Michigan Transportation Research Program

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A CONCISE ANNOTATED BIBLIOGRAPHY OF THE ENERGY EFFICIENCY OF VARIOUS TRANSPORTATION MODES

An MTRP Staff Paper
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Energy, the Economy, and Mass Transit, December 1975, U.S. Congress, Office of Technology Assessment, OTA-T-15.

This report reviews the relationship of mass transit to energy consumption and to alternative economic conditions. A portion of the report deals with the energy requirements for various passenger transportation modes. (See Attachment A for a table from this report).

Energy Conservation in Transportation and Construction, report of a conference sponsored by ARBA, Department of Civil Engineering at Clemson University, School of Civil Engineering at Georgia Institute of Technology, and U.S. DOT, December 2-5, 1975.

Particularly relevant in this conference report are the following papers:

- "Highway Transportation's Response to Energy Conservation", by J. R. Coupal, Jr. of U.S. DOT.
- "Energy Consumption of Alternative Transport Modes", by John Smylie of De Leuw, Cather, and Company. (See Attachment B, pp. 1-4, for tables from this paper).
- "Energy and Goods Movement: An Integrated Approach", by Frank J. Cesario of Cornell University.
- "Rail Transportation - Its Place in the Nation's Energy Conservation Program", by Bruce M. Flohr of FRA.
- "Energy Conservation: Views by a State Department of Transportation", by E. Wilson Campbell of New York DOT.
- "Energy Conservation in Transportation - Why and How", by Sydney D. Berwager of FEA.
- "Energy Conservation Related to Traffic Operations", by Harold L. Michael of Purdue University (See Attachment B, pp. 5-7, for a summary of this paper).

Transportation Energy Conservation Data Book, A. S. Loebl, et al., Oak Ridge National Laboratory, October 1976, ORNL-5198.

Statistical data on energy use in the transportation sector are presented in the form of tables, graphs, and charts. Some of the topics covered include:

characteristics of tranpsortation modes; energy characteristics, including energy consumption by source and by sector; conservation alternatives; government impacts, including expenditures, regulations and research, development, and demonstration spending; and, transportation demand. A bibliography of data sources is included in the report. (See Attachment C for tables from this report).

Energy Statistics - A Supplement to the Summary of National Transportation Statistics by William F. Gray of the Transportation Systems Center, August, 1974. DOT-TSC-OST-74-12.

The first and third sections of this report are the most relevant. Section one includes financial, inventory, and activity statistics related to the transportation of energy commodities via pipeline, water, truck, and rail. The third section containes U.S. energy consumption statistics. Included are data on fuel and oil costs for various modes of transportation and energy consumption disaggregated according to consuming sectors.

Dial-A-Ride's Impact on Transportation Energy Consumption in Small Cities, William R. Hershey, February 1976, The Huron River Group, Ann Arbor, Michigan.

This paper examines energy consumption of Dial-A-Ride systems. For the cities which were surveyed, it was found that the energy intensiveness of Dial-A-Ride is greater than that of most transportation alternatives, including driving. The principal reasons for these significant energy costs were low vehicle occupancies, circuity of routing, and poor vehicle fuel economy.

"Transportation Energy Conservation Policies", Eric Hirst, Science Vol. 192, No. 4234, April 2, 1976, pp. 15-20.

This paper presents an overview of the historical trends in passenger travel and energy use. It then goes on to discuss four transportation policies which could save energy -- improved mass transit, carpooling, gasoline taxes, and auto fuel economy standards. Data is presented on the estimated energy savings of each policy for 1980 and 1985. These savings are summarized in the following table:

Policy	Estimated Energy Savings (Thousand Barrels Per Day)	
	1980	1985
Increase percentage of urban travel carried by mass transit from 2.5% in 1973 to 5.0% in 1980 and 7.5% in 1985.	52	122
Increase carpooling sufficiently to reduce work-trip auto travel by 10% in 1980 and 1985.	69	105
Increase gasoline prices by 20% starting in 1975.	484	700
Increase new car fuel economy from 14 mpg. in 1974 to 20 mpg. in 1980 and 22 mpg. in 1985.	568	1327

* * *

Transportation Programming, Economic Analysis, and Evaluation of Energy Constraints, Transportation Research Record 599, Transportation Research Board, 1976.

