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RESEARCH AND DEVELOPMENT NEEDS FOR TRANSPORTATION

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RESEARCH AND DEVELOPMENT NEEDS FOR TRANSPORTATION

The energy policy of the United States in the post-embargo period is one of cooperation with the other industrialized countries by increasing domestic energy supplies and by conservation through increased efficiencies and reduced demands.[1] Project Independence spells out the U.S. contribution in these areas. In the LLL study, "An Assessment of U.S. Energy Options for Project Independence",[2] the fundamental problem of transportation's critical dependence on petroleum was identified. Figure 1 shows the projected result to be expected from increased domestic oil supplies and vigorous conservation in transportation on the energy flow of the United States in 1985. This scenario would result in essentially zero oil imports; however in order to accomplish this reduction of imports, it would be necessary to reduce transportation energy growth rates drastically (as well as to alleviate the drill rig constraint on domestic oil production). This is due to the fact that the transportation sector is inflexibly based on the use of oil as its energy source. Both the cost and availability of oil in the future are uncertain due to geologic and political issues. Reference will later be made to domestic petroleum reserves; however, the political issues involved presumably have been assessed in the determination of our energy policy, and will not be discussed in this paper.

Markets other than transportation have an inherent capability for inter-fuel substitution, subject to the constraints of capital equipment inventories. At the present time, this is not true for transportation and possible ways of introducing alternate energy sources and reducing energy consumption must be examined.

Energy use in the transportation sector in the United States for 1971 is shown in Figure 2. Trucks and automobiles together utilize 72% of total transportation energy. Clearly the potential impact on energy demand and consumption is greatest in the automobile sector since passenger cars consume 52% of total transportation energy. Additional data to support this contention follows.

Automobile usage by purpose is detailed in Figure 3. In the U.S., 36% of the vehicle miles travelled are utilized in going to and from work. The average trip length is less than 10 miles, and the load factor of 1.4 passenger miles per vehicle is very low. Figure 4, which gives further information on trip lengths and vehicle miles travelled, shows that 55% of all automobile trips are less than 5 miles long. An obvious conclusion is that there exists a large potential for reduction of energy consumption in automobile use by both mode shifting and load factor improvement.

Another issue raised in regard to transportation energy usage is the contribution to air pollution by the transportation sector. Figure 5a gives data for 1970, comparing the transportation contribution to U.S. air pollution with that of all other sources for hydrocarbons, carbon monoxide, oxides of nitrogen and sulfur, and particulates. The total contribution of transportation is also given. The data as shown have been adjusted for toxicity effects, and indicate that transportation accounts for approximately 25% of U.S. air pollution. The common quotation that half of U.S. air pollution is contributed by transportation is true, but on a toxicity-unadjusted basis, as shown in Figure 5b. It must be noted however, that the contribution of transportation to air pollution is rapidly changing as shown in figure 6. The projected portion of these data is dependent on implementation of planned motor vehicle emission regulations; however, the potential exists for dramatic effects on air quality as a result of technological changes. The important point is that the energy penalty involved in accomplishing these changes was not considered until very recently.

An examination of the energy intensiveness of passenger transportation is given in Figure 7. The effect of load factors as well as energy intensiveness expressed in miles per gallon indicate large improvements can be made in the automobile sector. For instance, the urban automobile at a load factor of 1.0 yields an energy intensiveness of 10,600 BTU per passenger mile; at current load factors of 56% in the aircraft industry, aircraft energy intensiveness is only 8100 BTU per mile. This indicates that in the worst case, the urban automobile is more energy intensive than a modern jet aircraft.

The inescapable conclusion is that the automobile is the most significant issue in transportation with respect to conservation potential.

There is a basic problem with the policy of conservation in the transportation sector, and that is that transportation habits are not easily changed. Figure 8 gives results of the 1973 oil embargo experience on current automobile load factors and on usage of public transportation for commuting to work. No appreciable change occurred in either the automobile load factor or in the slowly increasing trend toward public transportation. The popular remark that conservation can have an immediate effect on reducing energy usage in transportation clearly requires qualification with respect to the time required to implement conservation factors and with respect to the incentives required for implementation.

Another problem with the energy policy of the United States is the geological one; i.e., the size of domestic oil reserves. Figure 9 gives the "remaining life" of U.S. domestic oil reserves based on the U.S. Geological Survey (USGS) high and low estimates, and as a function of 3 depletion scenarios: a 1.8% per year growth rate in total petroleum demand, a no-growth situation, and an empirically fitted "more likely" depletion curve. The cumulative value for each scenario is equal to the USGS high or low reserve estimate as appropriate. (It should be noted that the USGS is currently revising its estimate downward.) The effect of petroleum imports on delaying depletion of U.S. reserves is not included. For comparison, the National Petroleum Council (NPC) pre-conservation base case(3) or "pre-embargo base case" of March 1974 gave a transportation energy growth rate of 3.4% per year; the FEA Project Independence Report(4) gave post-embargo projections of 2.9% per year at \$4.00 per barrel, 1.7% per year at \$7.00 per barrel, and 0.7% at \$11.00 per barrel. Our use of 1.8% per year is simply an attempt to inject post-embargo realism. Furthermore, the continuing controversy concerning the magnitude of petroleum reserves is recognized and therefore we do not wish to base our argument on either the high or low number. It appears from the depletion curves given in Figure 9 that within very broad limits an imperative for action results, which is not very dependent on the extent of domestic reserves or the growth of demand. We will have to implement fundamental changes in the use of oil, particularly in the transportation sector in the next 10 to 20 years.

