THE CURRENT AND FUTURE SAVINGS OF ENERGY ATTRIBUTABLE TO AMTRAK

A Staff Draft Analysis
Natural Resources and Commerce Division
Congressional Budget Office
May 1979

TABLE OF CONTENTS

SUMMARY

In weighing the merits of federal spending on passenger rail service in the United States, the Congress has considered costs, environmental benefits, effects on highway and airway congestion, impacts on urban and regional development, and benefits to persons without other forms of public transportation available to them. Increasing attention is also being given to the potential of Amtrak to help conserve energy, three aspects of which are examined here: the savings in energy associated with current Amtrak operations, the potential of Amtrak to save energy if it uses improved equipment and if it can attract more riders per car, and the potential of rail to save petroleum in the event of an acute national shortage of petroleum.

Current Situation

Amtrak currently saves energy for each passenger-mile it serves in the Northeast Corridor. These savings result because almost half of Amtrak's customers would use their cars if Amtrak were not available, and less energy is required for an average trip in the Northeast Corridor by rail than by auto. Also, one in six Amtrak passengers would use air service if no

trains were running, and far more energy is needed to make the trip by air. These energy savings from the availability of Amtrak are enough to offset energy losses resulting from travelers who would use bus if rail were not available.

Outside the Northeast Corridor, the nation would save energy if no rail service were operated. Amtrak outside the Northeast Corridor is less energy-efficient than the average auto. The energy losses from people who have switched to Amtrak from auto or bus are larger than the gains from those who switched from air.

Overall, both the current Amtrak route system and the system proposed by DOT lose energy since the savings in the Northeast Corridor are more than offset by losses outside the corridor (see the first column in the Summary Table).

Future Potential

Trains could use considerably less energy per passenger-mile than at present if they made use of new, more efficient equipment and were able to attract enough passengers to operate cars more nearly filled. By the time these improvements could be realized, however, autos will have efficient in their use of fuel, partly in response to the fuel economy standards embodied in the Energy Policy and Conservation Act of 1975. Airlines will also be more fuel-efficient as they phase in new aircraft. Under optimistic assumptions about future improvements for rail relative to other modes--that is, assuming rail passengers per car improve by 25 percent but there is no change for other modes--rail is far less fuel-efficient than bus and far more fuel-efficient than air, both inside and outside the Northeast Corridor. Rail appears to be more fuel-efficient than the typical auto inside the Northeast Corridor, but not outside it.

The second column in the Summary Table shows the results of maintaining rail service compared to shifting passengers to other modes assuming significant improvements in rail technology and passenger loads. The current rail system as a whole would exhibit a small loss of energy. The system proposed by the Department of Transportation would generate a small saving of energy. A system that offered rail service only in the Northeast Corridor would generate a much larger saving of energy, equivalent to about 877 barrels of petroleum per day. Furthermore, as shown in the third column of the Summary Table, because such a system would use electricity rather than petroleum, it could generate a saving of 1,777 barrels of petroleum per day. Even that savings represents less than one hundredth

SUMMARY TABLE. FUTURE SAVINGS AND LOSSES OF PETROLEUM AND OTHER ENERGY FOR ALTERNATIVE RAIL SYSTEMS: BARRELS PER DAY OF PETROLEUM

	Petroleum and Non-petroleum		Petroleum Only
Rail System	Assuming Current Efficiency	Assuming Improved Equipment and Increased Loads a/	Assuming Improved Equipment and Increased Loads a/
Northeast Corridor	411	877	1,777
System Proposed by DOT	-1,360	126	1,108
Current Amtrak System	-1,989	-141	873

NOTE: Based on passenger-miles projected for 1984 and on improvements for mid 1980s as described in text.

a/ Assumes a 20 percent improvement in Amtrak energy efficiency and a 25 percent improvement in load factor (to 55 percent).

of a percent of the nation's consumption of petroleum. More petroleum could be saved if each auto were driven five fewer miles each year.

Potential in an Emergency

If imports of petroleum were severely curtailed, tight restrictions could be placed on the amount of petroleum allocated to airlines and autos. Under these circumstances, both bus and rail could provide emergency transportation. In such a crisis situation, savings of petroleum are more important than savings of other forms of energy. Rail service in the Northeast is at an advantage in this regard since it runs chiefly on electricity, and electrification of additional track is planned for that region. Under assumptions that are very optimistic for rail service--namely, that the fuel efficiency of vehicles will increase by 20 percent and that trains will run absolutely full, including a large number of standing passengers--it appears that rail service in the Northeast Corridor can operate using only one-third as much petroleum per passenger-mile as buses. Even under these assumptions, rail service outside the corridor uses more than twice as much petroleum per passenger-mile as buses.

Conclusion

In all three situations examined here--current conditions, possible future improvements in rail efficiency, and the possibility of an acute shortage of petroleum—the same general conclusion is reached: Amtrak rail service may be helpful in conserving energy within the Northeast Corridor. In the rest of the country, however, Amtrak appears to be an energy-loser, both now and in the future. Both within and outside the Northeast Corridor, rail appears to be far outperformed by bus in its use of energy. Rail is more energy-efficient than bus only under crisis conditions and when the sole concern is petroleum use—and then only in the Northeast Corridor.

Other corridor-type services offered by Amtrak may resemble the Northeast Corridor in their energy use, and no attempt has been made to isolate them. The fact that rail service in the Northeast Corridor is electrified drives the conclusions about petroleum savings. While these conclusions may apply to other electrified corridor service, they would not be applicable to nonelectrified ones.

Obviously, energy use is but one of many dimensions upon whch the desirability of future federal spending on passenger rail service should be based.

