BASELINE ENERGY CONSUMPTION
FORECASTS FOR TRANSPORTATION:
A REVIEW AND EVALUATION

By

Frank Koppelman
Pat O'Sullivan
Tom Collum

May 1976

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ABSTRACT

A baseline projection of energy consumption is needed to estimate the potential energy savings from proposed transport technology and operational improvements. The Reference Energy System projection by Brookhaven National Laboratories and that which Stanford Research Institute produced for Gulf Oil are reviewed here. Attention is focused on the growth rate assumptions of the forecasts and the allowances made for the sensitivity of transport demand and technological efficiency to fuel price changes. The alternative trajectories of energy use are examined for automobile, bus and intercity air and rail passenger travel, and also for freight movement. Little, if any, justification can be found for many of the assumptions used to estimate transport demand and energy intensiveness. The assumptions underlying the Brookhaven National Laboratories projections are more explicit on changes in energy efficiency and energy price and shifts in transport patterns. However, the relationship of automobile travel, the largest component, to energy price is not specified clearly. The Stanford projection is based on seemingly arbitrary assumptions about changes in travel patterns and energy efficiency with no reference to the market process which must bring them about. It is concluded that the Brookhaven projection is a reasonable interim benchmark. Its structure should improve by refining and validating or revising the judgmental estimates on which it is based. This can be accomplished by identifying those judgements to which the energy consumption projections are most sensitive and modifying them, based on information presently available concerning the transport sector and/or information and relationships which can be developed by limited research.

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1. INTRODUCTION AND APPROACH

Argonne, along with several other National Laboratories, has been commissioned by ERDA to evaluate alternative approaches which the Federal Government might adopt to reduce energy consumption in the transportation sector. The Laboratories are explicitly considering government intervention to encourage development of more energy efficient technology and/or modification of the operating characteristics of transportation system. In order to evaluate the energy savings associated with proposed strategies, the Laboratories need a common baseline of expected energy consumption in the absence of new government initiatives. This provides the yardstick for comparison of the effects of proposed changes in technology, systems operations, price changes and combinations of these.

There are three primary reasons for establishing a baseline for energy consumption in transportation. First, in conjunction with baselines established for other sectors, it provides an advance notice of expected future energy demands in the absence of major new government intervention. Considered with information on domestic energy resources and assured foreign resources this information provides a basis for the formulation of major government policies in the areas of energy conservation, energy resource development and provisions for response to artificial shortfalls. Second, the baseline for transportation energy consumption indicates the relative importance of this sector in the development of comprehensive energy policies. Furthermore, to the degree that baseline projections are disaggregated to sub-sectors (air, water, surface freight, etc.), the relative importance of each of these sectors can also be identified. Finally, the baseline provides a common reference point against which the effectiveness of selected energy policies can be compared and evaluated.

Criteria which the selected baseline should meet in order to satisfy these three purposes include:

- the projections should be sound extrapolations of historic energy consumption patterns based on a logically consistent theoretical structure and the best empirical evidence available;
- the projections should be within the bounds of reason with respect to past trends;
- the projections should be understandable to decision makers who will be expected to make policy decisions based on them; and
- the assumptions underlying the projections, particularly assumptions about future energy prices and technological changes expected to occur in the absence of federal intervention, should be clearly stated and apparent to all users.

This report, prepared at the request of Argonne National Laboratory, reviews the two major baselines available with respect to the above criteria. Emphasis is in the realism and clarity of the underlying assumptions because of the particular concern of the National Laboratories to evaluate alternative energy saving policies. The two baselines to be evaluated are

- the Reference Energy System developed by the Brookhaven National Laboratory (Associated Universities, 1972), and
- projections developed by the Stanford Research Institute for the Gulf Corporation (SRI-Gulf, 1975).

The approach taken to accomplish this review is to disaggregate transportation into its major functional sub-sectors. Attention is concentrated on the sectors which consume large portions of total transportation energy: automobile, truck, bus, rail and air. Peripheral references are made to other transportation sectors. Energy projections for the agricultural machinery and "other" categories are not reviewed. The assumptions underlying the projections are elicited for each of the sub-sectors examined. In addition, comparison of the alternative projections reveals the nature and magnitude of the departures between them. The overall objective of the review is to assess which of the two baselines more closely satisfies the criteria listed above.

2. OVERVIEW OF PROJECTIONS

The baselines to be evaluated are that developed by Brookhaven National Laboratory (BNL) and that developed by Stanford Research Institute (SRI). The BNL projection is derived in part from the Federal Energy Administration's Project Independence forecasts (U.S. FEA, 1974). The SRI projection is derived from projections of the Ford Foundation's Energy Policy Project (Ford Foundation, 1974). The SRI projection is the average of the Ford Foundation's Historical Growth (HG) and Technical Fix (TF) series. To review the BNL and SRI projection, it is pertinent to examine the FEA and Ford studies from which they derive.