This fact has been recognized by the government. Figure 10 is a projection of highway energy savings potential developed by a Federal interagency task group comprised of the AEC, DC, DOD, EPA, FEA, NASA, and NSF.(5)

The dates and quantities must be considered qualitative since no decrease was achieved starting in 1972 as shown; however, this figure illustrates the savings potential of institutional and operational changes, increased use of "state-of-the-art technology" such as smaller cars, fuel injection, etc., and introduction of advanced propulsion systems such as stratified charge or lightweight diesel engines. Also shown is the effect of using alternate liquid fuels such as oil from oil shale and methanol or syncrude from coal, and energy storage systems such as electric cars. Clearly government intervention is not required in areas already receiving adequate attention from the private sector, such as small car technology. Further, motivational research required for conservation, although very important, is not a technical R&D issue. Federal R&D should be concentrated on long-range projects. Here, opportunities exist in the areas of alternate fuels, electric vehicles, and in increasing the supply of existing fuels. A smaller but very important aspect of federal involvement in automotive R&D is the assurance of the continued viability of present systems.

The major strength of the U.S. automobile industry lies in its ability to convert technical ideas into realities, rather than generation of technical innovations. For instance, automatic transmissions, power steering, disk brakes, radial tires, stratified charge and rotary engines, and the small car have all entered the American scene by a variety of routes outside the circle of U.S. automobile manufacturers.

Within the industry, there is a distinct tendency toward evolutionary development rather than technical excursion and experimentation. This is demonstrated by figures giving a breakdown within GM[6] between various types of research in 1969:

Basic Research	\$ 0.6 M
Applied Research	33.5
Development	310.0

Estimates of the R&D expenditures by the three major auto manufacturers on alternative power systems for 1973 were:[7]

Chrysler	\$ 3.5 M
Ford	24.5
GM	23.7

Thus, only a very small fraction of this R&D budget is devoted to basic research. Integration of national objectives of energy efficiency, alternatives to petroleum, and minimum environmental impact, into a coherent long-term program requires perspectives and responsibilities well beyond those of the private auto manufacturers whose objectives are based in the marketplace. Their perspective is too short and their view too narrow.

We therefore find a new and substantial direct role for the federal government in automobile research complimentary to the role of the private sector. This role includes:

1. Overall guidance of the long-term effort.
2. Financial support and involvement in alternate and improved propulsion technologies on a scale sufficient to assure national goals.
3. Creation of a cooperative R&D climate with industry for rapid advancement of new technology into the marketplace.

These would be implemented by a federally-financed program including in-house research. The in-house capability also provides a scientific and technological base necessary for wise government legislation and regulation.

An FEA report suggests that national R&D investment of $150M/year for 25 years or so will be required[8] to prepare for the time when oil will no longer be available as the major fuel for transportation. Experience in automotive engine development indicates that it takes 15-20 years to convert a radical new concept into reality:

Exploratory Development	$ 10-50M	2-4 years
Advanced Development	100-300	2-6 years
Engineering Development	200-2000	5-8 years

Using $1000 M over 25 years, each development costs approximately $40M/yr. In the 25 years to 2000, 3 or 4 major changes should flow from automotive R&D to advance the national goals. These might include 2 advanced heat engines and an electric vehicle. Since the electric vehicle may in reality be equivalent to 2 additional heat engine developments, $150M/year is not unreasonable.

With the current economic climate, private industry cannot be expected to increase its $50M/year contribution in the near future. The current federal R&D program of Alternate Automotive Power Systems in ERDA (formerly EPA) is not of the correct magnitude altogether:

FY 1971	$ 5.6 M
1972	8.5
1973	9.2
1974	12.3
1975	7.2

The effect of the addition of efficiency and alternative fuel objectives can be seen in FY'74, however anticipation of the transfer of the program to ERDA seems to have caused an unwarranted downward adjustment for FY'75.

We feel that the funding recommended by these reports:

AEC, "The Nation's Energy Future"(9)	50M/year
ERDA, "Contingency Plan for Highway Vehicle System"(10)	50M/year
FEA, "Role of Federal Government in Automotive R&D(8)	50M/year to start

indicates a consensus that cannot be ignored. Our recommendation is that the government adapt a strong leadership position in this field to assure an adequate and environmentally acceptable personal transportation system in the future.