Particularly relevant papers in this volume are:

- "Gasoline Consumption in Urban Traffice", by Man-Feng Chang, et al of General Motors Research Laboratories.
- "Energy Analysis for Urban Transportation Systems: A Preliminary Assessment", by David T. Hartgen of New York DOT.
- "New Technique for Evaluating Urban Traffic Energy Consumption and Emissions", by Edward K. Lieberman of KLD Associates and Stephen Cohen of FHWA.
- "Energy Conservation Potential of Urban Public Transit", by Mayo S. Stuntz, Jr. of Harvard Business School and Eric Hirst of Oak Ridge National Laboratory.
- "Relationships Between Transportation Energy Consumption and Urban Structure: Results of Simulation Studies", by Jerry L. Edwards of

the University of Minnesota and Joseph L. Schofer of Northwestern University.

"Energy in the Automobile", Doran K. Samples in Energy: The Impact of Availability and Prices on Future Business Prospects, David M. Peele, ed., 1975, Institute of Science and Technology, The University of Michigan, Ann Arbor, Michigan.

This paper is interesting in that it focuses on the energy required to produce an automobile rather that the energy required to operate an automobile. The concluding section of the paper does provide estimates of total energy consumption for automobiles, including energy used in producing, operating, and maintaining an automobile, and the energy consumed in refining, drilling, and transportation of auto fuels. The author concludes that 21% of total U.S. energy consumption was devoted directly and indirectly to the automobile in 1970.

"Energy Uitilization by Various Modes of Transportation", Address by R. Eugene Goodson of Purdue University before the Society of Automotive Engineers Automobile and Manufacturing Meeting, October 15, 1976.

This address summarizes the transprotation energy consumption for a variety of modes. Goodson also proposes conservation measures and estimates the energy savings from these measures. (See Attachment D).

"Transportation Energy Conservation: Opportunities and Policy Issues, Eric Hirst, Transportation Journal Vol. 13, No. 3, Spring 1974, pp. 43-52.

The basic thrust of this article is that transportation energy conservation is desirable and technologically feasible. Hirst includes the caveat that when transportation energy policies are devised, consideration must be given to impacts on the economy, employment, foreign trade, and the environment. Energy consumption patterns for transportation and savings from energy conservation strategies are included. (See Attachment E).

The Production and Consumption of Automobiles R. Stephen Berry and Margaret Fulton Fels, A Report to the Illinois Institute for Environmental Quality, July, 1972.

As with the paper by Samples discussed above, this paper analyzes the amount of energy used in the manufacture of automobiles. It goes futher than the Samples paper in that it also analyzes the energy that could be saved through the recycling of automobiles.

ENERGY REQUIREMENTS OF PASSENGER TRANSPORTATION MODES

Type of Transportation	Passengers	Vehicle Miles Per Gallon of Fuel or Equivalent	Passenger Miles Per Gallon of Fuel or Equivalent
Heavy Rail Transit (Subway) Car, Peak Load (a)	135	4.00	540
Intercity Passenger Train (b)	540-720	0.50	270-360
Transit Bus, Peak Load (c)	75	4.10	307
Intercity Bus (d)	47	6.00	282
Commuter Rail Car, Diesel Powered (a)	125	2.00	250
Heavy Rail Transit (Subway) Car, Off-Peak Load (a)	35	4.00	140
Transit Bus, Off-Peak Load (c)	30	4.10	123
Rail Turbine Train (b)	320	0.33	110
Standard Size Automobile, Intercity, Maximum Load (e)	6	18.00	108
Standard Size Automobile, Urban, Maximum Load (e)	6	14.40	86
Wide-Body Commercial Jet Aircraft, 1,000-Mile Flight (f)	256-385	0.14-0.22	54-60
Twin Jet Commercial Aircraft, 500-Mile Flight (f)	68-106	0.44-0.54	37-47
Average Commuter Automobile (a)	1.4	13.5	19

SOURCES:

(a) Commonwealth of Pennsylvania, Department of Transportation
(b) National Railroad Passenger Corporation (Amtrak)
(c) Cleveland Transit System
(d) U.S. Department of Transportation, Transportation Systems Center
(e) U.S. Department of Transportation, Federal Highway Administration
(f) National Aeronautics and Space Administration

(Reproduced from American Public Transit Association '74-'75 *TRANSIT FACT BOOK)*

