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ENERGY INTENSITY OF VARIOUS TRANSPORTATION MODES: Passenger and Freight Movements

MINNESOTA DEPARTMENT OF TRANSPORTATION

Prepared For
THE OFFICE OF MULTI-MODAL PLANNING

August 1979

ENERGY INTENSITY OF VARIOUS TRANSPORTATION MODES: PASSENGER AND FREIGHT MOVEMENTS

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1. INTRODUCTION

INTRODUCTION

This report is intended as a resource document for use by transportation analysts in comparing the energy intensities of various transportation alternatives. "Energy intensity" is defined as the energy use per unit of productive output.

$$\text{Energy Intensity} = \frac{\text{Energy Use}}{\text{Productive Output}} ,$$

and

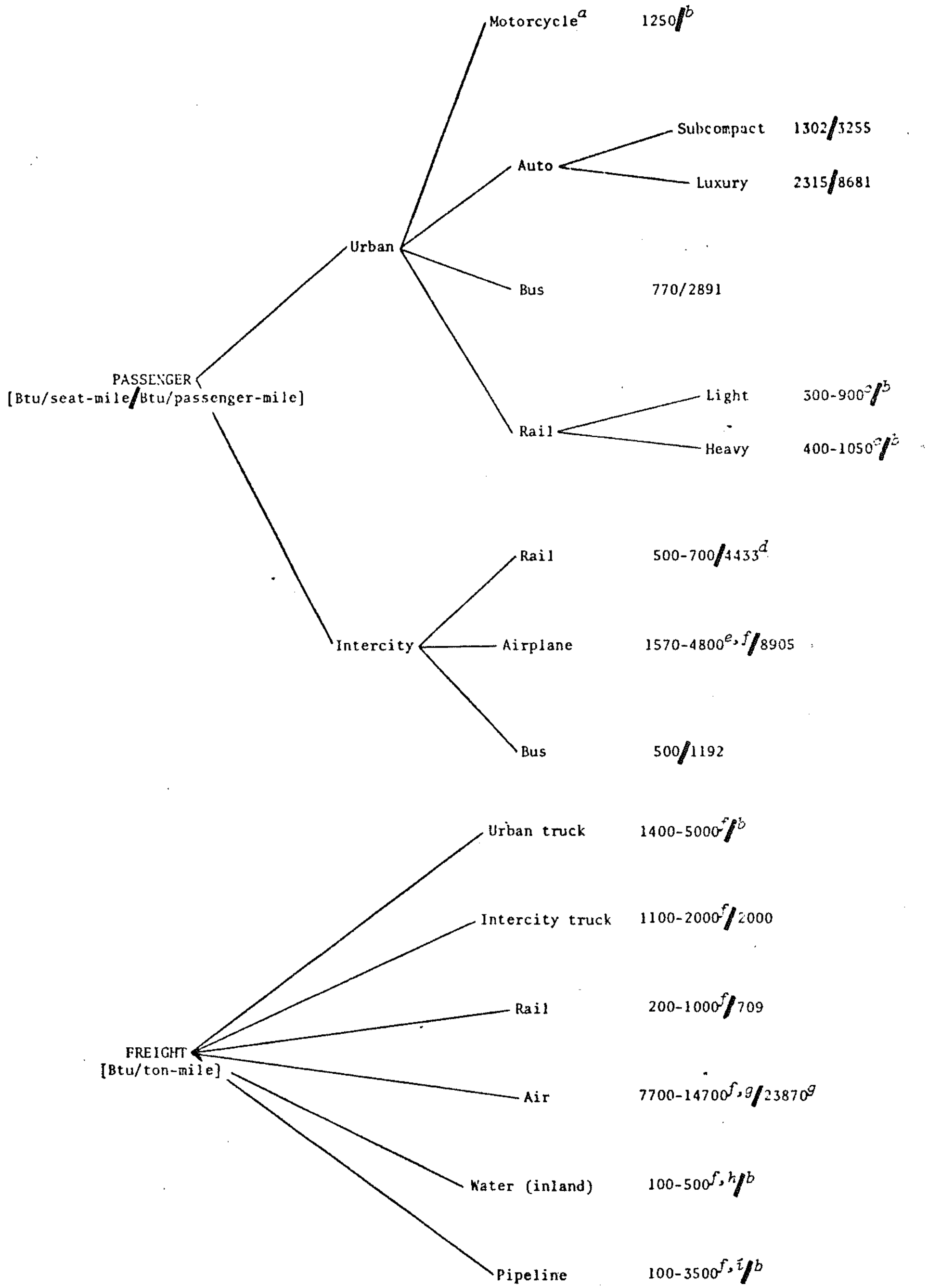
$$\text{Energy Efficiency} = \frac{1}{\text{Energy Intensity}} .$$