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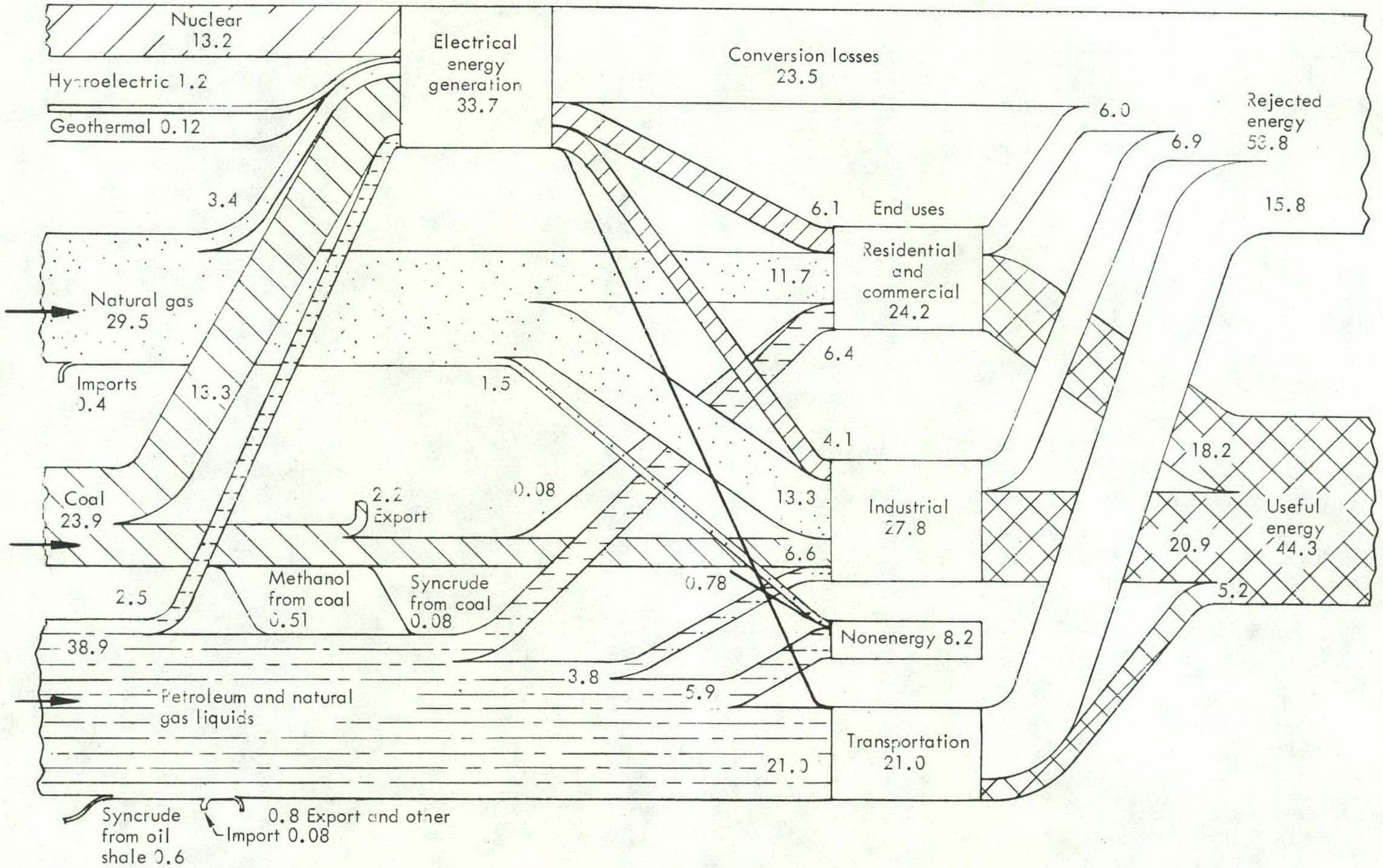
5. Federal Research and Development Program Plan for Transportation Energy Conservation, DOT-OST-TST-74-16, May 21, 1974.
6. Hearings and Research on Ground Propulsion Systems Subcommittee on Space Science and Applications, Feb. 4-6, 1974 (quoted in No. 8)
7. P. Chenea at a Meeting of the GM Public Policy Committee, 1970, (quoted in No. 8)
8. FEA Energy R&D Office, "The Role of the Federal Government in Automotive R&D", 11/6/74.
9. D. L. Ray, "The Nation's Energy Future", Dec. 1, 1973 WASH 1281
10. "ERDA Contingency Study - New Automotive Power Systems", July 1974, AEC