Energy Requirements of Automobiles, Commercial Vehicles and the CDL System

ALTERNATIVE	AUTOMOBILE			COMMERCIAL VEHICLE			CDL SYSTEM		
	MILLIONS OF MILES/ YR	MILLIONS OF GALLONS/ YR	BILLIONS OF BTU/ YR	MILLIONS OF MILES/ YR	MILLIONS OF GALLONS/ YR	BILLIONS OF BTU/ YR	MILLIONS OF MILES/ YR	MILLIONS OF GALLONS/ YR	BILLIONS OF BTU/ YR
BASELINE	7848	581.3	79057	1036	121.8	16565	26.198	6.666	863
EXPRESS	7825	579.6	78826	1027	120.8	16429	27.120	6.901	894
LIGHT RAIL	7811	578.6	78690	1022	120.3	16361	20.619	5.246	679
CONVENTIONAL RAIL	7817	579.1	78758	1025	120.6	16402	24.643	6.270	812
AUTOMATED SCHEDULED	7724	572.2	77819	1022	120.3	16361	20.928	5.325	690
DYNAMICALLY SCHEDULED	7729	572.5	77860	1022	120.3	16361	20.597	5.241	679

Non-Vehicular Energy Requirements of the Bus Alternatives

	ALTERNATIVE	BASELINE	EXPRESS BUS
STATIONS	AREA (THOUSANDS OF SQUARE FEET)	0	578
	NUMBER OF ESCALATORS	0	102
	NUMBER OF ELEVATORS	0	56
	ELECTRICAL CONSUMPTION (THOUSANDS OF KWH/YEAR)	0	19,832
	GAS CONSUMPTION (THOUSANDS OF CUBIC FEET/YEAR	0	8,666
MAINTENANCE AND STORAGE	MAINTENANCE AREA (THOUSANDS OF SQUARE FEET)	82.8	157
	BUS STORAGE AREA (THOUSANDS OF SQUARE FEET	310	587
	ELECTRICAL CONSUMPTION (THOUSANDS OF KWH/YEAR)	2,534	4,804
	GAS CONSUMPTION (THOUSANDS OF CUBIC FEET/YEAR	4,962	9,299
GUIDE-WAY	SNOW REMOVAL (KWH/YEAR)	NOT APPLICABLE	NEGLIGIBLE
PARKING FACILITIES	NUMBER OF PARKING SPACES	2,000	36,000
	LIGHTING (THOUSANDS OF KWH/YEAR)	420	7,560
TOTAL	ELECTRICAL CONSUMPTION (THOUSANDS OF KWH/YEAR)	2,954	32,196
	GAS CONSUMPTION (THOUSANDS OF CUBIC FEET/YEAR	4,962	17,965

Summary of the Energy Requirements for Alternatives

ALTERNATIVE	PETROLEUM BASE FUELS				ELECTRICAL ENERGY REQUIREMENTS PER YEAR AT POINT OF CONSUMPTION					NATURAL GAS
	AUTOMOBILES MILLIONS OF GALLONS OF GASOLINE PER YEAR	COMMERCIAL VEHICLES MILLIONS OF GALLONS OF GASOLINE PER YEAR	BUSES MILLIONS OF GALLONS OF DIESEL FUEL PER YEAR	SAVINGS POTENTIAL COMPARED TO BASELINE BARRELS OF OIL EQUIVALENT/YEAR	GUIDEWAY VEHICLES (KWH X 10^6)	STATIONS AND PARKING (KWH X 10^6)	MAINTENANCE AND STORAGE FACILITIES (KWH X 10^6)	SNOW MELTING EQUIPMENT (KWH X 10^6)	TOTAL (KWH X 10^6)	HEATING REQUIREMENTS THOUSANDS OF CUBIC FEET PER YEAR
BASELINE	581.3	121.9	6.67	0	N/A	0.42	2.53	NOT HEATED	2.9	5,000
EXPRESS BUS	548.5	121.0	13.55	636,593	INCLUDED IN PETROLEUM FUELS	27.4	4.8	NOT HEATED	32.2	18,000
LIGHT RAIL	545.8	120.9	5.25	887,567	119.6	28.1	8.0	0.074	146.8	13,000
CONVENTIONAL RAIL	551.9	121.2	6.27	714,724	61.7	17.4	5.2	0.036	84.3	12,800
AST (RUBBER TIRE)	539.6	120.7	6.33	1,035,850	209.1	29.2	8.7	8.6	255.6	17,845
AST (STEEL WHEEL)	539.6	120.7	5.33	1,035,850	121.8	29.2	8.7	NEGLIGIBLE	159.7	17,845
AST DYNAMICALLY SCHEDULED (RUBBER TIRE)	539.6	120.6	5.24	1,040,204	170.2	24.2	8.0	10.1	212.5	16,100
AST DYNAMICALLY SCHEDULED (STEEL WHEEL)	539.6	120.6	5.24	1,040,204	107.8	24.2	8.0	NEGLIGIBLE	140.0	15,100