Transportation accounts for a significant portion of the total energy consumption in the United States, utilizing over 25 percent of the annual total. Consequently, the energy impacts of transportation alternatives are a critical national concern. Any reduction in energy consumption which can be realized in the transportation sector will contribute substantially toward the alleviation of the U.S. energy problem.

It must be remembered that transportation modes use different sources of energy, and it is necessary to use a common base to permit the comparison of various energy sources and rates of consumption. It is recommended that the British Thermal Unit (BTU) be used as the basic unity of energy. The equivalent BTU values of various fuels used in transportation systems are listed in the Appendix.

2. COMPARISON OF MODES

Figure 2-1 Energy Intensity by Transportation Mode (theoretical/1972 operational)



[a]Assuming 50 mpg 2 seats.

[b]Insufficient data.

[c]Highly system dependent.

[d]1973 figure.

[e]Range from small passenger planes to high density wide body aircraft as used in charter service.

[f]Size and commodity dependent.

[g]All cargo configuration.

[h]Upstream and downstream values account for additional variation.

[i]Additional variation due to flow rates.

From Transportation Energy Conservation Data Book: Edition 2, D. B. Shonka, A. S. Loebl, P. D. Patterson, Energy Research and Development Administration, October 1977, p. 205.

Table 2-1 AUTOMOBILE AND LIGHT DUTY TRUCK ENERGY INTENSITY, MODEL YEAR 1977 (BTU/PASSENGER-MILE)[1]

Number of Passengers[2]	Passenger Automobiles[3]				Station Wagons[3]			Light Duty Trucks[4]		
	2-Seat	Small	Medium	Large	Small	Medium	Large	Small Pickups	Standard Pickups	Vans & Others
1	7,837	7,408	9,061	9,325	6,628	9,293	9,376	6,187	8,669	8,515
2	3,989	3,770	4,592	4,726	3,384	4,709	4,749	3,160	4,395	4,324
3		2,560	3,104	3,194	2,304	3,206	3,207	2,154	2,972	2,928
4		1,956	2,360	2,429	1,766	2,421	2,437			2,231
5			1,915	1,971	1,445	1,963	1,977			1,814
6				1,666		1,659	1,670			1,537
7							1,451			1,339
8							1,288			1,192
9										1,078
10										987
11										914
12										853

[1]All values are calculated on a route-mile basis. To convert these to a great-circle mile basis, they should be multiplied by the intercity automobile circuity ratio of 1.212. No circuity data for urban uses are available.

[2]Including driver.

[3]Size classes were defined based on interior volume: small <110 ft^3; medium 110-120 ft^3; large >120 ft^3; small station wagon <130 ft^3; medium station wagon 130-160 ft^3; large station wagon >160 ft^3.

[4]When used for personal transportation.

From Transportation Energy Conservation Data Book: Edition 3, Department of Energy, February 1979, pp. 2-33 and 2-37.

Table 2-2 Near Term Energy Intensity for Automobiles and Buses Compared with Operating Energy Intensity