CHAPTER I. INTRODUCTION

In weighing the merits of federal spending on passenger rail service in the United States, the Congress has considered costs, environmental benefits, effects on highway and airway congestion, impacts on urban and regional development, and benefts to persons without other forms of public transportation available to them. Since the Arab oil embargo, the effects of rail service on energy conservation have been added to the list of factors entering the debate over the appropriate level of passenger rail service. Three energy-related questions that are commonly asked are:

- How does rail service currently compare with other modes of intercity passenger service in the amount of energy, particularly petroleum, it consumes in moving people?
- How might improved rail equipment and better use of equipment affect such comparisons in future years?
- What unique advantages does rail service have in providing transportation during periods of acute energy stortages such as embargoes or other disruptions in international supply lines?

Answers to these questions are necessarily somewhat speculative because of variations in the performance of locomotives, differences in the number and type of cars in each train, differences in the quality of road beds, variations in the number of passengers per train and the distances they travel, and so forth. Nevertheless, some approximate answers can be constructed from the actual operating experience of Amtrak, computer simulations, and estimates of the improvements likely to be realized in the future. Based upon a review of available evidence, this paper develops estimates of the energy use of the major modes of intercity transportation. These estimates are then applied to estimate the fuel savings attributable to three alternative rail systems:

- The current Amtrak system,
- The reduced passenger rail system proposed by the Secretary of Transportation in his report to the Congress under the Amtrak Improvement Act of 1978, and
- A rail system serving only the Northeast Corridor of the United States.

Two sets of estimates are developed—one based upon current operations and patterns of energy use, the other based upon substantially improved rail operations and technology. These two sets of estimates provide a range within which future performance will most likely lie.

CHAPTER II. FACTORS INFLUENCING THE USE OF ENERGY IN INTERCITY TRANSPORTATION

The amount of energy needed to move vehicles varies widely from mode to mode, and computations based on vehicle miles are difficult to compare because vehicles vary widely in their seating capacity. A consistent index for gauging the potential performance of a technology is the energy consumed per seat mile. This should not, however, be considered as a measure of the efficiency of energy used in actual service, since no mode of intercity transportation is able to fill its vehicles to capacity on a regular basis.

A complete analysis of the energy required for each mode of transportation involves several factors:

- propulsion energy—the energy needed to move the vehicle. This is usually expressed in terms of the energy per seat-mile in order to facilitate comparison between vehicles with different seating capacities.

- vehicle manufacturing energy—some energy is required to manufacture vehicles, and, for completeness, this should be taken into account. It is allocated over each mile that is expected during the life of the vehicle.

- load factor--in order to convert the energy-efficiency of a vehicular technology into the amount of energy actually used per person, it is necessary to consider the fraction of seats that are typically occupied.

- circuity—meaningful comparison of the relative energy-efficiency also requires that adjustments be made for any unproductive miles that are operated. The main source of unproductive miles are detours from the direct airline distance, often due to the fact that service is offered only over some limited network of routes.

Each of these factors is examined in the remainder of this section.

PROPULSION ENERGY

On the basis of estimates of the propulsion energy required per seat mile, buses require the least energy per seat mile, followed by rail, auto, and air, in that order (see Table 1). These estimates are examined in detail, since they are the key to assessing overall energy use.

Rail in the Northeast Corridor

The estimate of propulsion energy for rail service in the Northeast Corridor--1,019 BTU 1/ per passenger mile--is based on computer simulations of Metroliner equipment, assuming current operating conditions along the Washington-New York City segment of the track. 2/ These simulations

---

1/ British Thermal Units. A gallon of gasoline contains about 125,000 BTU.

2/ Ram K. Mittal, "Energy Intensity of Intercity Passenger Rail," report submitted to the U.S. Department of Transportation, December 1977, pp. 6-13.

TABLE 1. FACTORS INFLUENCING THE USE OF ENERGY IN INTER-CITY TRANSPORTATION: CURRENT OPERATIONS

	Propulsion Energy (BTU per seat mile)	Vehicle Manufacturing Energy (BTU per seat mile)	Load Factor (Fraction of seats occupied)	Circuity Factor (Ratio of actual to great-circle mileage)
Northeast Corridor				
Rail	1,019	26	0.369	1.100
Auto	1,389	263	0.440	1.090
Bus	463	24	0.472	1.100
Air	4,374	15	0.558	1.050
Non-Northeast Corridor				
Rail	1,737	26	0.472	1.405
Auto	1,389	263	0.440	1.231
Bus	463	24	0.472	1.211
Air	3,480	15	0.558	1.050

SOURCE: Reports cited in text.

also develop a series of relationships, such as that shown in Figure 1, that depict the energy required for a specified train to cruise at different speeds. These relationships have a common feature: they show that, under cruising conditions, the least energy is required at a speed of about 20 to 30 miles per hour. This same study simulates the operation of trains under actual operating conditions, involving numerous accelerations and decelerations for stations, curves, other rail traffic, or grade crossings. They may also require operation at different speeds along various portions of the route. The simulations generally show that much more energy is needed under actual operating conditions than is needed for cruising, and that far more energy is needed for actual operations than for cruising at low speeds. This distinction is important because some of the debate about the efficiency of railroads is based upon low-speed cruising conditions, and this is not a realistic basis for assessing overall use of energy.

