assessment of Alternative Transportation Fuels." This study consists of three phases: Phase I is an extension and refinement of previous SRI work on the impacts of developing synthetic liquid fuels from coal and oil shale for transportation use; Phase 2 is a technology impact assessment of electrification of road and rail transportation; and Phase 3 is concerned with articulating and analyzing public policy options for all the future transportation propulsions alternatives based on the solid fossil fuel resources (coal and oil shale). Figure 1 shows the linkages between the tasks in these phases.

To date the vast majority of the work has been in Phase 1 which consists of Tasks I-A to I-E, II, and III shown in Figure 1. The work for these tasks is now complete except for printing of the corrected version of the final reports. Considerable time has been given to two workshops for Task V. We are now under way on the electrification studies of Task IV.

B. Financial Status

As of June 4, 1977, the SRI project team has expended \$215,156 on Tasks I to III, \$118,386 on Task IV and \$46,778 on Task V. In addition, payments of \$60,606 have been made to the Traverse Group Inc. for their subcontracting efforts on Task V; \$760 have been withheld from the final invoice of the Traverse group pending final audit.

C. Accomplishments

1. Tasks I-III

Two final reports entitled:

Synthetic Liquid Fuels Development: Assessment of Critical Factors

- Vol. III Regionalized Industry
Social Impact
Coal Resource Depletion
- Vol. IV Energy/Economic Comparison of Coal-Based
Automotive Energy Supply Systems

have been prepared, printed, and mailed to Daniel Maxfield, the ERDA Project Officer.

FIGURE 1. LINKAGES BETWEEN STUDY TASKS AND PREVIOUS STUDIES

2. Task IV

a. Railroad Electrification

A scenario depicting the transition of mainline freight railroads from being diesel to electric powered has been developed.

Private Enterprise with Federal Aid--Scenario 1

This scenario is prepared under the assumption that most, perhaps all, of the railroad electrification will require federal financial assistance in some (as yet undefined) form. Without a federal policy to provide such assistance, it is unlikely that electrification on this scale would be undertaken.

The scenario ranks track segments according to the approximate order in which it seems logical to the team--especially Mr. Albert Moon--that electrification proceed.

The segment end points in all cases are defined in terms of operationally logical break points--always the presence of a major classifying yard and often at points where track ownership shifts from one company to another.

In the scenario, we are assuming that about five years elapse between a railroad's decision to proceed with a serious estimate of the costs of electrifying a particular segment, the securing of all necessary approvals and financing, and by the actual physical construction. For the actual construction, we assume that the entire segment would be prepared for electrification over a period of a year or two. In particular, changes in signalling, erection of poles, power substations, etc. would all be done prior to the actual stringing of wires because these former activities will hardly disrupt the flow of traffic compared to the actual stringing of the high voltage wire. Therefore, the wire stringing would be accomplished rather rapidly--over a one or two month period--by a concerted effort during several hours a day when all train traffic would have to be held up, or diverted to another route. Thus, there is obviously a premium on accomplishing this final step very quickly.

In the scenario we also assume that the New Haven-Boston and the Pittsburgh to Harrisburg electrifications have already taken place since these decisions have already been made and the process is underway. Otherwise, no other specific decisions seem likely to be made in favor of electrification before 1980; therefore, we indicate the decision in 1980 and the first line in operation in 1985. We indicate both the decision and operating date, assuming a constant five year delay between them.

At the present we assume only one segment is electrified per year. We are also assuming that railroads continue to buy electricity in a geographically varying pattern similar to that which occurred in 1974:

Western states	1.5¢/kWh
Midwestern states	2.5¢/kWh
Eastern states	4.0¢/kWh

The attached map shows the segments in the order described as follows.