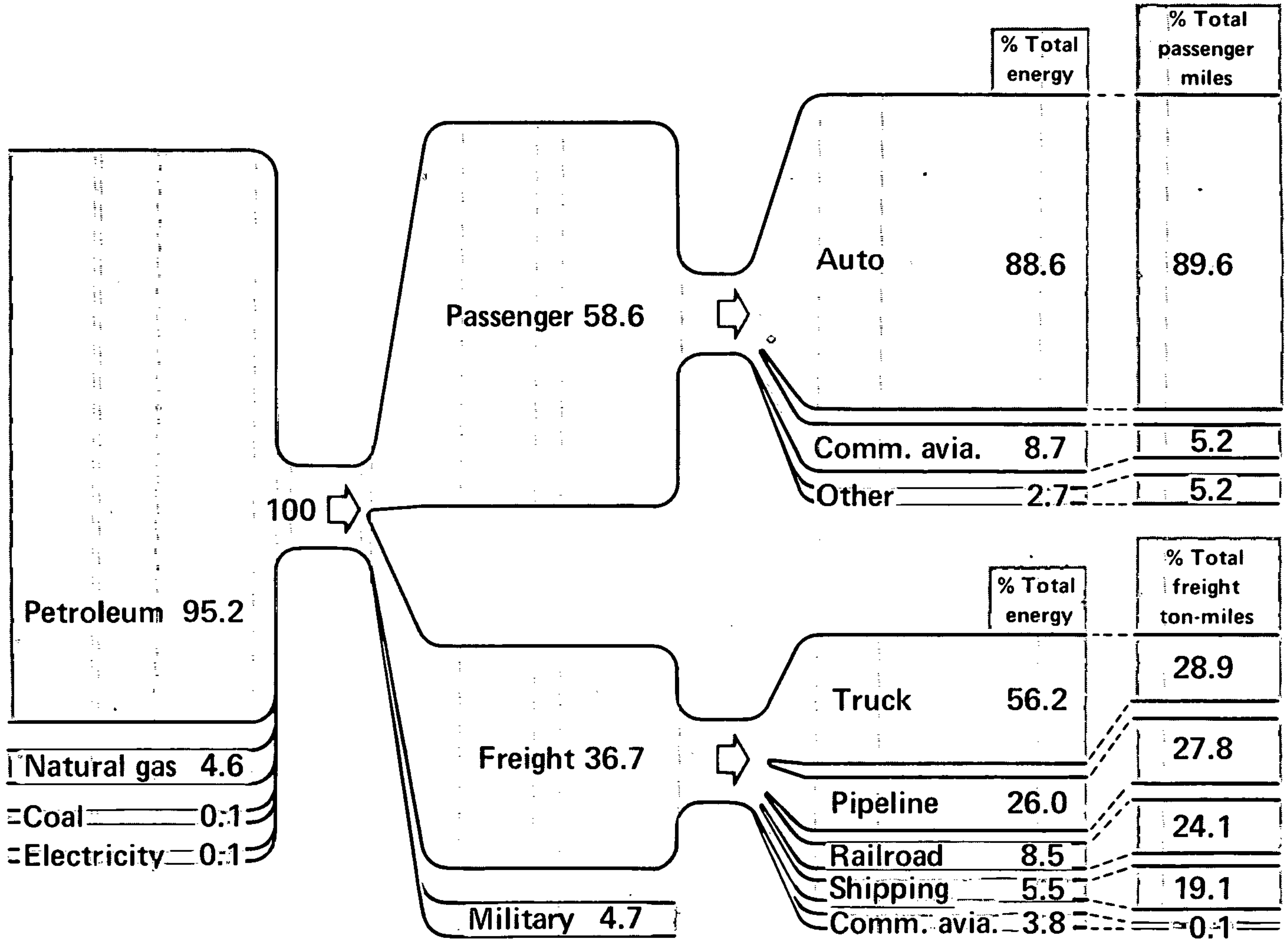
LLL ACCELERATED SUPPLY PLUS VIGOROUS CONSERVATION SCENARIO



Source: Ref. 2.

Fig. 1. Results by 1985 of the nation's current energy policy of accelerated supply plus conservation.[3] Units are 10^{15} Btu.

U.S. ENERGY USE IN TRANSPORTATION — 1971



Ref.: Mutch, J. J., "Transportation Energy Use in the United States: A Statistical History, 1955-1971," prepared for the National Science Foundation by Rand Corp., R-1391-NSF, December, 1973.

Figure 2.

AUTOMOBILE USAGE -- BY PURPOSE

	% Vehicle Miles (0 10 20 30 40)	Pass./Vehicle	Avg. Trip Length
Earning a Living			
- To and from work	xxxxxxxxxxxxxxxxxxxxxx	1.4	9.4
- Related business	xxxxx	1.6	16.0
Family Business			
- Medical and Dental	xx	2.1	8.3
- Shopping	xxxx	2.0	4.4
- Other	xxxxxxxx	1.9	6.5
Education/Civil/ Religious	xxxx	2.5	4.7
Social/Recreational			
- Vacations	xxx	3.3	165.1
- Visit friends/relatives	xxxxxxxxx	2.3	12.1
- Pleasure trips	xxx	2.7	19.6
- Other	xxxxxxxxxxxx	2.6	11.4
	Weighted Average:	1.9	8.9

Data Source: 1971 Automobile Facts and Figures
Taken from: MITRE Report 72-164

Figure 3.