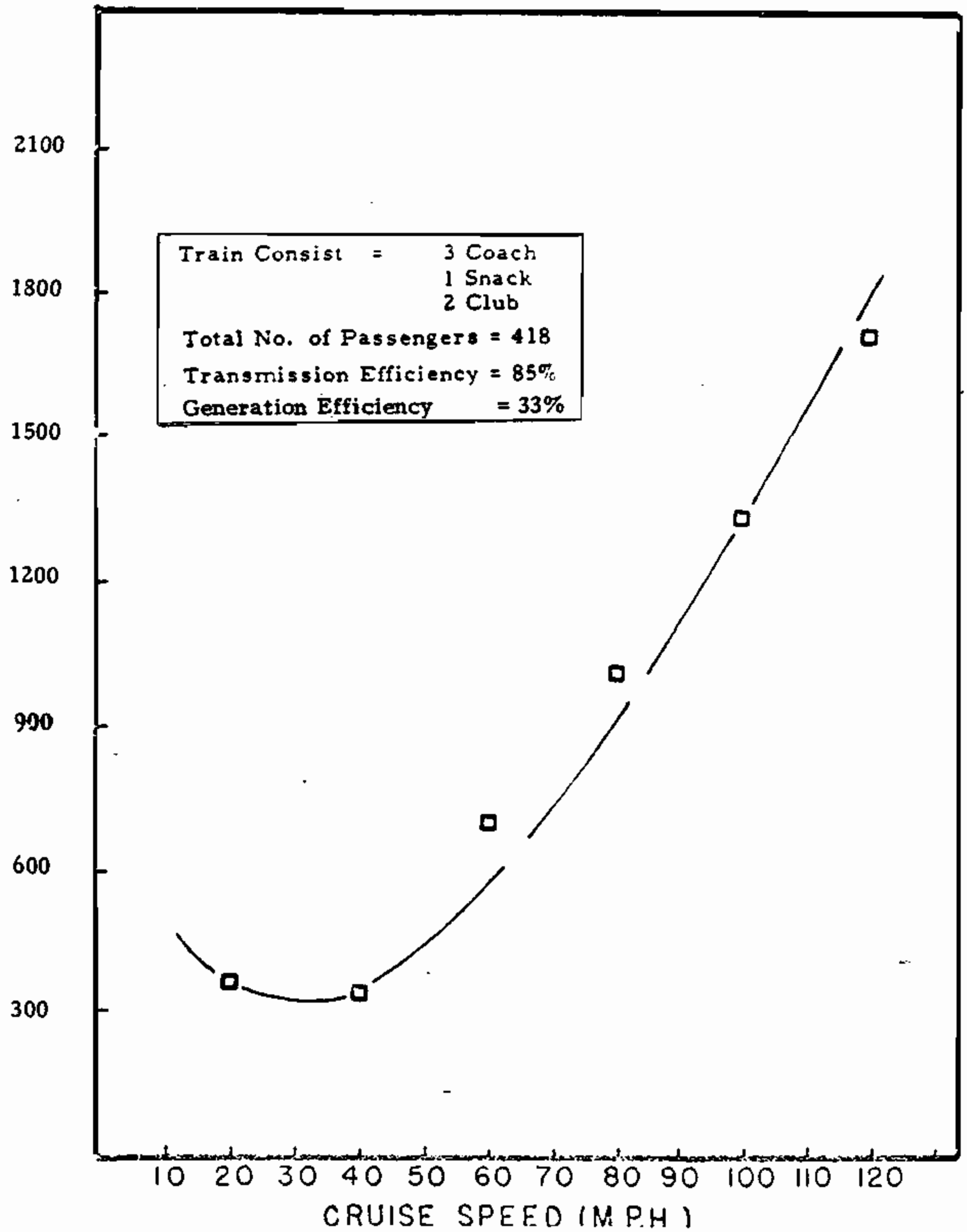
In particular, Amtrak has made comparisons that imply energy use by rail of 250 BTU to 312 BTU per seat mile. 3/ These numbers are based upon trains cruising at 50 or 55 miles per hour. This does not appear to be an appropriate basis for gauging the potential of trains, even when improvements within the Northeast Corridor have been completed, since trains will

---

3/ Testimony of Amtrak president Alan S. Boyd before the Senate Commerce Committee, March 5, 1979, p. 8.

FIGURE 1

CRUISING ENERGY INTENSITY OF STANDARD METROLINER (6 CARS)



SOURCE: Ram K. Mittal, "Energy Intensity of Intercity Passenger Rail," Report submitted to the U.S. Department of Transportation, December, 1977, p. 4-29. The units shown have been converted to reflect input to the generator assuming efficiency of 33 percent.

still operate at different speeds as they approach stations, curves, other trains, etc. Furthermore, one of the chief aims of the significant improvements that are being made to tracks and other rail facilities as part of the Northeast Corridor Improvement Project is to permit high-speed rail operations in this area. High-speed service is a vital factor in attracting passengers to use the service, but it requires more energy than low-speed service, as apparent from relationships such as that shown in Figure 1. The Northeast Corridor Improvement Project has estimated that current rail service in the corridor uses from 943 to 1,615 BTU per seat-mile, and that Metroliners use between 982 and 1,615 BTU per seat-mile. 4/ The estimate used here, 1,019 BTU per seat mile, thus lies toward the energy-efficient end of the estimates made by the Northeast Corridor Improvement Project.

Rail Outside the Northeast Corridor

The propulsion energy for trains outside of the Northeast probably varies widely from route to route depending upon the configuration of the trains. For example, a long-distance train with four coach cars, four sleeper

---

4/ Northeast Corridor Improvement Project, "Final Programmatic Environmental Impact Statement," vol. 1, June 1978 p. 3-106.

cars, one dining car, one baggage car, and one observation car has about the same passenger-carrying capacity as a train with five coach cars. Assuming that the energy required per car is roughly the same on either train, the long-distance train in this illustration requires more than twice the energy per seat mile as a train with five coach cars.