Cost of Energy

CONCEPT	ENERGY COST PER YEAR (MILLIONS OF DOLLARS/YEAR)								
	AUTOMOBILES	COMMERCIAL VEHICLES	C/D SYSTEM BUSES	GUIDEWAY VEHICLES	STATIONS AND PARKING	MAINTENANCE AND STORAGE	SNOW MELTING	TOTAL TRANSIT (DOLLARS/YR)	TOTAL (DOLLARS/YR)
BASELINE	327.2	70.6	2.06	N/A	.008	.052	N/A	2.12	409.92
EXPRESS BUS	318.1	70.1	2.14	2.56	.501	.088	N/A	4.79	392.98
LIGHT RAIL	316.6	69.8	1.62	2.02	.514	.146	NEGLIGIBLE	4.30	390.7
CONVENTIONAL RAIL	320.1	69.9	1.94	1.13	.319	.138	NEGLIGIBLE	3.53	393.53
AST (RUBBER TIRE)	312.9	69.8	1.65	3.83	.438	.159	.157	6.23	388.93
AST (STEEL WHEEL)	312.9	69.8	1.65	2.23	.438	.159	NEGLIGIBLE	4.63	387.18
AST DYNAMICALLY SCHEDULED (RUBBER TIRE)	312.9	69.8	1.62	3.11	.356	.147	.185	5.42	388.12
AST DYNAMICALLY SCHEDULED (STEEL WHEEL)	312.9	69.8	1.62	1.97	.356	.147	NEGLIGIBLE	4.09	386.79

1) COST OF GASOLINE ASSUMED TO BE $0.58 PER GALLON
2) COST OF DIESEL FUEL ASSUMED TO BE $0.31 PER GALLON
3) COST OF ELECTRICITY ASSUMED TO BE $0.0183 PER KILOWATT-HOUR
4) COST OF ELECTRICITY ASSUMED TO BE $0.0183 PER KILOWATT-HOUR AND NATURAL GAS TO BE $0.76 PER 1,000 CUBIC FEET.

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HIGHLIGHT SUMMARY

A. Petroleum supply for the near future as well as long term very likely will not be sufficient to meet demand. The need for fuel conservation in transportation is highly desirable. Traffic management offers many opportunities for fuel conservation.

B. Highway factors affecting fuel consumption of motor vehicles

   1. Distance, vertical grade, horizontal curves, and roadway surface factors are not primarily correctible by traffic operations.

   2. Speed and speed change factors are greatly affected by traffic operations.

C. Vehicle speed

   1. 55 mph maximum speed already saving about 4 million gallons of gasoline per day.

   2. 35 mph speed most conservative of fuel consumption.

   3. Under 20 mph speed very wasteful - under 15 more wasteful than 70 mph.

   4. Some classes of roads and streets should be operated at speeds around 35 mph for safety and fuel conservation.

   5. Maximum speed should be function of design, functional use and fuel consumption. High type roads might be 60 mph, low type arterial roads 35 mph. Not all should be 55 mph.

ENERGY CONSERVATION RELATED TO TRAFFIC OPERATIONS

D. Changes in speed, including stop minimization

1. From 30 mph, 100 less stops each day saves one gallon of gasoline and 150 less speed changes of 20 mph saves another gallon.

2. Goal of traffic engineer should be to keep traffic flowing safely at a steady 35 mph with as few stops and speed changes as absolutely necessary.

E. Traffic engineering management for speed change minimization

1. Some traffic engineering tools which improve functional use of roads and streets

   a. One-way streets
   b. Reversible lanes
   c. Parking prohibition

2. Some traffic engineering tools which improve local conditions

   a. Channelization
   b. Parking prohibition
   c. Turning lanes
   d. Lane striping
   e. Signing and marking
   f. Loading controls
   g. Proper intersection control

      (1) Right-of-way control only for low volumes
      (2) Yield and stop sign controls and proper use
      (3) Signal control and application

         (a) Phasing important, minimum number desired
         (b) Greer time of each phase proportional to volume
         (c) Flashing operation during low volume hours

3. Development of progressive flow

4. Enforcement is important

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F. Traffic management can save fuel

1. If just one less stop and one less speed change of 20 mph or more were made for each trip made in the U. S. over 5 million gallons of fuel would be saved each day.

2. Three additional reasons why better traffic management is very important and would have high payoff

   a. Motorists will accept new conditions eagerly
   b. Safety will also be improved
   c. It is practical as it is complementary to present system.