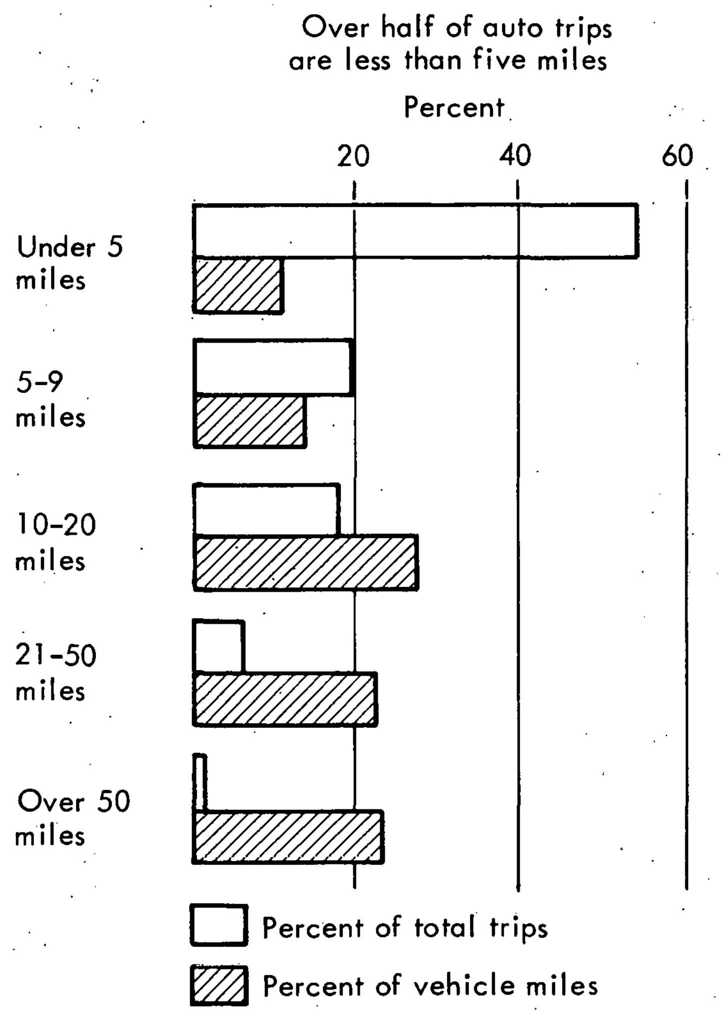


Figure 4.

Data Source: 1972 Automobile Facts and Figures

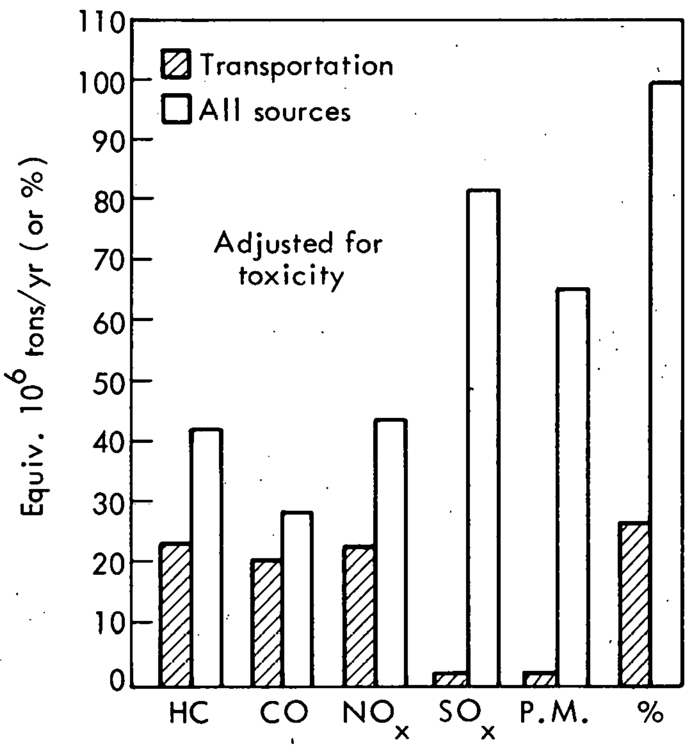


Figure 5a.

DATA SOURCE: MTP-391 (2/74)
Mitre Corp. Report
1970 data

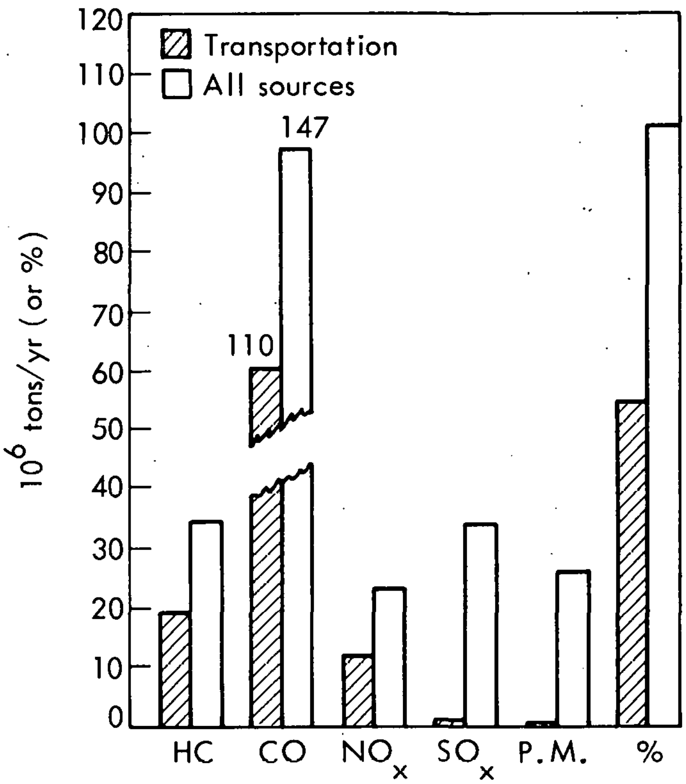


Figure 5b.