2.1 BNL

The BNL projections of future energy use in transport are based in part on prior projections made for the FEA by Jack Faucett and Associates (U.S. FEA 1974) in connection with Project Independence. This study identifies three energy

use projections based on imported crude oil prices of \$4 per barrel, \$7 per barrel and \$11 per barrel (1973 constant prices). The \$4 per barrel scenario is a modified extrapolation of existing trends in transport and shifting energy intensiveness. The \$7 per barrel and \$11 per barrel projections make adjustments in total transport demand, modal shares and energy intensiveness due to increased energy costs. The BNL projection is based largely on the \$7 per barrel scenario, with some elements of the forecasts modified by BNL staff projections. The effect of energy price is explicitly accounted for in the Project Independence Study and, therefore, in the portions of the BNL study which are based on it. The additional judgments incorporated in the BNL projections are not related to energy prices. They are stated explicitly; however, no justification is offered for them.

From all of this it follows that in order to evaluate the BNL projection it is necessary to review the FEA \$4 per barrel projection and trace the adjustments assumed to occur in response to a price increase to \$7 per barrel and, finally, the modifications applied by BNL.

2.2 HG and TF

The Ford Foundation Energy Policy Project developed three energy projections to the year 2000. The transport elements of the Historical Growth and Technical Fix scenarios will be reviewed here. The Zero Energy Growth projection is an extreme which has not been and will not be considered for adoption. HG purports to extrapolate the trend of energy usage as of the early 1970's. The trend reflects itself in the amount and types of travel and goods transport undertaken and the energy intensiveness of the various travel modes. The HG scenario, by admission of its authors, "is not realistic in view of current

expectations about future energy prices ... and ... is likely to be realized only if the price of energy to the consumer is set by subsidy at a level considerably below its true social cost ..." (Ford Foundation, 1974).

The TF scenario includes the same transportation volumes as HG but assumes energy savings as a result of:

- i) increased energy efficiency of private automobiles,
- ii) increased load factors and reduced flight speeds for airlines,
- iii) a shift in air passenger travel under 400 miles to high speed rail and shift in air freight to truck and rail,
- iv) increased dieselization of trucks,
- v) a shift of long haul truck traffic to rail, and
- vi) increased rail freight load factors.

These mode shifts and/or technological improvements occur under this scenario without any basis in structural changes, such as increased energy prices or government intervention.

2.3 SRI-Gulf

The SRI projection, which has been proposed as a baseline for appraising transportation conservation measures, is the average of HG and TF. The averaging process is purely arithmetic and does not concern itself with accepting, rejecting or compromising the assumptions underlying these trajectories.

2.4 Overall Comparison

All the projections reviewed are inadequate in the justification of their underlying assumptions about transport demand and energy intensiveness. Of those reviewed, the BNL projections are the most explicitly documented. This is largely due to the use of the FEA projections for most of the elements

included. However, even in the FEA study, many assumptions are made which are not justified in terms of available theory and empirical evidence. HG, TF and the derivative SRI projections share the common characteristics of poor documentation and explanation.

Given the prospective availability of North Slope and North Sea oil, the \$7 per barrel assumption underlying the BNL baseline may be only slightly on the low side. The Ford Energy Project scenarios are not explicit on this crucial determinant of the course of events. The BNL forecast accounts for increased fuel efficiencies to be expected independent of increased fuel prices as well as those which are expected to occur in response to increased fuel costs. Total demand for transportation, as well as demand by different modes, is considered to be potentially sensitive to price and this sensitivity is incorporated in the projections. Although some doubts have been expressed about the assumptions on the demand elasticity incorporated in the projections (Hausman, 1975), the explicit nature of the price elasticity assumptions enables users to make adjustments in response to new or better evidence on the correct elasticities.

The SRI average of the HG and TF projections has no rational basis. The HG and TF projections are designed to represent reasonable bounds on future energy consumption projections. The differences in energy consumption between the two projections are clearly stated but the structural basis for these differences is not explained. The selection of the average values is entirely arbitrary and does not include a description of the technological or systems operations improvements necessary to achieve this projection.

2.5 Summary of Projections

The projections of energy consumption by automobiles, bus, air, rail and truck are described in sections 3 through 6. These projections are summarized in figures 2.1 and 2.2.

2.6 Evaluation

The BNL projections are based on explicit assumptions about changes in energy efficiency expected to occur to the year 2000 in response to a particular energy price configuration. The assumptions about the growth and shifts in transportation patterns are also given. However, the relationship of automobile travel, the major transport energy user, to energy prices is not specified. The sensitivity of other passenger travel and freight transport to energy price is expressed by an arbitrary elasticity estimate. The values used are, nevertheless, within the bounds of reason.

The HG and TF projections are based on extreme assumptions about travel patterns and energy efficiency. These assumptions are not related to specific expectations about future energy prices or government intervention. In particular, the underlying market structure which generates these extremely different projections is not identified. The SRI projection, obtained by averaging HG and TF, has no underlying rationale.