2.1.1.02

United States total gross consumption of energy resources by major sources and consuming sectors[1]
(in trillions of Btu's)

	Coal	Petro-leum	Natural gas	Total fossil fuel	Nuclear power	Geo-hydro-solar power	Total gross energy inputs	Total four sector inputs	Utility electric consumed	Total three sector inputs
1974										
Household and commercial	309	6061	7518	13888			13888	13888	3388	17276
Industrial	4356	6153	10314	20823		37	20860	20860	2425	23285
Transportation	2	17720	685	18407			18407	18407	17	18424
Electrical generation	8540	3480	3512	15532	1202	3253	19987	19987	5830-	
Synthetics										
Total	13207	33414	22028	68650	1202	3290	73142	73142		58985
1980										
Household and commercial	156	6403	6137	12696			12696	12696	4662	17358
Industrial	4044	6769	12315	23129			23129	23129	3133	26262
Transportation	3	19413	681	20096			20096	20096	15	20111
Electrical generation	11486	3017	3614	18117	3876	3704	25696	25696	7810-	
Synthetics										
Total	15690	35601	22746	74037	3876	3704	81617	81617		63731
1985										
Household and commercial	114	8232	6440	14787			14787	14787	6432	21219
Industrial	4817	8236	14022	27075			27075	27075	3864	30939
Transportation	2	22367	811	23181			23181	23181	14	23195
Electrical generation	15381	3696	3050	21126	8665	3940	33732	33732	10311	
Synthetics	261		169	92			92			
Total	20575	41532	24154	86261	8665	3940	98866	98774		75353
1990										
Household and commercial	84	10119	6394	16597			16597	16597	8331	24928
Industrial	5803	9753	15602	31158			31158	31158	4823	35981
Transportation	2	24379	932	25313			25313	25313	14	25327
Electrical generation	19569	5731	159	25460	13279	4166	42904	42904	13168	
Synthetics	391		254	137			137			
Total	25850	49982	22833	98665	13279	4166	116109	115972		86236

[1]These figures correspond to the Project Independence Evaluation System (PIES) Reference Case with imported oil price set at $13.

Source: Federal Energy Administration, National Energy Outlook, pp. G-2, G-22, and G-24, Washington, D.C., February 1976.

Petroleum[1] consumption by sector, 1950-1974
(trillion Btu)

2.1.2.1.01

Year	Household and commercial			Industrial			Transportation[2]	Transportation as % total	Electrical generation	Other not specified	Total input
	Fuel use	Nonfuel use	Total	Fuel use	Nonfuel use	Total					
1950	2,603	435	3,038	2,213	453	2,666	6,785	50.3	662	337	13,488
1951	2,722	480	3,202	2,509	535	3,044	7,482	50.4	499	621	14,848
1952	2,833	517	3,350	2,514	520	3,034	7,868	51.3	492	590	15,334
1953	2,869	522	2,291	2,584	560	3,144	8,158	50.7	577	829	16,099
1954	3,094	556	3,650	2,542	576	3,118	8,358	51.8	480	531	16,137
1955	3,386	615	4,001	2,754	652	3,406	9,109	52.0	512	496	17,524
1956	3,523	660	4,183	2,975	713	3,688	9,448	50.7	497	809	18,625
1957	3,432	637	4,069	2,715	763	3,478	9,649	52.0	512	862	18,570
1958	3,889	679	4,568	2,519	773	3,292	9,819	51.0	515	1,020	19,214
1959	3,997	721	4,718	2,674	915	3,589	9,923	50.3	546	971	19,747
1960	4,189	734	4,923	2,674	1,008	3,682	10,372	51.7	564	526	20,067
1961	4,275	753	5,028	2,634	1,048	3,682	10,575	51.6	577	625	20,487
1962	4,423	804	5,227	2,750	1,130	3,880	11,001	51.7	579	580	21,267
1963	4,434	824	5,258	2,739	1,255	3,994	11,506	52.4	600	592	21,950
1964	4,350	841	5,191	2,922	1,262	4,184	11,791	52.7	636	585	22,387
1965	4,744	891	5,635	2,826	1,313	4,139	12,179	52.4	744	545	23,242
1966	4,830	936	5,766	2,883	1,470	4,353	12,777	52.4	905	594	24,395
1967	5,289	917	6,206	2,820	1,612	4,432	13,408	52.9	1,013	276	25,335
1968	5,145	984	6,129	3,186	1,780	4,966	14,535	53.7	1,180	242	27,052
1969	5,260	1,009	6,269	3,220	1,951	5,171	15,125	53.2	1,628	229	28,422
1970	5,371	1,082	6,453	3,252	2,015	5,267	15,592	52.7	2,087	215	29,614
1971	5,331	1,108	6,439	3,196	1,898	5,094	16,286	53.3	2,543	207	30,570
1972	5,531	1,137	6,668	3,553	2,135	5,668	17,264	52.4	3,114	233	32,966
1973[r]	5,425	1,264	6,689	3,819	2,240	6,059	18,164	52.1	3,656	283	34,851
1974[p]	5,148	1,241	6,390	3,648	2,177	5,826	17,608	52.6	3,448	218	33,490

[1]Petroleum products refined and processed from crude oil, including still gas, liquefied refinery gas and natural gas liquids.