Data source: MTP-391 (2/74)
Mitre Corp. Report
1970 data

ESTIMATES OF NO_X EMISSIONS, LOS ANGELES AREA

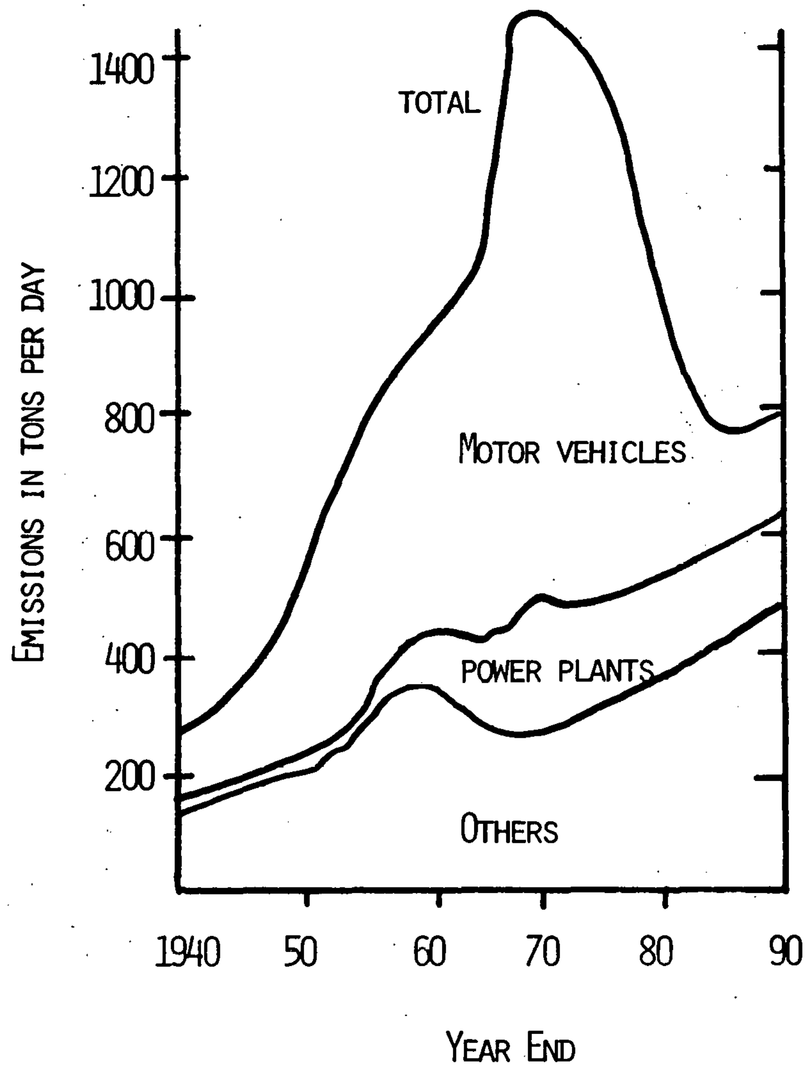


Figure 6.