Overall, both of the available baselines have serious inadequacies. Although the levels of energy use projected by either scenario are within the bounds of reason they are not based on a behavioral or theoretical structure and therefore are, at best, rough approximations of future energy consumption in transportation. The primary advantage of the BNL projection over the SRI projection is the more detailed statement of the energy saving technological and system operating assumptions on which it is based.

Figure 2.1 TOTAL TRANSPORTATION ENERGY PROJECTIONS - BNL

*Estimated by interpolation

Figure 2.2 TOTAL TRANSPORTATION ENERGY PROJECTIONS - SRI

It appears that either projection provides a reasonable, if not precise response to two objectives of developing a transportation energy baseline. They provide order of magnitude estimates which contribute to an estimate of the need for major government action in energy policy and indicate the relative importance of transportation in overall energy consumption.

Neither set of projections provides a fully satisfactory baseline for the evaluation of energy savings obtained by selected energy policies. However, the BNL projections are far superior to the SRI projections for this purpose because of the more detailed information on energy savings already assumed to occur in the absence of major new government initiatives. Energy savings expected to occur under existing government policies are identified in the sector specific descriptions of the alternative projections.

2.7 Recommendations

Based on the above, it is recommended that the BNL projections be used as a benchmark on an interim basis. However, use of this projection as a comparative benchmark should be accompanied by awareness of the savings in energy use already assumed to occur. Comparative analysis of energy consumption should specifically identify how a proposed policy or course of action differs from those included in the baseline and the consequent differences in energy consumption. In particular, where comparative consumption characteristics are not clearly stated in the baseline they must be explicitly assumed in order to provide a basis for comparison.

At the same time, efforts should be undertaken to improve the structure of this projection, to refine and validate or revise the judgmental estimates on which it is based and to clarify the structural assumptions which provide

its causal motivation. This can be accomplished by identifying those judgments to which the energy consumption projections are most sensitive, and modifying them based on information presently available in the transportation sector and/or information and relationships which can be developed by limited research. The following issues, which have significant influence on the projected levels of energy consumption, require particular attention.

First, the projected fleet mix of automobiles with respect to size and energy efficiency deserves special attention. The industry adoption and market penetration of energy efficient design or technological changes should be explicitly described. Specific attention should be focused on the sensitivity of market penetration to the first cost of energy conserving features, the projected price of gasoline and the effect of such features on the aspects of vehicle performance.

Second, the projected use of automobiles in terms of vehicle miles of travel, occupancy rates and fuel efficiency characteristics should be refined to account for changes in patterns of development, increasing opportunities to use alternative modes and projected gasoline price. Long term projections should also account for changes in patterns of development in response to the pattern of land cost, construction and the life cycle costs for different types of housing units and transportation costs as well as local, state and federal policies influencing development patterns.

Third, the projected use of public transportation modes should be related to changes in fare and service characteristics, changes in development patterns and energy prices. In particular, attention should be focused on the expected changes in load factors taking account of increases in service necessary to attract and serve additional riders.

Fourth, the magnitude of intercity travel in total and by mode is presently projected by guesswork. Postulated shifts between modes and future load factors are based on crude and arbitrary guesses. The behavioral basis for travel volumes and modal shift requires further analysis. The organization of intercity carrier markets must be analyzed to determine if competitive factors will actually lead to projected increases in load factors.

Fifth, the inelasticity of total demand for freight movement with respect to transport costs, which is reasoned plausibly in the BNL forecast, is still in need of close examination. More vitally, the goods and routes for which road and rail compete need identification and the volume of freight susceptible to switching in response to changing transport costs, needs measurement.

3. ENERGY USE IN AUTOMOBILE TRAVEL

Automobile use accounts for the major share of transportation energy consumption; approximately 54 percent of total transportation energy consumption in 1970 (National Transportation Statistics, 1973). Furthermore, automobiles are expected to continue to account for approximately half of expected transportation energy use into the 1980's except under extreme assumptions about improved automobile energy efficiency or major shifts in personal travel behavior.

Clearly, accurate projections of energy use in transportation, either "non-action" projections established as a baseline or "action conditional" projections developed to evaluate policies, depend largely on the accuracy of the projections of automobile energy consumption.

3.1 BNL

The Brookhaven National Laboratory projection of automobile energy use is based on an assumed growth in urban vehicle miles of travel of 4% per year from 1972 to 1985 and 2.5% per year thereafter and in rural vehicle miles of travel of 1.9% per year. The declining growth rate in urban vehicle miles after 1985 represents increasing saturation of the demand for travel. The assumed growth rates are not justified nor are they related to future energy prices. These growth rates imply an overall increase in vehicle miles of travel per year per person from about 4,770 in 1972 to 6,690 in 1990 and 7,740 in 2000 (based on U.S. Census Series E Population estimates). This is a dramatic increase in private automobile travel based on the use of constant load factors assumed in the study.