[2]Includes bunders and military transportation.

Source: U.S. Department of Transportation, Energy Statistics, p. 106, U.S. Government Printing Office, Washington, D.C., 1975.

Fuel consumption by mode of transportation, 1962-1973

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Class I railroads												
Locomotives												
Diesel oil, gals x 10^6	3,456	3,537	3,624	3,736	3,920	3,883	3,917	3,919	3,804	3,819	3,999	4,141
Fuel oil, gals x 10^6	101	90	85	77	65	47	42	33	-	-	-	-
Electricity, KWH x 10^6	1,094	1,018	931	933	922	832	750	610	578	534	605[r]	346
Coal, tons	8,256	7,332	6,831	3,695	3,235	2,310	1,669	1,137	1,238	1,191	1,400	1,202
Motor cars												
Diesel oil, gals x 10^6	7	7	7	6	6	6	5	5	8	4	3	3
Electricity, KWH x 10^6	592	591	583	576	576	580	567	538	763	756	715	901
Gasoline, gals	7,033	7,591	4,585	-	-	-	-	-	-	-	-	-
Air												
Certificated carriers												
Aviation gasoline, gals x 10^6	738	651	589	519	398	268	128	33	15	12	12	11
Jet fuel, gals x 10^6	2,808	3,291	3,830	4,650	5,670	7,523	8,891	10,113	10,085	10,140	10,302	10,671
General aviation												
Aviation gasoline, gals x 10^6	241	250	262	292	375	396	495	522	551	508	584	NA
Jet fuel, gals x 10^6	20	32	41	81	106	138	NA	168	208	226	245	NA
Highway												
Gasoline, gals x 10^6												
Passenger cars and taxis	43,771[2]	45,246[2]	47,567[2]	50,206	53,220	55,007	58,413	62,325	65,649	69,213	73,121	77,619
Motorcycles	-	-	-	69	92	103	111	123	135	301	342	392
Diesel + gasoline, gals x 10^6												
Commercial buses	610	606	622	645	637	646	655	657	644	631	561	520
School buses	227	232	242	249	259	264	277	290	300	316	320	327
Single-unit trucks[1]	NA	12,348	13,199	13,504	13,636	14,470	15,674	16,528	17,237	18,221	22,118	22,755
Combination trucks	NA	6,084	6,271	6,431	6,779	7,203	7,808	8,199	8,363	8,865	8,600	8,860
Water												
Vessels												
Residual fuel oil, gals x 10^6	3,545	3,213	3,487	3,093	3,093	3,389	3,678	3,506	3,774	3,307	3,273	3,859
Distillate fuel oil, gals x 10^6	665	636	672	652	699	734	766	793	819	880	1,013	1,125
Gasoline, gals x 10^6	NA	NA	NA	NA	485	501	533	569	598	645	687	717
Transit												
Electricity, KWH x 10^6												
Rapid Transit	2,115	2,125	2,171	2,185	2,075	2,194	2,250	2,291	2,261	2,262	2,149	2,098
Surface rail	325	255	222	218	226	180	179	173	157	153	146	140
Trolley coach	346	262	204	181	166	157	157	154	143	141	133	93
Gallons of motor fuel, gals x 10^6												
Gasoline	108	103	96	92	76	58	46	40	37	29	26	22
Diesel oil	229	235	242	248	256	270	274	274	271	257	247	273
Propane	36	36	33	33	34	33	32	32	31	27	24	15
Pipelines (Gas and oil)												
Natural gas, cu. ft. x 10^6	382,496	423,783	433,204	500,024	535,353	575,752	590,965	630,962	722,166	742,592	766,156	728,177

[1]Includes nonfreight truck movements.

[2]Includes motorcycles.

Sources: U.S. Department of Transportation, Energy Statistics, p. 115, U.S. Government Printing Office, Washington, D.C., 1975. U.S. Department of Transportation, Energy Statistics, p. 105, U.S. Government Printing Office, Washington, D.C., 1974.