SOURCE: SEALE AND SIERKA

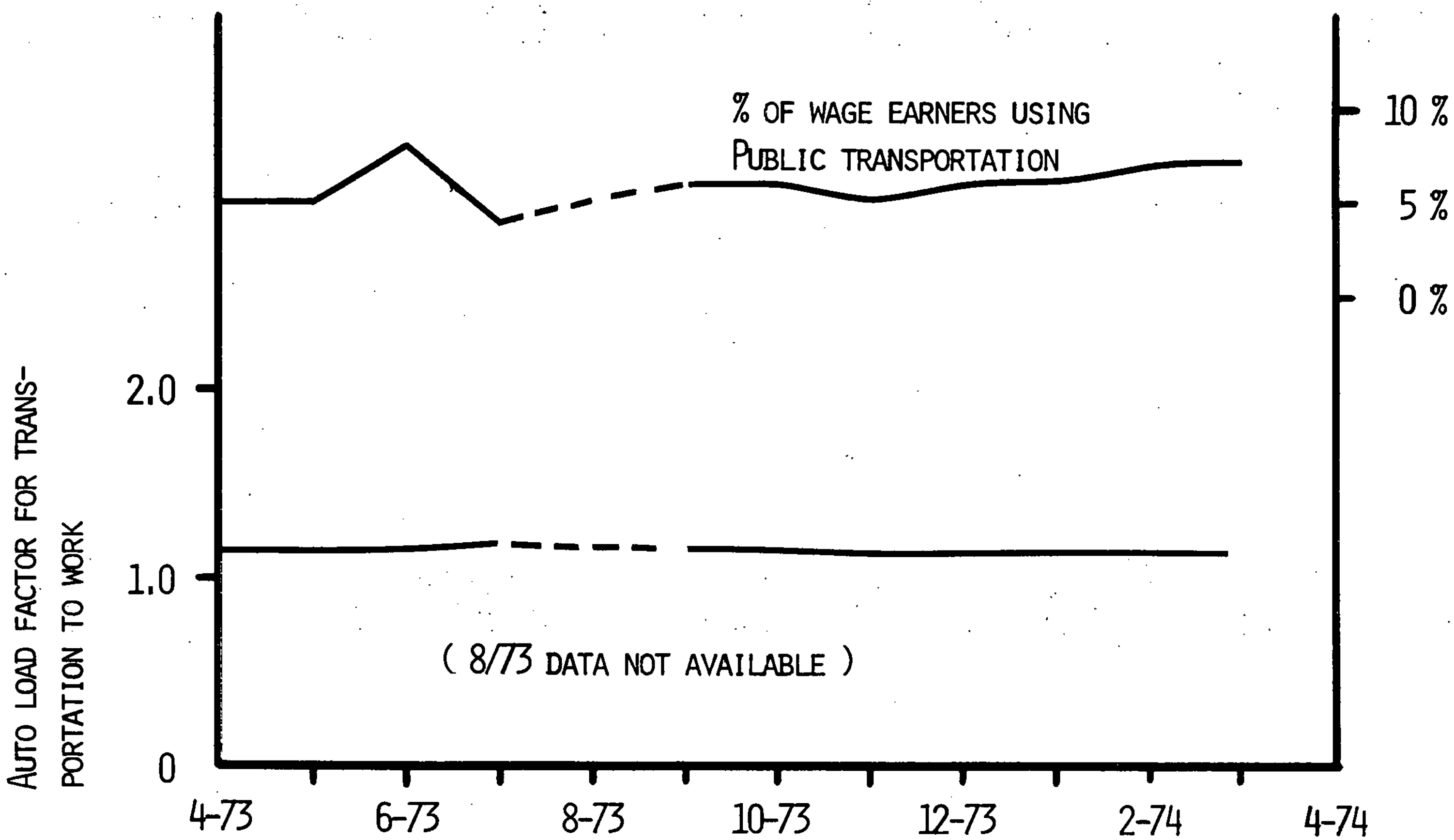
PASSENGER SERVICE - 1970 DATA

Mode	Passenger Miles (x 10^{12})	Load Factor	Energy Intensiveness Btu/Pass. Mile	(mpg)	Energy Consumption (10^{15} Btu)
Auto					
Urban	.69	1.4	7550	(12.1)	5.2
Intercity	1.04	2.5	3250	(16.0)	3.4
(Small cars)	.27	1.9	3220	(21.2)	.87
(Standard & compact cars)	1.46	1.9	5300	(12.4)	7.73
	1.73	1.9	5800	(13.6)	8.6
Light trucks	0.08	1.4	9000	(10.1)	0.72
Air					
Short Haul (<500 miles)	0.018		12200		0.22
Long Haul (>500 miles)	0.101		8720		0.88
	0.119	49%	9300		1.1
Bus					
Urban	0.017	10 pass/vehicle	2940	(4.4)	0.05
Intercity	0.028	22 " "	1070	(5.5)	0.03
School	0.052	25 " "	770	(6.75)	0.04
Rail					
Urban	0.007	25%	4300		.03
Intercity	0.011	37%	2730		.03
All Passenger Service	2.44 x 10^{12}		5250		10.6

Taken From: Mitre Report, MTP-391

Figure 7.

Impact of Embargo on Mode Choice for Transportation to Work



Source: FEA Project Independence Report, November, 1974

Figure 8.