Estimates of average energy efficiency in urban and rural use are obtained from the Project Independence \$7 per barrel scenario (U.S. Federal Energy Administration, 1974). These energy efficiencies are based on market responses to increased fuel prices including vehicle design changes and shifts to greater use of compact and intermediate vehicles from standard and luxury vehicles. The Project Independence energy efficiency estimates are developed in two stages. First, energy efficiencies are developed based on a \$4 per barrel scenario (real imported crude oil prices return to pre-OPEC levels). In this case, it is assumed that no technological or design changes are made to increase vehicle efficiency. However, it is assumed that market shares of automobiles will shift toward smaller and therefore less energy intensive models. As a second step, these energy efficiency levels are modified in response to a rise in imported oil prices to \$7 per barrel. The increased price of energy provides market incentives to improve energy efficiency through use of radial

tires, improved aerodynamics, reduced weight and, in other than sub-compacts, lower axle ratios, etc., all to be completed by the early 1980's or before. The increased price also encourages an additional shift to smaller vehicles.

The overall predictions of energy use are obtained by dividing vehicle miles of travel in urban and rural use by the corresponding energy efficiencies. These predictions are responsive to energy price changes with respect to average fuel efficiency due to both technological changes and market share changes. They are not responsive to energy price with respect to vehicle usage characteristics either by changes in travel patterns or shifts to alternative modes or increased car pooling.*

3.2 HG and TF

Vehicle miles of travel for both the HG and TF scenarios are determined as the product of population, average vehicle registrations per person and average annual miles of travel per vehicle. Population estimates are based on the U.S. Census Series E. Vehicle registration per person show a trend toward increased vehicle ownership (French et al., 1972). Vehicle registrations per person increases from 0.49 in 1970 to 0.52 in 2000. Taking account of the portion of the population which is driver age (over 16 years), this is very close to one vehicle per driver age person which is presumably the upper limit of automobile ownership. Vehicle miles of travel per vehicle are assumed to be fixed at 10,000 miles per year. This assumes no further growth of average annual vehicle miles per vehicle which was 9,4000 in 1965 and 10,100

*Fixed vehicle occupancy rates of 1.4 persons in urban areas and 2.4 persons in rural areas are assumed but not directly used. These occupancy rates do not account for different trip lengths which suggest occupancy rates in terms of passenger miles per vehicle mile of about 1.9 and 2.4 for urban and rural areas respectively. (National Passenger Transportation Study: Automobile Occupancy, 1972)

in 1971 (National Transportation Statistics, 1973). The vehicle registrations per person increases from 0.44 in 1970 to 0.52 in 2000. Neither the auto registration nor vehicle mileage estimates are related to expected fuel prices.

The proportion of total vehicle miles of travel which occurs on urban and rural roads shifts toward increasing urban travel (French et al., 1972) to reflect the increasing urbanization of the American population.

Energy efficiency of automobiles is differentiated between the HG and TF scenarios. In the HG scenario energy efficiency is assumed to decline continuously over the projection period to reflect a continuing desire for larger cars with more energy consuming features and without improved technology and design. This trend shows a decrease in average miles per gallon of about 10% between 1970 and 2000. Energy efficiency in the TF scenario parallels that of the HG scenario to 1975 followed by rapid increases in energy efficiency by 1985, 59% over 1975, and further improvements to 2000, 98% over 1975. The increased energy efficiency is based on manufacturers' efforts to use radial tires, reduce aerodynamic drag, improve the load to engine match and reduce vehicle weight, and a longer term shift to light weight diesel engines. There is no explicit expectation of a shift to smaller or otherwise less energy intensive vehicles. These improvements in energy efficiency are not conditioned on consumer or manufacturer incentives in the form of higher energy prices or government requirements. The average energy efficiency is disaggregated to energy efficiency in urban/rural use to preserve an assumed 1:3 ratio between their respective energy efficiencies.

The HG scenario is based on the extreme assumption of increasing energy intensiveness without regard to the costs of bigger automobiles with more optional equipment and/or probable trends in energy prices. The TF scenario represents the opposite extreme based on optimistic* estimates of energy savings due to adoption of some major and some minor technological and design changes which are assumed to occur without regard to their feasibility, market adoption or the incentives necessary to create this change. The changes identified occur without any corresponding changes in automobile ownership or use characteristics. Neither scenario is sensitive to future prices.

3.3 SRI

The SRI projection is the median of the HG and TF projections. The vehicle mile estimate is therefore the same as in these scenarios. The average of HG low energy efficiencies and TF high energy efficiencies results in an arbitrary estimate of energy efficiency. This average prediction is not price sensitive.

3.4 Comparison of Projections

The BNL projections reflect a substantially higher rate of growth of vehicle miles of travel than Ford based HG, TF, and SRI projections (Figure 3.1). The growth in Ford based predictions (56%) reflects a 29% increase in population and a 20% increase in vehicle registrations and vehicle miles per person. This corresponds to a 107% growth in vehicle miles of travel projected by BNL.