The make-up of trains outside the Northeast Corridor is probably far more variable than that within the corridor because of the greater variations in the amount of patronage and in trip distance that are likely outside the corridor. Thus, rather than attempt to postulate the composition of a typical train outside of the Northeast Corridor and then analyze its use of energy, it is possible to construct an estimate of the average use of energy by trains throughout the Amtrak system, and then exclude that which is attributable to trains in the Northeast Corridor, using the results discussed above. 5/ The estimate thus computed is about 70 percent higher than the

---

5/ For simplicity, this computation assumed that all Amtrak trains experience a load of 44.1 percent, the load reported by the Transportation Association of America, and that Amtrak trains in the Northeast Corridor have a load of 36.9 percent, as reported by Amtrak. Assuming that Northeast Corridor trains require 1,019 BTU per passenger mile as discussed earlier, this implies that Northeast Corridor trains consume 1,019 ÷ 0.369 = 2,762 BTU per passenger mile. Over the Amtrak system as a whole in 1977, it took 3,410 BTU to produce a passenger mile. (A.B. Rose, "Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements," Oak Ridge National Laboratory, January 1979, pp. 6-9). Amtrak reports that 29.4 percent of its passenger miles occur in the Northeast corresponding number for the Northeast Corridor. This appears consistent with the train composition expected along long-distance routes.

Auto, Bus, and Air

The estimates of propulsion energy for auto, bus, and air rely on a study by the Oak Ridge National Laboratory. 6/ The estimates are based upon the following assumptions: Air operations in the Northeast Corridor utilize short-haul aircraft, which tend to be smaller planes that are relatively energy-intensive on a seat-mile basis. Air operations outside the Northeast Corridor use long-haul aircraft. Autos average 18 miles per gallon in intercity driving and five seats per car.

There is relatively little dispute about the numbers for energy used per seat mile by the air, auto, and bus modes. Minor variations (typically 5-10

Corridor. In order to find the appropriate rate of energy consumption for the trains outside the Northeast Corridor, it is necessary to find a rate which, when weighted by its share of passenger miles and combined with Northeast Corridor use of energy, results in an overall average of 3,410 BTU per passenger mile. This turns out to be 1,737 BTU per seat mile. The estimate of BTU per seat mile is directly linked to the BTU per seat mile for trains inside the corridor. To the extent that this estimation procedure may overstate the efficiency of trains outside the corridor, it would simultaneously understate the efficiency of trains in the corridor, and vice-versa.

6/ Rose, "Energy Intensity and Related Parameters of Selected Transportation Modes, pp. 3.15 and 5.9.

percent) can be found, depending upon the year of the estimate and details of the estimation procedure. By and large, however, the numbers shown in Table 1 for the propulsion energy of these modes are representative of a wide body of research. 7/

VEHICLE MANUFACTURING ENERGY

The energy required to manufacture a vehicle, when allocated on a seat-mile basis over the life of the vehicle, typically represents only a small fraction of the energy needed to move a vehicle. 8/ Thus, the figures in the second column of Table 1 affect the overall results developed here only slightly, in the case of the automobile, for which the manufacturing energy represents about 19 percent of the propulsion energy. The inclusion of vehicle manufacturing energy in this analysis thus tends to diminish the energy-efficiency of automobiles relative to other modes of travel. In

---

7/ See, for example Mittal, "Energy Intensity of Intercity Passenger Rail"; Rose "Energy Intensity and Related Parameters of Selected Transportation Modes"; Northeast Corridor Improvement Project," Final Programmatic Environmental Impact Statement," vol. I, June 1978; U.S. Department of Transportation, "Amtrak and the Energy Crisis"; and Eric Hirst, "Energy Intensiveness of Passenger and Freight Transport Modes: 1950-1970," Oak Ridge National Laboratory, April 1973.

8/ The numbers reported are drawn from Margaret Fulton Fels, "Suburb-to-Suburb Intercity Travel: Energy, Time and Dollar Expenditures," Princeton University, June 1976.

particular, to the extent that rail attracts riders from automobiles, including manufacturing energy tends to increase the savings of energy that are attributed to rail.

LOAD FACTOR

The load factor, or fraction of seats occupied, which is shown in the third column of Table 1, ranges from 0.37 to 0.56 for intercity passenger modes. 9/ Air has the highest load factor, rail in the Northeast Corridor has the lowest.

A load of 2.2 persons per car is assumed for automobiles. This is the average load for the longest category of trips that was recorded in the Nationwide Personal Transportation Survey. 10/ Assuming five seats per car, the load factor for autos is thus .44. This average load is toward the

---

9/ The values shown are for 1977 as computed by the Transportation Association of America (TAA) from data furnished by carriers to the Interstate Commerce Commission and the Civil Aeronautics Board. Adjustments have been made to the rail load that TAA reports. Those adjustments reflect the fact that, as supported by detailed statistics available from Amtrak for earlier years, load factors in the Northeast Corridor are slightly lower than the average for the remainder of the system.

10/ Federal Highway Administration, Nationwide Personal Transportation Survey, vol. 1: Automobile Occupancy.

low end of the range of numbers reported for intercity auto travel. (Amtrak, for example, has assumed a load of 2.5 persons.) For purposes of this study, the lower number seems appropriate since rail passengers are more likely to be travelling alone so that, if they switch to autos, they would probably have average loads lower than those of other auto users. 11/ Using this relatively low load factor in the analysis favors rail relative to auto in the use of energy.

CIRCUITY

In comparing the energy efficiency of alternative intercity modes, it is useful to do this "as the crow flies"—on the basis of great circle statute miles. Because of network limitations, however, most trips require traveling more than the great-circle mileage, although modes differ substantially in this regard. For example, on a trip from New York to Chicago, the normal Amtrak route is by way of Philadelphia and Harrisburg. The same trip by auto, using the Interstate Highway System, is somewhat shorter in miles, while travel by air is potentially the most direct.

11/ Single-person parties make up 40 to 60 percent of travel on air, bus, or rail, while less than 20 percent of intercity auto travel is by single-person parties; see U.S. Bureau of the Census, National Travel Survey of 1967, TC67-N1, p. 37. This suggests that users of commercial modes that switch to cars are probably more likely to travel alone than current auto users, and that a relatively low load factor should be used for rail users who switch modes.