Vehicle type	Gross weight (1000 lbs.)	Trip length (statute miles)	Average trip hrs @ MPH	Fuel type[1]	Vehicle statute miles/gal	Number of seats: Available (full load)	Number of seats: 1972 Actual aver. oper.	Specific energy, stop/start — Seat-miles/gallon: Available (full load)	Seat-miles/gallon: 1972 Actual aver. oper.	BTU's/seat-mile: Available (full load)	BTU's/seat-mile: 1972 Actual aver. oper.
Urban, subcompact auto	2.0-2.4	10.0	.24/25	Gas	24.0	4.0	1.6	96	38.4	1,302	3,255
Urban, compact auto	2.5-3.4	10.0	.24/25	Gas	18.0	5.0	1.6	90	28.8	1,389	4,340
Urban, standard auto	3.5-4.4	10.0	.24/25	Gas	14.4	6.0	1.6	86.4	23.0	1,447	5,435
Urban, luxury auto	4.5-6.0	10.0	.24/25	Gas	9.0	6.0	1.6	54	14.4	2,315	8,681
Urban, bus	(18.5 empty) 20.3-3-26.0	13.0	1.25/ 10.3	Diesel	3.6-4.0	50	12	180	48	771	2,891
Intercity, bus	(28.7 empty) 45.0	100.0	1.81/55	Diesel	6.0	46	19.4	276	116.4	503	1,192
Intercity, subcompact auto	2.0-2.4	100.0	1.81/55	Gas	30.0	4.0	2.0	120	60	1,042	2,083
Intercity, compact auto	2.5-3.4	100.0	1.81/55	Gas	22.5	5.0	2.2	112.5	49.5	1,111	2,525
Intercity, standard auto	3.5-4.4	100.0	1.81/55	Gas	18.0	6.0	2.6	108	46.8	1,157	2,671
Intercity, luxury auto	4.5-6.0	100.0	1.81/55	Gas	13.0	6.0	3.0	72	36	1,736	3,472

[1]Gasoline = 125 X 10^3 BTU/gal, Diesel = 138.8 X 10^3 BTU/gal.

Source: W.F. Gay, U.S. Department of Transportation, Energy Statistics, Washington, D.C., 1975, p. 137.

From Transportation Energy Conservation Data Book: Edition 2, D. B. Shonka, A. S. Loebl, P. D. Patterson, Energy Research and Development Administration, October 1977, p. 187.

Table 2-3 Variations of Energy Intensity Estimates for Urban Passenger Transportation Modes

Mode	Per passenger-mile Range (Btu/PM)	Per passenger-mile Maximum error[a] (%)	Per seat-mile Range (Btu/sM)	Per seat-mile Maximum error[a] (%)
Auto				
Compact	3220–4748	47.5	1187–1660	39.8
Average	4791–9500	98.3	1447–2799	93.4
Bus				
Urban Transit	1533–3700	141.4	375–771	105.6
Van	2670–3593	34.6	1130–1600	41.6
School	758–1100	45.1	300–410	36.7
Rail				
Commuter	1130–4310	281.4	452–1320	192.0
Rapid Transit	2133–4666	118.8	770–1400	81.8
Trolley	2521–4080	61.8	866–1400	61.7

Table 2-4 Variations of Energy Intensity Estimates for Intercity Passenger Transportation Modes

Mode	Per passenger-mile Range (Btu/PM)	Per passenger-mile Maximum error[a] (%)	Per seat-mile Range (Btu/SM)	Per seat-mile Maximum error[a] (%)
Auto				
Compact	1900–2738	44.1	958–1352	41.1
Average	2400–7600	216.7	1167–1976	69.3
Bus	1100–1778	61.6	308–645	109.4
Rail				
Cross Country	924–3852	316.9	352–1000	184.1
Metroliner	1800–3650	102.8	436–1850	324.3
Commuter	1387–3186	129.7	693–1308	88.7
Aircraft				
Wide body	4827–6136	27.1	1985–4090	106.0
Average	5625–9642	71.4	2596–6136	136.4

[a]The maximum error which could be incurred (expressed as percent of the true value) if any value within the range may be used and the true value also falls into the range. This worst case error is given by $\frac{(h - l)}{l} \times 100$.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 2-2.

Table 2-5 INTERCITY PASSENGER MOVEMENT FUEL UTILIZATION (PASSENGER GREAT CIRCLE MILES/GALLON)

Mode	Load Factor (%)	Range (Great Circle Statute Miles)						
		250	500	750	1000	1500	2000	2500
Airplane	60	14-21	18-27	20-30	21-32	23-34	24-35	24-35
Automobile	Range Dependent	17-35	22-40	26-44	29-47	34-51	38-54	40-55
Intercity Bus	60	88-169	91-165	94-161	96-159	101-155	105-154	107-153
Intercity Train	60	15-73	15-68	15-63	15-60	20-54	23-51	25-50

	Low Values	High Values
Airplane	Least Efficient In-Service Equipment	Most Efficient In-Service Equipment
Automobile	4,500 Lb. Automobile High Circuity Large City Urban Driving Penalty	3,700 Lb. Automobile Low Circuity Small City Urban Driving Penalty
Intercity Bus	5.4 Road MPG High Circuity	6.6 Road MPG Low Circuity
Intercity Train	High Circuity Least Efficient Equipment	Low Circuity Most Efficient Equipment

Data from Intercity Passenger Transportation Data Energy Comparison: Volume 2, The Boeing Commercial Airplane Company, May 1975, p. 35.