The energy efficiency estimates (Figure 3.2) for HG are lowest and represent an extreme projection of a trend toward increased energy intensiveness

* Estimated gain of 18% due to a 450 pound weight reduction in 3000 pound vehicles seems unrealistic and the 5% estimated gain due to reduced aerodynamic drag is greater than the 3% expectation of current tests by U.S.D.O.T.

which is inconsistent with present changes and expected increasing energy costs. The TF efficiency estimates are highest and appear to be over assessments of the potential for technological and design efficiency improvements. The BNL estimates, are intermediate. The SRI projections, determined as the mean of the energy intensiveness of the HG and TF projections, are also intermediate.

The overall energy usage projections range from TF which is the lowest to SRI to BNL to HG which is highest (Figure 3.3). The SRI and BNL projections are within approximately 15% of each other on total energy use due to partially offsetting differences in vehicle use and efficiency estimates.

4. ENERGY USE IN BUS TRAVEL

Buses account for less than one percent of all energy used in transportation, but are considered here as the major complements or competitors to auto travel, in cities at least.

4.1 BNL

Urban and intercity bus passenger miles are adopted from the Project Independence \$7 per barrel scenario (U.S. FEA, 1974). Intercity bus passenger miles are initially assumed to increase at the rate of 2% per year to 1980, 2.3% to 1985 and 2.4% to 1990 based on the \$4 per barrel scenario.* The effect of price increases to \$7 per barrel for imported crude oil is assumed to reduce total intercity travel and to adjust mode shares in such a way as to have a negligible effect on bus passenger miles.* Urban bus passenger miles are projected as a fixed portion (18%) of total projected urban passenger mileage

*The adjustment process is based on assumed relative energy price elasticities of the different intercity passenger modes.

AUTO MILES (10^{12})

ANNUAL AUTOMOBILE MILES

Year	HG, TF and SRI				BNL
	Population (10^9)	Persons Per Auto	Total Autos (10^8)	Total Auto Miles (10^{12})	Total Auto Miles (10^{12})
1970	205	2.28	89	893	
1972	209				992
1975	215	2.12	101	1,010	
1980	225				1,258
1985	236	1.99	119	1,190	1,467
1990	245				1,638
2000	265	1.91	139	1,390	2,050

Figure 3.1 ANNUAL AUTOMOBILE MILES

YEAR	URBAN			
	HG	TF	SRI	BNL
1970	12.1	12.1	12.1	
1972				12.1
1975	11.2	11.2	11.2	
1980				13.4
1985	10.8	18.1	13.5	15.0
1990				15.5
2000	10.4	22.7	14.2	18.0

Figure 3.2 AUTOMOBILE ENERGY EFFICIENCY

YEAR	RURAL			
	HG	TF	SRI	BNL
1970	15.7	15.7	15.7	
1972				15.7
1975	14.6	14.6	14.6	
1980				20.5
1985	14.1	23.5	17.6	22.9
1990				23.8
2000	13.5	29.5	18.5	24.0

Figure 3.2 (Contd.)

YEAR	TOTAL			
	HG	TF	SRI	BNL
1970	13.6	13.6	13.6	
1972				13.8
1975	12.6	12.6	12.6	
1980				16.5
1985	12.0	20.0	15.0	18.3
1990				18.9
2000	11.4	25.0	15.7	20.3

Figure 3.2 (Contd.)

YEAR	TOTAL ENERGY USE (QUADS)			
	HG	TF	SRI	BNL
1970	8.2	8.2	8.2	
1972				9.1
1975	10.0	10.0	10.0	
1980				10.0
1985	12.5	7.5	10.0	10.5
1990				11.3
2000	15.2	6.9	11.1	12.3

Figure 3.3 AUTOMOBILE ENERGY USE

for all time periods and price levels. Total local passenger mileage is estimated based on growth in GNP (4.1% to 1980, 3.6% to 1990) and adjusted, according to assumed elasticities of different modes, for increasing energy prices. The effective growth rate in local bus passenger miles is 4.1% to 1980 and 2.9% to 1990. The growth rates for local and intercity bus passenger miles are substantially greater than the growth rates used for local and intercity automobile usage.

School bus passenger miles are assumed to be fixed for all time periods and all energy price levels.

Fuel efficiency estimates for buses are adopted from the Project Independence Report. The efficiencies are based on assumed average passenger loads of 18.9 persons urban and 20.0 persons intercity, assumed energy efficiency of five miles per gallon urban and six miles per gallon intercity for overall efficiencies of 89.5 passenger miles per gallon urban and 120 passenger miles per gallon intercity. School bus energy efficiency is assumed equal to that for urban buses which ignores the higher loadings of most school bus operations. These estimates are not sensitive to changes in energy prices. Estimated passenger loadings compare to increasing intercity averages of 20.5 in 1966 to 20.9 in 1970.*

The energy intensiveness used in the BNL projection are about ten percent higher than the FEA Project Independence estimates.** The BNL projection assumes increasing dieselization of buses from 53 percent in 1972 to 80 percent in 1990 and 2000; however, this shift is not reflected in the efficiency estimates which are constant for the projection year.