Circuity—the ratio of actual travel distance to the great-circle statute mileage—generally tends to be small when networks are extensive, and large when network limitations force many trips to rely on connections through out-of-the-way junctions. Thus, the Amtrak system proposed by the Department of Transportation (DOT), which would operate 57 percent of Amtrak's current route miles, would necessarily make some rail travel more circuitous than it is at present. The average circuity on the system would not, however, be affected in the same way. Since most of the major population centers in the Northeast Corridor lie roughly in a straight line, rail travel in the corridor is not circuitous. Under the DOT proposal, the Northeast Corridor would account for a larger fraction of the system than at present, and this would tend to reduce the circuity of the system as a whole. A rail system that served only the Northeast Corridor would result in low average circuity, even though the network would be very limited.

In addition to limitations in the network that require travel through some out-of-the-way city, circuity for airlines depends upon the traffic patterns around airports and enroute flight lanes. 12/

12/ Michael P. Miller, "Energy Efficiency of Current Intercity Transportation Modes," Proceedings of the Third National Conference on the Effects of Energy Constraints on Transportation Systems, August 1976, pp. 245-68.

The circuity factors shown in the last column in Table 1, 13/ which are based on current travel patterns, show that rail travel in the Northeast Corridor is relatively direct, while rail travel nationwide is relatively circuitous. Auto and bus have similar circuity, while air is shown to be fairly direct (that is, circuity of 1.05). Actual monitoring of distances in flight shows that airlines are far from perfectly direct. Because of the way aircraft mileage is recorded, however, the in-flight data already adjust for circuity. That is, data collected by the Civil Aeronautics Board show actual fuel consumption for a flight, but show only the statute miles for the trip flown. Thus, even if an airplane flew 300 miles to get from Washington to New York, the vehicle miles shown by the Civil Aeronautics Board would be 205, the great-circle mileage between those two cities. Accordingly, no further correction for circuity is required for air travel, except to allow for trips that are routed through intermediate points. Circuity of this sort is probably quite small since there is direct non-stop air service between most major population centers. Nevertheless, there may be, on average, circuity equivalent to a few percent on the nation's air system. Accordingly, an allowance of 5 percent has been made by assuming a circuity factor of 1.05.

13/ The circuity factors for air are assumed to be 1.05 as discussed in the text. The circuity factors for the Northeast Corridor are based on a study of New York-Washington travel. (Boeing Commercial Aircraft Company, Intercity Passenger Transportation Data-Energy Comparisons, vol. 1, Seattle, Washington, May 1975. The circuity for travel outside the Northeast Corridor are based on Rose, "Energy Intensity and Related Parameters of Selected Transportation Modes," using the circuity for the longest distance category reported under each mode.

By including circuity in this analysis, it is possible to compare modes on the basis of the productive miles of travel they produce. In particular, this tends to favor travel by rail in the Northeast Corridor, where service is fairly direct, and to penalize rail outside the Northeast Corridor, where it ranks as the most circuitous mode.

ENERGY USED FOR CONSTRUCTION AND ACCESS

Two uses of energy associated with intercity transportation have not been included in this analysis—energy for construction and access. 14/ Construction of highways, rail lines, and air terminals can consume large amounts of energy. This energy is not included here for two reasons. First, since Amtrak carries only a minor share of the nation's intercity passenger traffic, it is not clear that additional facilities would need to be constructed for the other modes if Amtrak discontinued operations. Nor does it appear fair to burden rail with the energy expended in the Northeast Corridor Improvement Project, since it is not clear that additional rail patronage would influence the amount of energy expended in construction there. Second, after allocating construction energy over the expected life of each

14/ These elements should generally be included, following the practice in Congressional Budget Office, Urban Transportation and Energy: The Potential Energy Savings of Different Modes, Committee Print of the Senate Committee on Environment and Public Works, September 1977.

facility, the energy per passenger mile is typically quite small.

The omission of the energy used getting to and from stations is potentially more serious. Even so, the energy used to gain access to a station or terminal is likely to be quite small compared with the energy required for the line-haul portion of the trip. This is quite different from urban transportation, where access energy can be a significant portion of total energy. A second major reason for excluding access energy from this analysis is the lack of consistent data about access modes and distances for each intercity mode. In absolute terms, access energy is probably the largest for air, although this may not be true when it is allocated over the entire trip. It is the lowest for auto.

CHAPTER III. CURRENT ENERGY SAVINGS

The use of energy by each mode under current operating conditions is summarized in Table 2. The first column, operating energy, simply shows the energy needed to move a passenger one route-mile. This is calculated as the propulsion energy per seat-mile divided by the load factor, or fraction of seats that are occupied. On this basis, bus is the most energy-efficient mode, using about one-third the propulsion energy per passenger-mile as that used by the next most efficient mode. Air is the least efficient mode. Within the Northeast Corridor rail is about 14 percent more efficient than auto, while outside the Corridor it is about 14 percent less efficient than auto.

Modal energy, shown in the second column in Table 2, provides a more accurate summary of the energy requirements for each mode than does operating energy. In addition to operating energy, modal energy includes the energy used in manufacturing vehicles and it adjusts for circuity. Modal energy is thus a measure of energy per productive mile traveled. The inclusion of circuity, or the ratio between actual miles traveled and the minimum or great-circle distance between two points, has little effect on modal energy in the Northeast Corridor. Outside the corridor, however, rail

TABLE 2. CURRENT USE OF ENERGY BY INTERCITY PASSENGER MODES: BTU PER PASSENGER-MILE

	Operating Energy (Energy used in propulsion only, computed per actual mile traveled)	Modal Energy (Energy used in propulsion and vehicle manufacturing, computed per great-circle mile traveled)	Program Energy (Net energy gained or lost per passenger-mile attracted to rail)
Northeast Corridor			
Rail	2,762	3,115	544
Auto	3,157	4,092	
Bus	981	1,135	
Air	7,839	8,259	
Non-Northeast Corridor			
Rail	3,680	5,248	-1,267
Auto	3,157	4,622	
Bus	981	1,249	
Air	6,237	6,577	

tends to be significantly more circuitous than other modes, causing its modal energy to increase.