Table 2-6 1977 TRAVEL BETWEEN THE TWIN CITIES AND DULUTH--AN ENERGY ANALYSIS

Mode	Total Ridership	Percentage	Trip Length (Miles)	Circuity Ratio	Load Factor		Operating Efficiency		
					%	No. of Passengers	MPG	SM/Gal	PM/Gal
Automobile	3,861,700	93.4	148	1.14	41	2.47	12.5	75	31
Bus	157,179	3.8	165	1.27	54	23	6.0	258	138
Train	80,551	2.0	144	1.11	54	110	0.6	122	66
Air	33,104	0.8	157	1.21	57	53	0.3	30	17

Data from Amtrak Rail Service Between the Twin Cities and Duluth--An Energy Analysis, Minnesota Department of Transportation, Bureau of Policy & Planning, June 1978, pp. 2 and 5-8.

Table 2-7 PASSENGER TRANSPORTATION

Present Fuel Consumption

(Based on Seating Capacity and Average Fuel Use Rates)

		Seat Miles/Gallon (Representative)
Rail–(U.S. Current–includes allowances for engine idling between runs.)		
3000 hp locomotive, turbocharged, 0.5 mpg, 9 coaches per locomotive, 60–80 seats each (Amtrak data)–Relatively new Amtrak locomotives. Many Amtrak cars were less than 60 seats when acquired, now being refurbished with higher density seating.		270–360
2250 hp E-8, not turbocharged, 0.63 mpg, 6 coaches per locomotive, 60–80 seats each (Amtrak data)–relatively old Amtrak locomotives, extra engines sometimes added for reliability.		225-300
2250 hp E-8, not turbocharged, 0.63 mpg, 4-5 coaches per locomotive, 60–80 seats each (Amtrak data interpolated).		150–250
2250 hp E-8, not turbocharged, 0.62 mpg, 4 cars per locomotive–sleepers, dining, and club cars (Southern Railroad data)–locomotive performance essentially the same as Amtrak data. For cross-country, added engine for reliability and added luxury cars sharply reduce seat miles per gallon.		50
Rail diesel car (RDC) (Budd), 3 mpg, 75–85 seats.		250
Rail diesel car (RDC) (B&M) 2 mpg, 75 seats–illustrates difference between manufacturers estimate and operating experience. Single B&O demonstration of same cars got 3.48 mpg.		150
Rail turbine train; 0.33 mpg, 320 seats (296 + 24 snack bar) (Amtrak data) (Amtrak's French RTG)–delivery test at 80 mph average.		110
Autotrain, 0.37 mpg, 3600 hp locomotive, 18 cars per locomotive, 30 automobile–miles/gallon, at 5 seats per auto.		150
Bus–(U.S. Current)		
Intercity, 6.0 mpg (Greyhound), 47 seats (TSC Industry average)–over-the-road test of Greyhound and Trailways buses by TSC indicated 8.8 mpg at 50 mph, 8.1 mpg at 60 mph.		282
Urban, 3.6-4.6 mpg, 50 seats (FHWA, UMTA data).		180–230
Automobile–(FHWA Data)		
Urban subcompact	4 seats, 24 mpg	96
Urban compact	5 seats, 18 mpg	90
Urban standard	6 seats, 14.4 mpg	86.4
Urban luxury	6 seats, 9.0 mpg	54
Intercity subcompact	4 seats, 30 mpg	120
Intercity compact	5 seats, 22.5 mpg	112.5
Intercity standard	6 seats, 18.0 mpg	108
Intercity luxury	7 seats, 12.0 mpg	72
Air–(NASA Data)		
Twin engine turbofan, 68-106 seats		
short (250 mi. stage) .34-.44 mpg		30–38
medium (500 mi. stage) .44-.54 mpg		37-47
3 & 4 engine turbofan, 131-200 seats		
medium (500 mi. stage) .21-.29 mpg		35-41
long (1,000 mi. stage) .26-.34 mpg		44-51
3 & 4 engine turbofan, widebody, 256-385 seats		
wide body jets use new high by pass turbofan engines with low specific fuel consumption		
medium (500 mi. stage) .11-.19 mpg		44-51
long (1,000 mi. stage) .14-.22 mpg		54-60

Source: Report to Congress on the Rail Passenger Service Act by Transportation Secretary Claude Brinegar, July 22, 1974.