* Obtained by dividing reported passenger miles by vehicle miles from National Transportation Statistics (1972).

** BNL energy intensiveness is given as 1550 BTU/PM urban and 1150 BTU/PM intercity compared to FEA values of 1397 and 1042 respectively.

Total energy use in bus transportation is obtained by dividing the projected energy efficiencies into projected future passenger miles. The result of holding constant load factors is to ignore the source of increased ridership. That is, if increased ridership is due primarily to higher gasoline prices or more reliable service without comparable increases in bus vehicle miles, average load factors would increase. Alternatively, if increased ridership is due to service improvements due to increasing bus miles (more routes, increased frequency, longer hours, etc.), average load factors might remain constant or decline.

4.2 HG and TF

Projected intercity, local and school bus passenger miles are "based on projections in the 1972 National Transportation Report" (Ford Foundation, 1974). The growth rates for urban and intercity bus passenger miles are lower than the corresponding rate of growth for automobile passenger miles.

Energy intensiveness is set at 3700, 1600, and 1100 BTU per passenger mile for urban, intercity and school buses (Hirst, 1973). The BTU per passenger mile energy intensiveness combines the technical efficiency of the vehicle (BTU per vehicle miles) with the occupancy rate to obtain an overall energy intensiveness. Use of this approach ignores possible efficiency improvements due to technological changes or systems operation changes which may affect bus occupancy. The energy efficiencies are assumed to be invariant over the prediction period and are independent of energy prices.

The estimated bus passenger miles and energy efficiency are identical for the HG and TF scenarios.

4.3 SRI

The SRI projection for bus energy use is identical to that for the HG and TF scenarios.

4.4 Comparison of Projections

The BNL projections reflect a substantially higher rate of growth of bus travel than the HG, TF and SRI projections (Figure 4.1). The BNL energy efficiency estimates are significantly higher than for the HG, TF, and SRI projections. The resulting energy consumption is lower for the BNL projection but increases more rapidly to 2000 when they are of similar magnitude.

The total energy used in bus transportation is extremely small compared to that consumed in automobile travel.

5. ENERGY USE IN INTERCITY AIR AND RAIL PASSENGER TRANSPORT

Energy consumed in intercity air passenger transportation is presently about ten percent of transport energy consumption. This share is expected to increase in the future. Energy consumed in rail passenger transport is a negligible portion of total transport energy.

5.1 BNL

Intercity air and rail transport passenger miles are taken from the Project Independence Study (U.S. FEA, 1974). These initial \$4 per barrel projections are based on growth rates of 6.8, 6.3 and 5.9% for air travel in the periods 1972 to 1980, 1980 to 1985, and 1985 to 1990 based on "projecting various factors". The corresponding growth rates for rail passenger travel are 0.8, 1.3 and 1.8%, respectively. The effect of price

BUS PASSENGER MILES OF TRAVEL (10⁹)

Year	HG, TF, SRI				BNL			
	Urban	Inter-city	School	Total	Urban	Inter-city	School	Total
1970	25	25	40	90				
1972					23	26	40	89
1975	26	26	40	92				
1980					32	30	40	102
1985	30	27	40	97	36	34	40	112
1990					46	38	40	124
2000	39	28	40	107	71	50	40	161

BUS ENERGY USE
(QUADS)

<u>Year</u>	<u>HG, TF, SRI</u>	<u>BNL</u>
1970	0.18	
1972		0.13
1975	0.18	
1980		0.15
1985	0.20	0.16
1990		0.18
2000	0.23	0.20

Figure 4.1 BUS ENERGY USE

increases to \$7 per barrel is to reduce total intercity travel and to adjust modal shares in such a way as to have a negligible effect on intercity, air and rail passenger miles.

Energy efficiency is assumed to increase gradually for air, from 15 passenger miles per gallon presently to over 17 passenger miles per gallon in 1990, and rail to increase from 36 passenger miles per gallon to 47 passenger miles per gallon. These efficiencies are applied to passenger mile projections to yield total energy demand.

5.2 HG and TF

For air travel, under the HG scenario, the upper limit of a recent industry forecast (Boeing 1974) of growth in passenger miles is accepted to 1985, extrapolated to 1990, and judgmentally extended to 2000 at a "somewhat slower rate, reflecting further maturation of the industry." It is assumed that technology, trip length distribution, and load factors (54.1%) remain at 1970-71 levels.

The TF scenario projects an immediate increase in load factors to 67% and a reduction in flight speed by 6% to the optimal energy efficiency speed. After 1985, it is assumed that all air passenger trips under 400 miles are shifted to high speed rail.

For rail, the HG scenario assumes a continuation of a recent growth rate of 3.7% (from Associated Universities, 1972) and assumed constant technology and load factors which give 2900 BTU/PM.

Under the TF scenario, rail gains passengers from air, and load factors increase so that energy requirements drop from 2900 BTU/PM to 1000 BTU/PM.

Total passenger miles of travel are the same under each scenario. Both the HG and TF projections are insensitive to changes in energy price.