On the basis of modal energy, bus is the most energy-efficient mode, air is the least efficient, and rail ranks better than auto in the Northeast Corridor but slightly worse outside the Corridor. In the Northeast Corridor, bus is far more energy-efficient than rail, while air is far less energy-efficient. Outside the Northeast Corridor, bus is far more energy-efficient than rail, auto is roughly the same as rail, and air is far less energy-efficient than rail.

Program energy, the last column in Table 2, measures the net energy savings or losses of rail compared with the mode that passengers would use if rail service was not available. For example, since travel by rail is much more energy-efficient than travel by air, energy is saved when someone uses rail instead of air. In the Northeast Corridor, 5,144 BTU of energy are saved for each mile of travel diverted from air to rail. On the other hand, energy is lost when travelers are attracted from bus to rail. Such losses can be substantial, averaging 3,999 BTU per passenger-mile diverted outside the Northeast Corridor.

In order to estimate the fraction of passengers that would use each of the other modes if there were no rail service, the figures in Table 3 were

TABLE 3. MODES USED BY RAIL PASSENGERS IF TRAINS NOT AVAILABLE: IN PERCENTS

	Northeast Corridor	Non-Northeast Corridor
Auto	48.0	45.8
Bus	32.2	25.0
Air	16.1	23.6
No Trip	3.7	5.6

SOURCE: Calculated from Amtrak Passenger Assessment Survey of February 1979.

used. These reflect the results of the latest Amtrak survey, which asked riders which mode they would use if Amtrak were not available. In the Northeast Corridor, about half of Amtrak's riders say they would use auto instead: each such trip reflects a saving in energy due to rail. About one in six Amtrak riders say they would use air if train service were not available: these also imply energy savings. Roughly one-third of Amtrak's riders in the Northeast Corridor say they would use bus if rail service were not available: each of these represents a loss of energy due to rail.

Overall, rail saves 544 BTU per passenger-mile in the Northeast Corridor. Outside the Corridor, rail results in energy losses of 1,267 BTU per passenger-mile. That is, without Amtrak service in the Northeast Corridor, each current rail user would use 17 percent more energy, on average, per passenger-mile than at present. But outside the Corridor, each current rail user would need 24 percent less energy, on average, if rail service were not provided.

CHAPTER IV. POTENTIAL ENERGY SAVINGS

The previous chapter described the energy currently used by each mode of intercity transportation. But, given the expected improvements in energy efficiency for rail and other modes, the results shown in Table 2 are not the best basis for assessing the future potential of each mode.

POTENTIAL USE OF ENERGY BY MODE

Table 4 shows the potential energy savings of rail in the mid 1980s assuming that substantial improvements are made in technology and load factors. The technological efficiency of rail is assumed to improve by 20 percent. Amtrak president Alan S. Boyd testified before the Subcommittee on Transportation of the House Committee on Appropriations that Amtrak's new equipment should improve its energy efficiency by between 7 percent and 22 percent. The load factor systemwide is assumed to increase to 55 percent, up 25 percent from its current level. Both assumptions appear quite optimistic. In particular, the load factor assumption is substantially greater than the 37.6 percent reached by Amtrak in 1974, the year most affected by the oil embargo. It is also significantly greater than the typical load factors achieved in other high-speed rail corridors around the world.

TABLE 4. POTENTIAL USE OF ENERGY BY INTERCITY PASSENGER MODES: BTUs PER PASSENGER MILE IN THE MID 1980s:

	Operating Energy (Energy used in propulsion only, computed per actual mile traveled)	Modal Energy (Energy used in propulsion and vehicle manufacturing, computed per great-circle mile traveled)	Program Energy (Net energy gained or lost per passenger-mile attracted to rail)
Northeast Corridor			
Rail	1,482	1,682	1,162
Auto	2,702	2,946	
Bus	981	1,135	
Air	6,271	6,613	
Non-Northeast Corridor			
Rail	2,527	3,616	-537
Auto	2,105	3,326	
Bus	981	1,250	
Air	4,989	5,267	

NOTE: The following assumptions were made about future (mid 1980s) energy efficiencies for each mode:

Rail: Operating energy efficiency will improve by 20 percent and load factors will improve to 55 percent, a 25 percent improvement over current levels. Both of these represent optimistic assumptions.

Auto: A 50 percent improvement in fuel economy from 18 miles per gallon to 27 miles per gallon.

Bus: No improvement—a pessimistic assumption.

Air: A 20 percent improvement in operating efficiency but no change in load factor—a pessimistic assumption.

As shown in Table 5, only the Tokyo-Osaka line exceeds the load factor assumed for Amtrak in this section. The Tokyo-Osaka corridor also has a load factor of 80 percent for air operations, a number well outside U.S. experience. It is questionable whether such loads could ever be generated in the United States.

Automobile fuel efficiency is assumed to improve to 27 miles per gallon for highway travel. This is in line with improvements expected under the Energy Policy and Conservation Act of 1975, which calls for new cars to achieve an average of 27.5 miles per gallon for a combination of city and highway driving by 1985. The load factor for auto trips is assumed to remain at an average of 2.2 persons per car.

No improvements in fuel efficiency or load factor are assumed for buses. This assumption is probably not realistic, but gives rail the benefit of the doubt about the relative performance of bus and rail in future years.