PRIVATE ENTERPRISE WITH FEDERAL ASSISTANCE—SCENARIO 1

Rank	Date Decide/ Operate)	RR	Route/Length (miles)	Comment
1	1980/1985	Southern Pacific (SP)	Colton, CA- El Paso, TX (760)	Colton is near Los Angeles, CA. Assumes SP purchase of Rock Island line between Tucumcari, NM and Kansas City goes through. This would give SP a new, more direct route to the midwest and the track segment in question should experience increased traffic. It is presently single track but the new traffic would not be enough to make double tracking an attractive investment. Since electrifying gives a traffic handling capability intermediate between single track and double track (about 125% of single track), electrification should be an attractive substitute investment. It is important that the motivation here is seen as a choice between two investment options.
2	1981/1986	Santa Fe (ATSF)	Barstow, CA- Clovis, NM (968)	Barstow is near Los Angeles, CA. This is a double track, high speed route. The motivation here is to achieve a lower operating cost for energy. Thus a capital investment is being substituted for an on-going, rising, operating expense.
3	1982/1987	Union Pacific (UP)	Council Bluffs, IA- North Platte, NB- Ogden UT-Salt Lake City, UT (1,016)	This route is attractive because it is a long segment over which traffic simply passes with very little diversion; thus the virtues of electrification are easily realized and the clumsiness encountered with non-electric branch lines is generally a minor factor.
(Ranks No. 4, 5, 6 are about equal in attractiveness and could be largely interchanged)				
4	1983/1988	Chicago and Northwestern (C&NW)	Chicago, IL- Omaha, NB (506)	Expanding the electrified network is a big factor here as it connects with No. 3 (Council Bluffs, IA is directly across the Missouri River from Omaha NB). It is also, perhaps, the basis for consolidating the traffic among the various roads in this corridor. Already the Rock Island and the Milwaukee Road have begun to run trains over the same mainline track with a joint track agreement.

Rank	Date Decide/ Operate)	RR	Route/Length (miles)	Comment
5	1984/1989	Conrail (CR)	Chicago, IL- Cleveland, OH Buffalo-Selkirk NY (810)	Selkirk, NY is near Albany, NY. This should be the first route in the east because it is the spine of the eastern system, but it ranks lower than western routes owing to the higher electricity costs.
6	1985/1990	Burlington Northern (BN)	Lincoln, NB- Alliance, NB (360) [Lincoln, NB- Gillette, WY (541)]	This segment is a candidate primarily because of an expected large increase in coal traffic. There is some possibility that this line may be extended to Gillette, a town in the center of Wyoming's famed coal-rich Powder River Basin.
7	1986/1991	Southern Pacific (SP)	Ogden, UT- Roseville, CA (670)	Roseville, CA is near Sacramento, CA. This segment, following segment nos. 4 and 5, would essentially complete the first transcontinental electrified rail corridor. This segment will have many clearance problems in tunnels and snow sheds in the Sierra Nevada mountains. This segment would not rank so high were it not for the "completion" consideration. Whether to also electrify the portion of the Western Pacific (WP) line that parallels the SP in mid-Nevada, and which--through a joint track agreement--both SP and WP use, remains an unresolved question.
8	1987/1992	Santa Fe (ATSF)	Clovis, NM- Kansas City, MO Chicago, IL (1102)	Competition is the prime motivator here. Electrifying this segment allows Santa Fe to compete with the electrified transcontinental route established above and to enhance its competitive posture with the SP on the Los Angeles, CA to Kansas City, MO run.
9	1988/1993	Norfolk and Western (N&W)	Bellview, OH- Columbus, OH- Portsmouth, OH- Roanoke, VA (512)	This segment nearly connects with No. 5. This is a high traffic-density line. It was not ranked higher because of the high eastern electricity cost. There is a great deal of coal traffic, much of it downhill. Regenerative braking may actually yield a net electric gain.

Rank	Date Decide/ Operate)	RR	Route/Length (miles)	Comment
(Ranks No. 10, 11, 12 are about the same and could be interchanged.				
10	1989/1994	Baltimore & Ohio (B&O)	Chicago, IL- Akron, OH- Pittsburgh, PA (416)	We are now mainly completing electrification of the mainline system and the differences between alternative segments has become small.
11	1990/1995	Baltimore & Ohio (B&O) Chesapeake & Ohio (C&O)	Pittsburgh, PA- Cumberland, MD- Washington, DC (302)	
12	1991/1996	Baltimore & Ohio (B&O)	Toledo, OH- Cincinnati, OH, Chattanooga, TN- Atlanta, GA (683)	
13	1992/1997	Norfolk & Western (NW)	Roanoke, VA- Norfolk, VA (268)	This connects to No. 9 as much of the coal (metallurgical) is exported through the Norfolk area.