5.3 SRI-Gulf

This is the average of HG and TF. It is also price-insensitive.

5.4 Comparison of Projections

The highest demand for travel and fuel is projected by HG, followed by SRI, TF, and BNL. Comparisons of passenger miles and energy use projections are contained in Figure 5.1.

6. ENERGY USE IN FREIGHT MOVEMENT

In 1970, road haulage accounted for 21% of total transportation energy consumption while rail carriage accounted for only 3.5%, the majority of which was applied to moving freight. Only a radical change in circumstances is likely to invert this situation. It follows from this that the greatest attention must be paid to the trucking sector and its likely response to changed circumstances.

6.1 BNL

The estimates of freight energy consumption generally are taken from the FEA \$7 a barrel scenario. This in turn, is an adjustment of the \$4 a barrel trend, based on a 4% annual growth of GNP. The adjustments allow for the effects of energy-price-induced fuel efficiency and transport demand adjustments. Thus, it is necessary to examine the basis of the \$4 a barrel projection, the adjustments applied to reduce it to a \$7 level, and finally BNL's modifications.

AIR (see "FREIGHT" for
RAIL)

PASSENGER MILES OF TRAVEL (10^9)

	<u>AIR</u>					<u>RAIL</u>				
	HG	TF	SRI	FEA \$7	BNL	HG	TF	SRI	FEA \$7	BNL
1970	160	160	160			11	11	11		
1972				102	153				12	14
1975	235	235	235			13	13	13		
1980			201						15	
1985	494	494	494	272	421	19	19	19	15	19
1990				361					16	
2000	1110	1037	1073		874	33	108	70		28

ENERGY USE (QUADS) See "Freight" for Rail Figures

	<u>AIR</u>				
Year	HG	TF	SRI	FEA \$7	BNL
1970	.9	.9	.9		
1972				1.4	2.2
1975	1.3	1.3	1.3		
1980				2.2	
1985	2.8	2.8	2.8	2.9	4.7
1990				4.0	
2000	6.0	5.6	5.8		8.6

Figure 5.1 INTERCITY PASSENGER TRAVEL & ENERGY USE

The \$4 projection is based on a model of national production incorporating changes in production relationships and projections of the distribution of final demand expenditures (Jack Faucett Associates, Inc., 1969). Some increased fuel efficiency is assumed to occur even at \$4.

Railroads

It is assumed that rail energy intensiveness (i.e. BTU/ton mile) will fall by 7% by 1990 due to adjustments in operating procedures and capital improvements in motive power, control systems and switching yards. Reductions in branch line operations, idling time and tank spillage are assumed to further decrease energy intensiveness. It is argued that the 2.4% increase in ton mile costs arising from a price of \$7 a barrel on imported oil will not induce further fuel efficiencies.

Trucking

Intercity trucking is assumed to adopt radials and complete dieselization to obtain a once-and-for-all improvement of 7% in fuel efficiency, operational by 1980, even at \$4 a barrel. Improved loads are expected to give a 5% reduction in energy intensiveness by 1990. Local trucking is not expected to change significantly at this price. At \$7 a barrel, the ton mile costs for local trucking are calculated to increase by .7% while those for intercity trucking increase by 1.7%. This would result in some small adjustments in capital and operations reducing intercity truck fuel intake slightly. At this price radials and improved load factors would result in a 3-6% saving in fuel for local trucking, but no reduction in mileage.

Air Freight

\$7 a barrel was postulated to result in the same fuel efficiencies and load factor increases as \$4 a barrel. Estimates of the elasticity of demand for air freight predicted some overall decreases in demand as well as some shift to less energy intensive modes. This does not amount to a major saving.

Total Demand and Modal Shifts

Possible product price changes and locational shifts are discussed with the conclusion that no significant changes in quantities or location of production and, thus, demand for transport, will result from a change in energy prices. In terms of shifts between road and rail, a switch of 10% of the 25% of traffic for which they compete is postulated. Thus, the projections do not, in fact, include adjustments to transport demand due to changes in product demands resulting from higher transport costs. They incorporate only a small shift between modes. The projected change in fuel consumption arises from increased efficiency and a slight modal shift to rail from road.

One major weakness in BNL's analysis is the failure to close the gap between the reported vehicle miles of non-freight and government trucking and the mileage estimated for these operations by assuming that they fill the gap in energy consumption between local and intercity freight truck energy consumption and total truck energy consumed. For 1972 they estimate and project 171 billion vehicle miles of non-freight and government trucking while other sources suggest 111 billion vehicle miles. This could constitute a 60% overestimate of demand in this category. No explanation or justification of this difference is offered.

In extending the FEA projections of 2000, BNL assumes that the intercity truck fuel mix reaches 100% diesel by 2000 but that other efficiencies achieved in the \$7 a barrel scenario remain constant beyond 1990. Ton miles for freight vehicles are grown at 2% p.a. from 1990 to 2000. Vehicle miles of non-freight trucking were projected at the same growth rate as freight ton miles.