From <u>Energy Handbook</u>, Robert L. Loftness, 1978, p. 416.

Table 2-8

Inter-City Passenger Transport Fuel Efficiencies by Vehicle Type (1)

VEHICLE TYPE		AVERAGE SEATING CAPACITY	Fuel Economy		Average Fuel Efficiencies			
			Average km/litre	Average miles/U.S. gall.	Seat-km litre	Seat-miles gallon	Passenger km/litre (2)	Passenger miles/gallon (2)
AUTOMOBILE								
Luxury	1800kg 4000lb	6	6	14	36	84	18	42
Standard	1800-1125kg 4000-2540lb	5	8	18	40	90	20	45
Compact	1125kg 2500lb	4	11	26	44	104	22	52
BUS								
Highway Diesel		50	3	7	150	350	68	158
RAIL								
Diesel/Electric		100	1	2.5	100	250	40	100
AEROPLANE								
Short-Range (B-737, etc)		130	.18	.43	24	56	12	28
Medium-Range (Airbus, etc)		260	.11	.27	30	70	15	35
Long-Range (B-707)		164	.07	.17	12	28	6	14
Jumbo-Jet (B-747)		435	.06	.14	25	59	13	30

Sources: William P. Goss and Jon G. McGowan, "Energy Requirements for Passenger Ground Transportation Systems", paper presented at the Intersociety Conference on Transportation, Denver, September 1973. Eric Hirst, "Energy Consumption for Transportation in the United States", Oak Ridge National Laboratory Report CRNL-NSF-EP-15, March 1972. Richard A. Rice, "Historical Perspective in Transport System Development", Advanced Urban Transportation Systems, Carnegie-Mellon University, Pittsburg, Pa., 1971. Council on Environmental Quality, "Energy on the Environment", United States Government Printing Office, August 1973. Jane's All the World's Aircraft, 1973.

1) C.K. Orski, "The Potential for Fuel Conservation; The Case of the Automobile", Transportation Research, September 1974.

2) The Average passenger-kilometres/litre (passenger-miles/U.S. gallon) have been computed using load factors encountered under typical urban operating conditions; automobile 50 per cent; bus 45 per cent; railroad 40 per cent and aeroplane 50 per cent.

Source: Energy Prospects to 1985, Volume II, Organization for Economic Co-operation and Development, Paris, 1974.

From Energy Handbook, Robert L. Loftness, 1978, p. 416.

Table 2-9

Energy and Price Data for Transport

Mode	Energy (Btu/ton-mile)	Price (cents/ton-mile)
Intercity Freight Transport		
Pipeline	450	0.27
Railroad	670	1.4
Waterway	680	0.30
Truck	2,800	7.5
Airplane	42,000	21.9
Passenger Transport		
Intercity[a]		
Bus	1,600	3.6
Railroad	2,900	4.0
Automobile	3,400	4.0
Airplane	8,400	6.0
Urban[b]		
Mass transit	3,800	8.3
Automobile	8,100	9.6

[a]Load factors (percentage of transport capacity utilized) for intercity travel are about: bus, 45%, railroad, 35%; automobile, 48%; and airplane, 50%.

[b]Load factors for urban travel are about: mass transit, 20%; automobile, 28%.

Source: Proposed Final Environmental Statement Liquid Metal Fast Breeder Reactor Program, Volume III, WASH-1535, U.S. Atomic Energy Commission, December 1974.

From Energy Handbook, Robert L. Loftness, 1978, p. 413.

Table 2-10

FUEL EFFICIENCIES FOR RAIL AND FREIGHT
(Simplified Case)

Mode	Type of Movement	Fuel Efficiency (ton-miles/gallon)
Rail	Branchline[1]	55
Rail	Mainline[2]	270
Truck	Shorthaul[3]	65
Truck	Mainhaul[4]	55

1 30 cars or less.
2 100 car train
3 diesel truck at 30 mph
4 diesel truck at 55 mph

* Source: U.S. DOT Transportation System Center, Cambridge, Mass.