LIFE OF DOMESTIC OIL RESOURCES

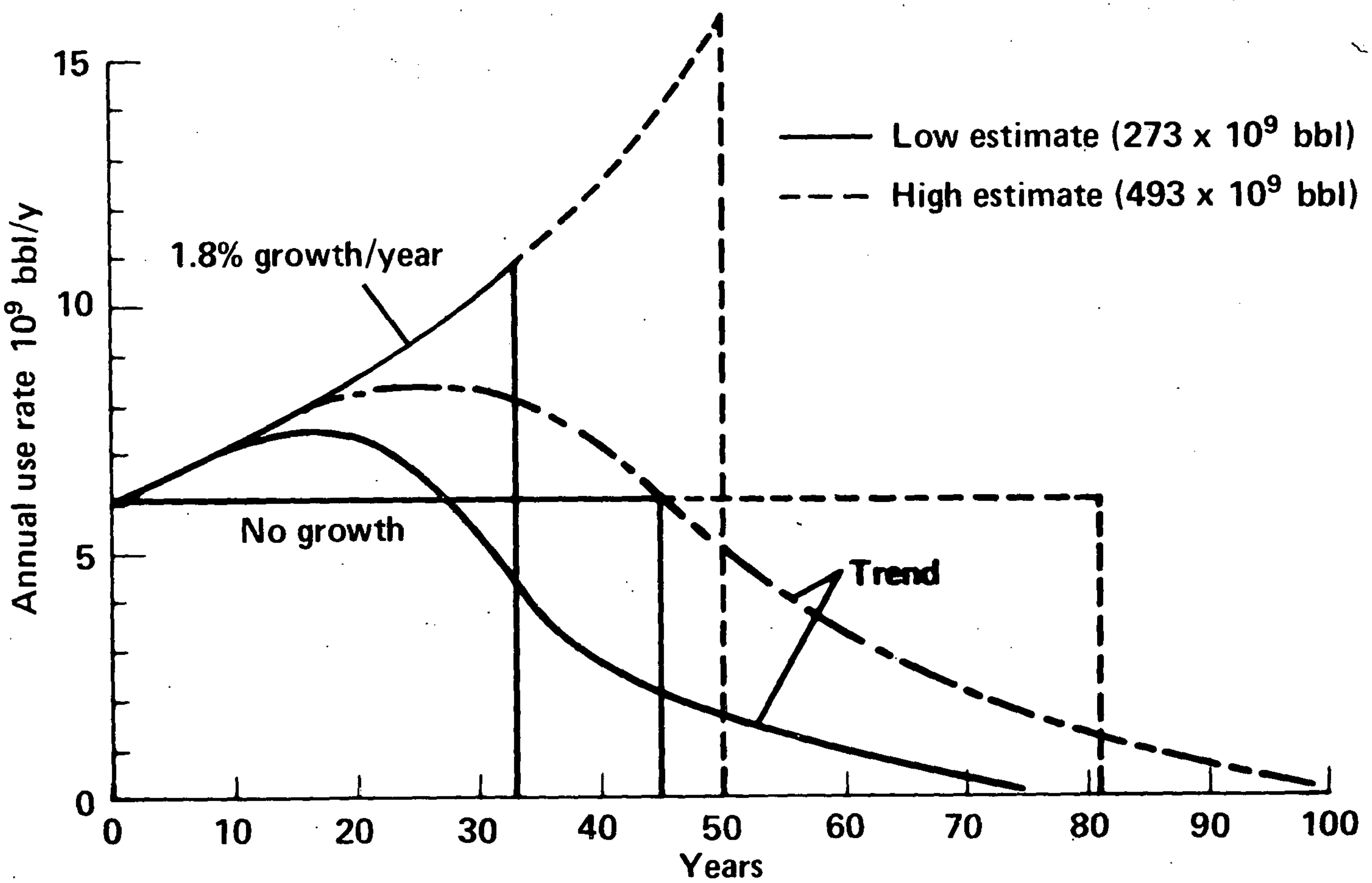
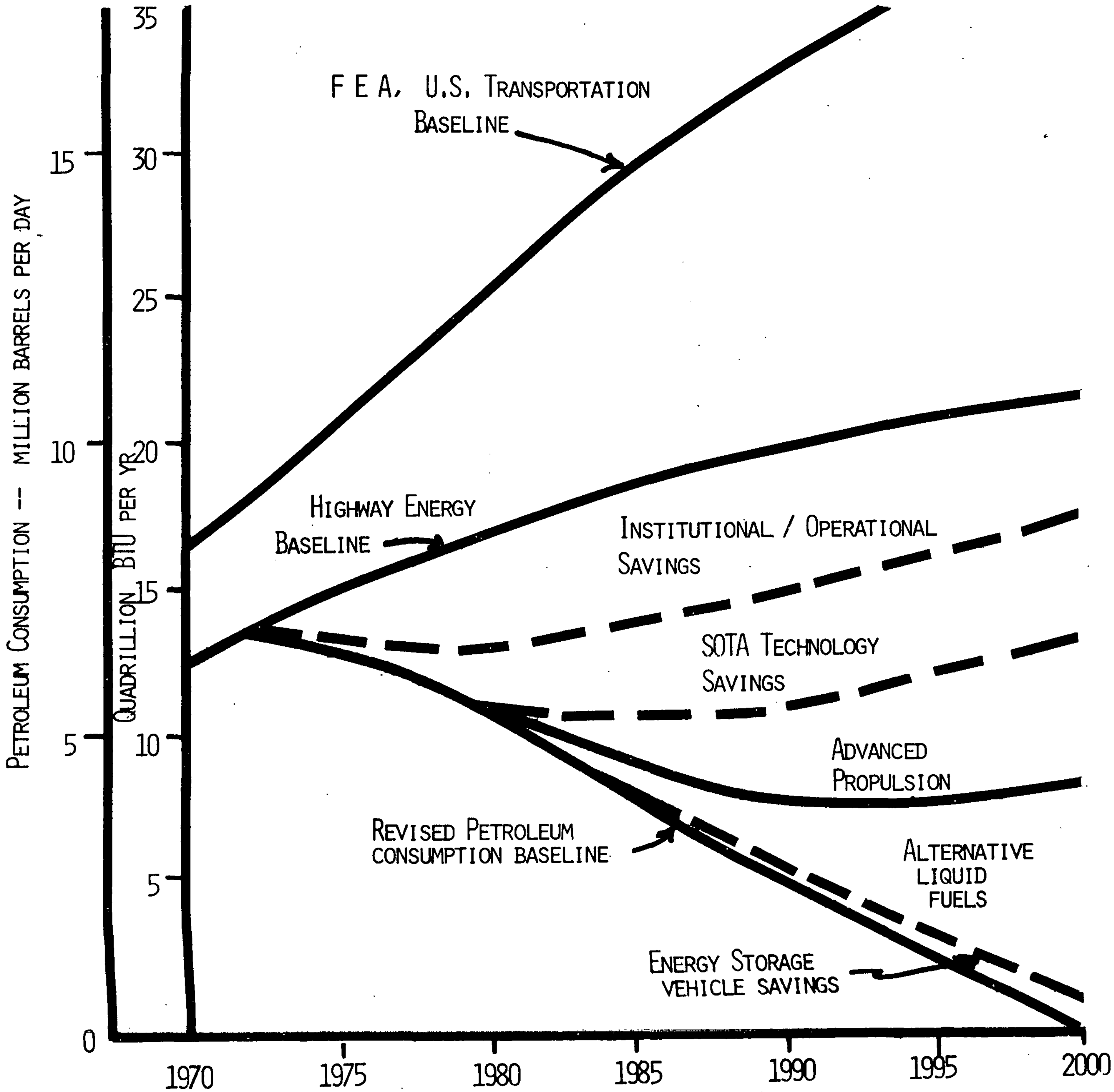


Figure 9.

HIGHWAY ENERGY SAVINGS POTENTIAL



Data Source: Federal R&D Program Plan for Transportation, Energy Conservation May 21, 1974, DOT-OST-TST-74-16

Figure 10.

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