6.2 SRI

The SRI Energy Model used high, low, and medium trajectories of end-use demand using TF, HG and their arithmetic mean as estimates. Thus, what is required is a review of the two Ford projections and their average.

Trucking

The HG forecast of total energy use for trucking is based on the Associated Universities (1972) project for the Office of Science and Technology, which is seemingly an extrapolation of the 1969 figure from the "Statistical Abstracts of the United States" (U.S. Bureau of the Census, 1970). To project this figure it is assumed that the energy demand for trucking is a constant fraction of automotive demand.

This gives the total energy use trajectory in Figure 6.1. This total is then disaggregated into 2 axle - 4 tire (30,200 BTU/TM), other single unit (6,300 BTU/TM) and combination vehicles (2,900 BTU/TM) on the basis of the 1969 split of the ton miles into 7%, 26% and 67%.

This is modified for the TF forecast by assuming a switch to diesel and a shift of long haul traffic to rail. There is no reference to the sensitivity of total demand to price. It is simply assumed that by 2000 the conversion to diesel is complete and includes all 2 axle - 4 tire and single units.

Figure 6.1 FREIGHT ENERGY USE

FREIGHT TON MILES (10^{12})						
	HG	<u>TRUCK</u> TF	BNL	HG	<u>RAIL</u> TF	BNL
1970	.53	.53		.77	.77	
1972			.63			.77
1975	.74	.74		.92	.92	
1980			.84			.91
1985	.89	.77	.99	1.03	1.46	1.03
1990			1.17			1.16
2000	1.12	.82	1.43	2.34	2.64	1.46

FREIGHT ENERGY USE (QUADS)								
	HG	<u>TRUCK</u> TF	SRI	BNL	HG	<u>RAIL</u> TF	SRI	BNL
1970	3.5	3.5	3.5		.5	.5	.5	
1972				3.7				.6
1975	4.2	4.2	4.2		.6	.6	.6	
1980				4.7				.6
1985	5.3	5.0	5.1	5.5	.9	1.0	.9	
1990				6.5				.8
2000	6.5	4.4	5.4	7.9	1.6	1.8	1.7	1.0

Figure 6.1 (Contd.)

For the switch to rail, it is assumed that the competitive area is 40% of all freight tonnage (1967) of which trucks carry 80% (Morton, 1971) and that longer haul traffic is the most likely to switch. They presume, on the basis of the 1972 National Transportation Report, that relaxation of regulation and marginal cost pricing would make rail attractive to over half the intercity freight moving by truck now. They assume that 20% of combination truck traffic (corresponding to hauls over 500 miles) shifts to rail by 1985 and 40% (hauls over 250 miles) by 2000. This yields the following values for ton mileage:

$$1985 \quad 0.2 \times 600 \times 10^9 \text{ TM} = 120 \times 10^9 \text{ TM}$$

$$2000 \quad 0.4 \times 750 \times 10^9 \text{ TM} = 399 \times 10^9 \text{ TM}$$

Assuming a rail intensiveness of 670 BTU/TM (equivalent to FEA 1980 figure) and diesel truck intensiveness of 2340 BTU this gives savings of .2 Q BTU in 1985 and .5 Q BTU in 2000 and a requirements trajectory as in Figure 6.1.

Railroad

HG projects railroad energy use at 3.7% p.a. (Associated Universities, 1972). An intensiveness value of 670 BTU/TM is taken from Hirst (1973). The resulting rail freight energy usage is given in Figure 6.1. The shift from truck assumed previously yields the following output and energy requirements for rail freight at 670 BTU/TM

<u>TF</u>	<u>Q BTU</u>	<u>TM bill</u>
1985	0.98	1460
2000	1.77	2640

There is no discussion of the implications of these shifts on rail track and rolling stock capacity and costs of expansion.

Air Freight

For air freight, HG takes the upper limit of an industry forecast of growth of ton-miles from 1985 to 1990 then judgmentally extends it to 2000 at a slower rate, assuming 1971 technology, trip length distribution and load factors.

TF assumes an increase in load factors and freight speeds to 1985 but a long term switch of freight traveling between 250 and 400 miles to rail and that under 250 miles to road.

6.3 Comparison of Projections

The BNL forecast of truck energy use rapidly overtakes the HG and TF profiles, which bracket SRI's profile, in the 1990's to exceed the SRI value by 2.5 QUADS by the year 2000. This departure is explicable in terms of the large shift from truck to rail embodied in the TF scenario which strongly influences the SRI profile. The TF scenario envisages a 20% shift of truck traffic to rail by 1985, rising to 40% by 2000 (Ford Foundation 1974, Appendix A, pp. 451-452). Even though the BNL and SRI forecasts are based on similar extrapolations of total ton miles, the assumption of a 3.5 times greater energy efficiency for rail freight transport and a shift of 1.1×10^{12} ton miles of freight from truck to rail, would account for the 2.5 QUADS BNL excess of truck energy use as compared to the 0.7 QUADS greater consumption by rail in the SRI forecast.

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