From Assessment of Environmental Impacts Associated with Railroad Abandonment Proposals, Interstate Commerce Commission, October 1976, p. 6-7.

Note: This table contains simplified data which is to be used in evaluating non-controversial abandonments.

Branchline data applies to lines less than 25 miles in length with less than 500 carloads per year.

Table 2-11

COMPARISON OF FUEL EFFICIENCIES FOR RAIL AND TRUCK IN BRANCH LINE SERVICE*
(ton-miles/gallon)

NET LOAD (tons)	RAIL	TRUCK	
25	15	65	Truck shipments have the fuel efficiency advantage for shipments of these magnitudes.
50	30	65	
75	43	65	
100	50	65	
125	57	65	
150	63	65	Approximate range where neither mode has an advantage.
175	67	65	
200	69	65	
300	80	65	Rail shipments have the fuel efficiency advantage for shipments of these magnitudes.
400	87	65	
500	94	65	
600	100	65	
700	105	65	
800	110	65	
900	113	65	
1000	115	65	

* Based on actual branch line measurement performed for U. S. DOT Transportation Systems Center, Cambridge, Mass.

From Assessment of Environmental Impacts Associated with Railroad Abandonment Proposals, Interstate Commerce Commission, October 1976, p. 6-16.

Table 2-12

TYPICAL INTERCITY FUEL EFFICIENCIES

Category	Ton Miles/Gallon	Approximate Net Load (Tons)
Rail*	210	1,000 - 2,000
Trucks***	55	25
Barges**	300	24,000 - 60,000
Oil Pipelines	290	-
Air Freight	8	100 - 350

* Unit trains can carry from 10,000 - 20,000 tons and can get 300 - 400 ton miles/gallon.

** Barge tows have achieved as high as 1,150 ton miles/gallon.

*** Trucks on intercity hauls can achieve 75 ton-miles/gallon.

From Assessment of Environmental Impacts Associated with Railroad Abandonment Proposals, Interstate Commerce Commission, October 1976, p. 6-18.

Table 2-13 RAIL, TRUCK, AND BARGE ENERGY INTENSITIES FOR VARIOUS COMMODITY CLASSES

Commodity	Average Carload (Tons)	Average Truckload (Tons)	Energy Intensity in BTU/Ton-Mile: By Route-Miles		By Great-Circle Miles**		Barge
			Rail*	Truck	Rail	Truck	
Coal	86.2	20.30	330	2,260	430	2,590	296
Food and Kindred Products	49.8	17.36	750	2,540	1,000	2,914	201
Chemicals and Allied Products	73.4	18.02	450	2,470	590	2,830	290
Farm Products	66.9	19.45	510	2,330	670	2,680	172
Lumber and Wood, Except Furniture	46.8	19.13	750	2,360	1,000	2,710	226
Pulp, Paper and Allied Products	43.1	15.55	890	2,760	1,170	3,170	221
Nonmetallic Minerals, Except Fuels	76.1	20.05	400	2,280	530	2,620	339
Stone, Clay and Glass	56.8	19.91	590	2,290	780	2,630	230
Primary Metal Products	63.1	18.98	510	2,370	680	2,720	240
Transportation Equipment	23.3	11.77	2,240	3,460	2,960	3,970	270
Metallic Ores	81.5	19.87	370	2,290	490	2,630	263
Petroleum and Coal Products	59.4	24.45	610	1,980	800	2,270	321
Miscellaneous Mixed Shipments	22.6	13.95	2,090	3,010	2,760	3,460	
Freight and Forwarding Traffic	22.2	12.19	2,150	3,560	2,840	3,860	
Fabricated Metal Products	34.2	13.53	1,180	3,090	1,560	3,540	231
Machinery, Except Electrical	24.8	13.39	2,020	3,110	2,670	3,570	284
Electrical Machinery	17.2	11.21	3,450	3,600	4,550	4,130	265
Rubber and Miscellaneous Plastic Products	18.8	12.13	2,890	3,370	3,820	3,870	169
Basic Textiles	19.6	13.13	2,750	3,160	3,640	3,630	306

* All mileage-related data are based on short-line distances rather than the actual routings.
** A circuity ratio of 1.321 was used for the rail data, and 1.148 for the truck data.

Rail and truck data from <u>Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements</u>, A. B. Rose, Department of Energy, January 1979, pp. 5-17 and 6-11.