Energy Requirements of Passenger Transportation Modes

	Assumed Passenger Loading	Vehicle Miles Per Gallon of Fuel or Equivalent	Passenger Miles Per Gallon of Fuel or Equivalent
Heavy Rail Transit (Subway) Car Peak Load	135	4.00	540
Intercity Passenger Train	540-720	0.50	270-360
Transit Bus Peak Load	75	4.10	307
Intercity Bus	47	6.00	282
Commuter Rail Car, Diesel Powered	125	2.00	250
Heavy Rail Transit (Subway) Car Off-Peak Load	35	4.00	140
Transit Bus, Off-Peak Load	30	4.10	123
Rail Turbine Train	320	0.33	110
Standard Size Automobile Intercity, Maximum Load	6	18.00	108
Standard Size Automobile Urban, Maximum Load	6	14.40	86
Wide-Body Commercial Jet Aircraft, 1,000 Mile Flight	256-385	0.14-0.22	54-60
Twin Jet Commercial Aircraft, 500 Mile Flight	68-106	0.44-0.54	37-47
Average Commuter Automobile	1.4	13.5	19

Source: Transit Fact Book '75-'76 Edition, p. 46, American Public Transit Association, Washington, D.C., 1976.

Amount of fuel consumed by type of highway motor vehicle, 1963-1974[1]
(millions of gallons)

Year	Passenger Vehicles							Cargo vehicles			
	Personal passenger vehicles			Buses			All passenger vehicles				All motor vehicles
	Passenger cars	Motor-cycles	All personal passenger vehicles	Commercial	School	All Buses		Single-unit trucks	Combi-nations	All trucks	
1974	73,797	447	74,244	525	333	858	75,102	21,116	10,083	31,199	106,301
1973	77,619	392	78,011	520	327	847	78,858	22,755	8,860	31,615	110,473
1972	73,121	342	73,463	561	320	881	74,344	22,118	8,600	30,718	105,062
1971	69,213	301	69,514	631	316	947	70,461	18,221	8,865	27,086	97,547
1970	65,649	135	65,784	644	300	944	66,728	17,237	8,363	25,600	92,328
1969	62,325	123	62,448	657	290	947	63,395	16,528	8,199	24,727	88,122
1968	58,413	111	58,524	655	277	932	59,456	15,674	7,808	23,482	82,938
1967	55,007	103	55,110	646	264	910	56,020	14,470	7,203	21,673	77,693
1966	53,220	92	53,312	637	259	896	54,208	13,636	6,779	20,415	74,623
1965	50,206	69	50,275	645	249	894	51,169	13,504	6,431	19,935	71,104
1964			47,567[2]	622	242	864	48,431	13,199	6,271	19,470	67,901
1963			45,246[2]	606	232	838	46,084	12,348	6,084	18,432	64,516

[1]For the 50 states and District of Columbia.

[2]Only totals are presented for 1963 and 1964 as motorcycles account for less than 1 percent of all travel.

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, Table VM-1, annual.

Average gallons of fuel consumed by type of highway motor vehicle, 1963-1974[1]

Year	Passenger Vehicles							Cargo vehicles			All motor vehicles
	Personal passenger vehicles			Buses			All passenger vehicles				
	Passenger cars	Motor-cycles	All personal passenger vehicles	Commercial	School	All Buses		Single-unit trucks	Combi-nations	All trucks	
1974	704	90	676	5,827	933	1,290	681	898	9,471	1,269	788
1973	763	90	736	5,810	973	1,991	741	1,025	8,620	1,361	851
1972	755	90	730	6,318	1,006	2,165	736	1,092	8,687	1,446	859
1971	746	90[2]	723	6,988	1,028	2,382	730	968	9,102	1,368	838
1970	735	48	714	7,132	1,039	2,491	722	969	8,711	1,365	830
1969	718	54	700	7,276	1,058	2,600	708	976	8,826	1,384	821
1968	698	53	682	7,310	1,056	2,649	690	972	8,964	1,382	804
1967	684	53	669	7,178	1,065	2,693	677	942	8,678	1,338	786
1966	679	52	666	7,538	1,085	2,772	674	928	8,237	1,316	778
1965	667	50	656	7,588	1,086	2,844	665	964	8,172	1,347	775
1964			652[3]	7,558	1,085	2,829	661	994	8,497	1,389	778
1963			648[3]	7,372	1,076	2,813	657	976	8,618	1,380	773

[1]For the 50 states and District of Columbia.

[2]Significant differences in values for 1971 and the corresponding values for 1970 represents a change in the basic assumptions of miles per vehicle and miles per gallon, not a shift in the trend.

[3]Only totals are presented for 1963 and 1964 as motorcycles account for less than 1 percent of all travel.