The energy efficiency of air travel is assumed to improve by 20 percent by the mid to late 1980s. 15/ No improvement in air load factors is

---

15 J.D. Alexander et al, "Time, Cost, and Energy Factors for Intercity Transportation", presented at Engineering Foundation Conference, Henniker New Hampshire, July 1978, p. 32.

TABLE 5. LOAD FACTORS IN CORRIDORS WITH HIGH-SPEED RAIL SERVICE IN OTHER COUNTRIES

Corridor	Percent of Seats Occupied
Tokyo-Osaka (1975)	66.0
Paris-Bordeaux (1976)	50.0
Montreal-Toronto (1975)	49.7
Northeast Corridor (1977)	47.1
Rome-Milan (1976)	45.0
London-Manchester/Liverpool (estimated for 1976)	35.0

SOURCE: Robert A. Nelson, Donald Goldman, and Edward Ward, "High Speed Rail Passenger Transportation in Six Countries and the Northeast Corridor of the United States," Report submitted to the Federal Railroad Administration, 1979.

assumed in these calculations. This assumption is probably pessimistic, since any event that gives rise to increased loads on rail (such as a shortage of automotive gasoline) would most likely increase the load factors for buses and airlines as well. Nevertheless, in attempting to put an upper bound on the potential contributions of rail, increased loads on other modes are ignored.

The results in Table 4 show that Amtrak operations in the Northeast Corridor could result in larger energy savings than currently experienced: 1,162 BTU per passenger-mile, a little more than double the savings estimated assuming continuation of current technology and load factors. Rail passenger operations outside the corridor continue to result in energy losses, although not as large as currently. The projections show a loss of 537 BTUs per passenger-mile as compared with a loss of 1,267 BTU now.

POTENTIAL SAVINGS OR LOSSES OF ENERGY

The total energy savings potential of rail, estimated using the results developed earlier, are summarized in Table 6. Under both current operating conditions and assumed future improvements in energy efficiency, the Northeast Corridor rail service results in energy savings while the current Amtrak network wastes energy. The assumed future improvements in rail energy efficiency could be enough to change the rail system proposed by DOT from an energy loser to a small energy saver.

TABLE 6. SAVINGS OR LOSSES OF TOTAL ENERGY FOR ALTERNATIVE RAIL SYSTEMS, 1984: IN BARRELS OF PETROLEUM PER DAY a/

Rail System	Assuming Current Efficiency	Potential, Assuming Improved Equipment and Increased Loads
Northeast Corridor	411	877
System Proposed by DOT	-1,360	126
Current Amtrak System	-1,989	-141

a/ Assuming that the number of annual passenger-miles for each system is as follows: Northeast Corridor, 1.447 billion; System proposed by DOT, 4.128 billion; Current Amtrak System, 5.079 billion.

If only the Northeast Corridor were served, the energy savings would be more substantial. Given current energy efficiency, the difference between the amount of petroleum used by the current Amtrak system and that used by rail service limited to the Northeast Corridor is 2,400 barrels per day. (BTU is the conventional unit for measuring vehicle efficiency while barrels per day are generally used for total energy savings or losses). Even with future improvements in energy efficiency, the difference between the current Amtrak system and a Northeast Corridor only system is more than 1,000 barrels per day. Relative to the current Amtrak system, the system proposed by DOT would save the equivalent of 267 barrels of petroleum per day.

CHAPTER V. ADVANTAGES IN TIMES OF CRISIS

In the event of an acute shortage of petroleum, it is argued that rail service offers two unique advantages over other modes of transportation:

- o Some rail services can operate on electrical power, and electricity can be generated from fuels other than petroleum.
- o Curtailment of petroleum imports could result in a situation where air and auto travel, which are generally relatively fuel-intensive, could be severely restricted. In this instance, unprecedented demands could be placed on the rail and bus modes. In particular, Amtrak may be able to make much greater use of long trains with better energy efficiency than that achievable under normal circumstances.

These two potential advantages are evaluated in the following sections.

DECREASED RELIANCE ON PETROLEUM

The discussion in Chapters III and IV shows the total energy requirements for each mode from all the primary sources of fuel—including oil, coal, and nuclear. If there is another oil embargo, or a similar sharp cut in petroleum supplies, however, there will be particular concern about saving petroleum-based energy. Most of the modes considered here depend on petroleum for the vast majority of their energy needs, so recomputing their energy requirements in terms of petroleum energy saved is unlikely to result in many dramatic shifts from previous calculations. The only significant exception is for rail in the Northeast Corridor.

About 80 percent of Amtrak's seat-miles in the Northeast Corridor are on electric-powered trains. In turn, about 37 percent of electric power in the Northeast is generated by petroleum. The net effect of this is that roughly 50 percent of rail propulsion energy in the Northeast is provided by petroleum--30 percent via electricity and 20 percent directly. Thus, assuming that the energy required for vehicle manufacture is non-petroleum based, rail requires about 1,519 BTU of petroleum energy per productive passenger-mile (modal energy). This is still more than the total energy required to provide one passenger-mile by intercity bus. In terms of program energy, the net savings or losses taking into account the mode that would be used if there were no rail service, rail service in the Northeast Corridor saves over 1,800 BTU of petroleum per passenger-mile. During peak periods of electric demand, petroleum is used disproportionately, so to the extent that rail service coincides with electric generating peaks, these savings are overstated.

Outside the Northeast Corridor, viewing savings or losses in terms of petroleum instead of all energy has little effect on the earlier results shown in Table 4. Less than 10 percent of Amtrak's system is electrified outside of the Northeast Corridor, and thus most of the energy used by all modes is petroleum-based.