Barge data from <u>Transportation Energy Conservation Data Book: Edition 2</u>, Energy Research and Development Administration, October 1977, p. 202.

3. AUTOMOBILE TRANSPORTATION

Table 3-1 City-Highway Sales-Weighted Passenger Car Fuel Economy by Inertia Weight Class, 1970–1978[a]

Model year	Inertia weight class (lb)										Sales-weighted average
	2000	2250	2500	2750	3000	3500	4000	4500	5000	5500	
1970	27.9	27.1	23.3	22.6	19.5	16.2	14.6	13.6	12.8	10.2	15.5
1971	26.4	26.7	25.5	21.6	18.7	15.5	14.5	13.1	11.6	12.5	15.1
1972	26.6	25.7	23.2	23.8	18.8	15.7	14.3	13.1	12.5	11.3	15.0
1973	26.9	26.6	23.0	21.5	17.5	15.0	13.9	13.2	11.6	10.8	14.5
1974	27.7	26.3	23.5	20.8	18.6	16.4	13.4	12.4	11.8	11.1	14.4
1975	31.4	27.9	24.3	22.2	21.4	17.5	15.6	14.6	13.0	12.0	15.6
1976	32.1	28.7	26.0	24.4	23.4	19.1	17.3	15.5	14.6	13.3	17.7
1977	36.1	31.6	28.8	25.2	23.9	20.2	18.0	16.6	14.2	12.7	18.6
1978	35.4	32.4	28.0	24.5	22.4	20.1	18.0	16.3	14.6	12.4	19.6

[a]1970–1973 data are from registration summations, 1974 data are based on production figures, and 1975–78 data are based on manufacturers' sales forecasts.

Source: J. D. Murrel, *Light Duty Automotive Fuel Economy — Trends Through 1978*, SAE Paper 780036.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 4-16.

Table 3-2 PROJECTED FUEL CONSUMPTION OF PASSENGER CARS

Composite passenger automobile operating on U. S. roads, based on 55% urban and 45% highway driving.

Year	Miles per Gallon	Kilometres per litre
1977	15.5	6.59
1978	15.9	6.76
1979	16.4	6.97
1980	17.0	7.23
1981	17.8	7.57
1982	18.7	7.95
1983	19.8	8.42
1984	20.9	8.89
1985	22.1	9.40
1986	23.2	9.86
1987	24.2	10.29
1988	25.0	10.63
1989	25.7	10.93
1990	26.2	11.14
1991	26.6	11.31
1992	26.9	11.44
1993	27.1	11.52
1994	27.3	11.61
1995	27.4	11.65
2000	27.5	11.69

From Energy Factor Handbook--Appendix A, Caltrans, 1977, p. A-35.

Table 3-3 ESTIMATED URBAN AUTOMOBILE ENERGY INTENSITY

Average speed (mph)	Energy efficiency (mpg)	Energy Intensity (BTU/VMT)
10	10.3	12,150
12	11.6	10,770
14	12.8	9,790
16	13.8	9,050
18	14.7	8,480
20	15.6	8,020
22	16.4	7,650
24	17.0	7,330
26	17.7	7,070
28	18.3	6,840
30	18.8	6,650

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 4-23.

Table 3-4 INTERCITY AUTOMOBILE ENERGY INTENSITY, 1976

One-way trip length[a] (great-circle miles)	Average vehicle[b] occupancy	Energy intensity (Btu/route PM)	Circuity[c] ratio	Great-circle-mile-based energy intensity (Btu/VMT)	(Btu/PM)
63.9-95.9	2.17	2940	1.226	7820	3610
95.9-127.9	2.08	3070	1.111	7080	3410
127.9-191.9	2.15	2970	1.218	7770	3610
191.9-319.9	2.18	2930	1.264	8070	3700
319.9-639.9	2.32	2750	1.231	7870	3390
Over 639.9	2.43	2630	1.213	7760	3190
All	2.27[d]	2810	1.217[e]	7770	3420

[a]These odd categories arise when the round-trip categories from the NTS are converted to one-way mileages and the erroneous circuity of 1.56 is removed.

[b]Occupancy — Person-trips divided by the number of trips, from the NTS data. The resulting occupancy should be considered a lower bound value because the NTS only shows the number of household members in the travel party.

[c]Derived from disaggregate data in Appendix B (see Section 4.2).