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, Table VM-1, annual.

Passenger Transportation

Mode	Speed	Passenger Miles per Gallon
Bicycle	10-30 MPH	700-1000
Walking	3-7	300-500
Bus	30-60	50-120
Train	50-150	50-400
Automobile	30-60	12-80
Airplane	150-600	8-100
Luxury Liner	5-25	3-10
Helicopter	120	8
SST	1500	5

Mode	Speed	Ton-Miles Per Gallon
Truck	30-60 MPH	~ 45
Rail	30-60	~ 213
Water	5-15	~ 193
Pipeline	10-20	~ 342
Air	400-600	~ 3

SELECTED TRANSPORTATION ACTIONS AND ESTIMATED SAVINGS AS PERCENTAGE OF TOTAL TRANSPORTATION ENERGY (1970)

NUMBER	ACTION	TOTAL TRANSPORTATION ENERGY SAVINGS (%)
1	Convert 50% of Passenger Car Population to Small Cars (22 MPG)	9.0%
2	Introduce in 50% of Highway Vehicles a 30% Reduction in Fuel Consumption	11.5%
3	Eliminate 50% of Urban Congestion	1.1%
4	Achieve 50% Success in Limiting Highway Speeds to 50 MPH	2.9%
5	Persuade 50% of Urban Commuters To Car Pool	3.1%
6	Shift 50% of Commuters (To and From City Centers) To Dedicated Bus Service	1.9%
7	Shift 50% of Intercity Auto Passengers To Intercity Bus and Rail, Evenly	3.0%
8	Shift 50% of Intercity Trucking to Rail Freight	3.4%
9	Shift 50% of Short Haul Air Passengers To Intercity Bus	0.29%
10	Persuade 50% of the People to Walk or Bike up to 5 Miles, Instead of Driving	1.6%

Historical Energy Consumption Patterns for Transportation

Year	Total Traffic	Per cent of Total Traffic						Total Energy (10^{12} Btu)	Average EI
		Air	Truck	Rail	Waterway & Pipeline	Auto	Bus [a]		
				Inter-City Freight Traffic					
1950	1350 [b]	0.02	13	47	41	—	—	2700	2000 [d]
1960	1600	0.05	18	38	44	—	—	1800	1100
1970	2210	0.15	19	35	46	—	—	2400	1100
				Inter-City Passenger Traffic					
1950	500 [c]	2	—	7	—	86	5	1700	3400 [e]
1960	800	4	—	3	—	91	2	2700	3400
1970	1120	10	—	1	—	87	2	4300	3800
				Urban Passenger Traffic					
1950	310 [c]	—	—	—	—	85	15	2100	7000 [e]
1960	430	—	—	—	—	94	6	3300	7700
1970	710	—	—	—	—	97	3	5700	8000

[a] Inter-city bus or urban mass transit.
[b] Billion ton-miles.
[c] Billion passenger-miles.
[d] Btu/ton-mile.
[e] Btu/passenger-mile.

Transportation Energy Conservation Strategies

FROM 1970 Situation	TO energy-efficient alternative	ENERGY SAVINGS [a] (per cent of total transportation energy)
	Passenger traffic: modal shifts	
Inter-city auto	Inter-city bus	0.22
Airplane	Inter-city bus	0.82
Urban auto	Mass transit	0.52
Urban auto	Bicycle	0.90
	Passenger traffic: load factor increases [b]	
Urban auto (28%)	Urban auto (38%)	0.25
Mass transit (20%)	Mass transit (30%)	0.16
Inter-city train (37%) [c]	Inter-city train (47%)	0.07
	Passenger traffic: technological changes [d]	
Inter-city auto (3400)	Inter-city auto (2300)	0.13
Urban auto (8100)	Urban auto (5400)	0.33
Airplane (8400)	Airplane (5600)	0.34
Train (2900) [c]	Train (1900)	0.12
	Freight traffic: modal shifts	
Truck	Train	0.26
Airplane [e]	Train	5.01

[a] Energy savings are computed on the basis of a 20 billion passenger-mile (or ton-mile) effect, about 1% of 1970 passenger traffic (or inter-city freight traffic). Total transportation energy use in 1970 was 16,500 trillion Btu.
[b] Energy savings are for a 10-percentage-point increase in load factor; numbers in parentheses are load factors.
[c] In 1970 trains carried only 11 billion passenger-miles.
[d] Energy savings are for a 33% reduction in vehicle EI; numbers in parentheses are EI values in Btu/passenger-mile.
[e] In 1970 airplanes carried only 3.4 billion ton-miles of freight