Beyond here, other segments might be electrified, but ranking them becomes more difficult than it is worth.

b. Electric Vehicles

(1) Market Penetration Model

Dan Dick, the team economist, has programmed an electric vehicle market penetration model designed for interactive use. The model is based on an econometric one made by R. T. Crow and B. T. Ratchford of the Electric Power Research Institute (EPRI).^{*} The model determines the ratio of electric or hybrid cars to a base case car as a function of relative price, brand name, as well as performance and comfort characteristics.

The statistically significant variables for data over the period 1960-73 were shown by EPRI to be (1) price, (2) front leg room, (3) rear leg room, (4) passing performance, (5) handling, (6) transmission type, and (7) brand name. The model output is the number of electric cars relative to the number of full sized Chevrolets (used as the base car). This ratio applied to a forecast of the number of base cars sold yields the number of electric or hybrid vehicles. A simple demand equation is being estimated econometrically, and using forecast values for the independent variables, the number of base case sales will be generated.

EPRI found, somewhat surprisingly, that fuel economy was statistically insignificant and, moreover, consistently had the wrong a priori algebraic sign. Crow and Ratchford think that this stems from "luxury" and poor fuel economy being closely related and therefore impossible to disentangle statistically. Our treatment of the problem of fuel economy is to assume that the "price" variable is really a life-cycle price that includes (1) purchase price and (2) discounted operation and maintenance costs. Thus we implicitly assume that people are as price sensitive to operation and maintenance costs (appropriately discounted) as they are to purchase price. This allows us to account for electric and hybrid

* "An Econometric Approach to Forecasting the Market Potential of Electric Automobiles," presented at the Conference on Energy Demand and Energy Conservation, International Institute for Applied Systems Analysis, Schloss Luxemburg, Austria, May 22-23, 1975.

vehicle sales which might result from changes in the price of gasoline, changes in the federal tax on gasoline, or the expected relatively low maintenance costs of the electric and hybrid vehicles.

The utility of this simulation model is that virtually all of the variables which might affect a consumer's choice can be explored-- for example, the fuel economy of a conventional (base car), energy economy in an electric car, price of gasoline, price of electric power, maintenance and repair costs, and performance and comfort variables.

We are constructing a plausible set of benchmark initial assumptions, based upon our (and GRC's) best estimates of performance and comfort characteristics of electric vehicles, SRI-National Energy Model price forecasts for gasoline and electricity, estimates of life cycle operation and maintenance costs, and estimates of initial prices.

We expect that use of the EPRI model will test the demand-side reasonableness of our supply-side scenarios.

Our output is expected to be a simulation projection of EVs based on revealed consumer behavior (as estimated by Crow and Ratchford) at three-year intervals starting in 1980 and going to 2010.

We recognize, however, that this market penetration model will yield optimistic results for the number of electric vehicles sold because it assumes that vehicle range is unimportant to the vehicle purchaser. This, of course, is not true. Moreover, as our supply-side scenarios consider explicitly, the number of electric or hybrid cars sold will depend not only on the potential market sized, but also on the actual ability of manufacturers to produce vehicles of appropriate performance and cost.

(2) Discussion with Garrett Corporation

Mr. John P. Martin, Senior market analyst for the Garrett Corporation, visited with Walton and Newgard regarding the future role for his company in the electric car components business. He is in the process of making recommendations to the senior officers of the corporation and wanted to speak with us before making those recommendations.

He feels his corporation is best suited to develop high technology components for electric and hybrid vehicles but not best suited to manufacture large numbers of components. His company is most interested in what other companies are doing. We exchanged views of the industry and of the potential for electric and hybrid vehicles.