In the future, after completion of the Northeast Corridor Improvement Project, it is assumed that rail service in the Northeast will rely completely on electric power. In 1987, it is estimated that about 29 percent of the Northeast Corridor's electric power will be generated by petroleum, so that 29 percent of rail propulsion energy will be provided by petroleum. 16/ Outside the Northeast Corridor, it is assumed that 10 percent of Amtrak's service will be electrified, none of which will be provided by petroleum. In calculating future petroleum savings, it has been assumed that all vehicle manufacturing energy is non-petroleum based.

Table 7 shows estimated petroleum savings for three alternative rail networks: Amtrak's current system, the system proposed by the Secretary of Transportation, and the Northeast Corridor only. The Northeast Corridor only system could save 1,773 barrels of oil per day in 1984. This estimate is probably optimistic. Within the two larger systems, these savings are offset by petroleum losses outside the corridor, so that the

---

16/ Estimated by CBO from data for the Middle Atlantic Area Council and the Northeast Power Coordinating Council contained in the Eighth Annual Review of the National Electric Reliability Council, August 1978.

TABLE 7. SAVINGS OR LOSSES OF PETROLEUM AND NON-PETROLEUM ENERGY FOR ALTERNATIVE RAIL SYSTEMS, 1984: IN BARRELS PER DAY OF PETROLEUM

	Total Energy	Non-Petroleum Energy a/	Petroleum Energy Only
Northeast Corridor	877	-900	1,777
System Proposed by DOT	126	-982	1,108
Current Amtrak System	-141	-1,014	873

NOTE: Assumes improved equipment, increased loads, and greater rail electrification.

a/ Non-petroleum energy is converted to the equivalent petroleum-based energy for ease of comparison.

petroleum savings for both the system proposed by DOT and the current Amtrak system are somewhat smaller, 1,108 and 873 barrels per day, respectively.

These results indicate that rail service can help to save petroleum, but only in the Northeast Corridor. The potential savings of petroleum for the Northeast Corridor, estimated to be 1,773 barrels per day in 1984, are the greatest of any of the three alternative systems examined. This estimate is based upon the improved efficiency and increased load factor discussed earlier. Even so, the savings of petroleum represent less than one-hundredth of one percent of the nation's consumption of petroleum.

POTENTIAL WHEN AIR AND AUTO TRAVEL ARE RESTRICTED

Under extreme limitations on petroleum, allocations to airlines and gasoline stations could be severely restricted, and rail and bus operations could face unprecedented demand for service. Under such conditions many persons who would have made air or auto trips would avoid taking trips; those that continued to use cars would probably arrange intercity carpools wherever possible. The percentage of seats occupied on all modes would probably increase to near the limit, although most routes would still average less than 100 percent full since some passengers would get off at intermediate stops, and it may be impossible to keep all seats on all routes filled all the time. Rail loads, particularly on short-distance travel, could exceed the seating capacity of the vehicles if standees were carried, and buses could increase their loads somewhat for the same reason.

Any estimate of fuel savings by mode in such a crisis situation is particularly speculative but, in planning for such a contingency, it is instructive to examine the comparative advantages of bus and rail. Should such conditions develop, the nation will obviously need both modes since the capacity of both would be severely stressed. Nevertheless, if the nation takes steps to guard against such an emergency—such as purchasing fleets of reserve vehicles—it may be best to concentrate those reserves using the mode that appears to offer the greatest help in emergencies.

In order to examine the maximum potential of rail service in a period of extreme petroleum shortage, it is assumed that rail operates above its seating capacity (load factor of 1.2); that all rail service in the Northeast Corridor is electrified, and that 29 percent of electricity in the Northeast Corridor is generated from petroleum. Similarly, it is assumed that buses achieve a load factor of 0.8. Under these assumptions, the amount of petroleum needed to furnish a passenger-mile of travel by bus and rail is summarized in Table 8. In the Northeast Corridor, rail requires only about one-third as much petroleum per passenger-mile as bus, although its total

TABLE 8. POTENTIAL USE OF PETROLEUM BY BUS AND RAIL UNDER CRISIS CONDITIONS

	Principal Assumptions			
	Percent of System Electrified	Percent of Electricity Generated from Petroleum	Load Factor	Petroleum Used per Passenger-Mile a/ (BTU)
Northeast Corridor b/				
Rail c/	100	29	1.2	217
Bus	0	N/A	0.8	637
Non-Northeast Corridor				
Rail c/	10	0	1.2	1,464
Bus	0	N/A	0.8	701

a/ Based upon great-circle mileage

b/ Assumes completion of Northeast Corridor Improvement Project.

c/ Assumes 20 percent improvement in railroad fuel efficiency relative to current equipment.

energy requirements would still be greater. Outside the Northeast Corridor, rail requires over twice as much petroleum per passenger-mile as bus.

The assumption that rail could operate on a regular basis with every seat filled and many people standing is clearly extreme. Amtrak itself has indicated that a 75 percent load factor would be more likely. 17/ Such an extreme assumption may be justified, however, since in a time of great national emergency, Amtrak could take other actions to improve energy efficiency, such as operating at slower speeds, with longer trains, or with fewer 'unproductive' cars such as dining cars or sleepers.

Developing workable contingency plans for periods of petroleum shortage involves a huge array of social and economic concerns. To the extent that savings of petroleum are a factor, they suggest that rail may be the most effective means inside the Northeast Corridor and that bus may be the best outside the corridor. This analysis, however, has not included any consideration of either the capital or operating costs required to achieve these petroleum savings. These costs may be considerable, particularly for railroad electrification, and their inclusion in the analysis may show that there are more cost-effective ways to prepare for a petroleum supply crisis than these approaches.

17/ Testimony of Amtrak President Alan S. Boyd before Transportation Subcommittee of House Committee on Appropriations, 1979.