[d]This is the passenger-mile-weighted mean occupancy rather than the unweighted value from the NTS.

[e]The passenger-mile-weighted circuity ratio calculated in Section 4.2.

From <u>Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements</u>, A. B. Rose, Department of Energy, January 1979, p. 4-21.

4. BUS TRANSPORTATION

Table 4-1 SUMMARY OF BUS ENERGY INTENSITIES, 1970-1977

	Trolley coaches (Btu/VMT)	Transit buses (Btu/VMT)[a]	School buses (Btu/VMT)	Intercity buses	
				(Btu/VMT)[a]	(Btu/PM)[b]
1970	49,300	32,500	17,710	NA	NA
1971	52,100	30,420	17,710	NA	NA
1972	50,800	30,540	16,820	22,850	1,050
1973	41,200	30,800	16,820	22,840	1,020
1974	NA	31,520	16,850	22,300	960
1975	44,300	33,750	16,960	22,280	990
1976	NA	34,600	16,890	22,620	1,010
1977	NA	35,100		22,890	980

NA — no available.

[a]Large system-to-system variations exist within this category.

[b]These values are calculated on a route-mile basis. For purposes of intermodal comparisons they should be multiplied by a circuity factor of 1.114 to convert them to a great-circle-mile basis.

Sources: American Bus Association, *American's Number 1 Passenger Transportation Service*, Washington, D.C., 1977, supplemented with private communications with the American Bus Association; American Public Transit Association, *Transit Fact Book, '76-'77 ed.*, Washington, D.C., June 1977.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. S-8.

Table 4-2 FUEL CONSUMED IN NORMAL BUS USE

1. Metropolitan Transit Operations (average vehicle):

   Fuel Consumption: 0.257 GPM [.604 litres/Km]

2. School Bus (var. seats) Gasoline:

   Fuel Consumption: 0.135 GPM [.318 litres/Km]

3. Minibus (10-13 seats) Diesel:

   Fuel Consumption: 0.081 GPM [.191 litres/Km]

4. Minibus (10-13 seats) Gasoline:

   Fuel Consumption: 0.146 GPM [.343 litres/Km]

5. Minibus (33 seats):

   Fuel Consumption: N.A.

6. Standard (53 seats) Diesel:

   Fuel Consumption: 0.234 GPM [.550 litres/Km]

7. Standard (48 seats) Electric Trolley:

   Fuel Consumption: 3.95 KWH/mile [2.45 KWH/Km]

8. Standard (50 seats) Gasoline:

   Fuel Consumption: N.A.

9. Standard (50 seats) Propane:

   Fuel Consumption: 0.531 GPM [1.249 litres/Km]

   (equivalent 51500 BTU/mile)

From <u>Energy Factor Handbook--Appendix A</u>, Caltrans, 1977, p. A-64.

Table 4-3 ENERGY INTENSITY OF CONVENTIONAL TRANSIT BUSES, 1970-1977

	Vehicle-miles (10^6)	Fuel consumption (10^6 gal)			Energy use (10^{12} Btu)	Energy intensity (Btu/VMT)
		Gasoline	Diesel	Propane		
1970	1,409.3	37.2	270.6	31.0	45.17	32,050
1971	1,375.5	29.4	256.8	26.5	41.85	30,420
1972	1,308.0	19.65	253.3	24.4	39.94	30,540
1973	1,370.4	12.33	282.6	15.2	42.21	30,800
1974	1,431.0	7.46	316.4	3.1	45.11	31,520
1975	1,526.0	5.02	365.1	2.6	51.51	33,750
1976[a]	1,581.4	5.20	389.2	1.0	54.72	34,600
1977	1,623.3	8.07	402.8	1.1	56.98	35,100

[a]Preliminary data.

Source: American Public Transit Association, *Transit Fact Book*, 1977-1978 Edition, Washington, D.C., May 1978.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 5-13.

Table 4-4 OPERATING STATISTICS AND ENERGY INTENSITIES OF INTERCITY BUSES,[a] 1970-1976

	Passengers (10^6)	Passenger-miles (10^6)	Vehicle-miles (10^6)	Fuel used[b] (10^6 gal)	Route-miles-based energy intensities		Great-circle miles-based[c] energy intensities	
					Btu/VMT	Btu/PM	Btu/VMT	Btu/PM
1970								
Regular route intercity	309	20,405	1,030					
Other operations	92	4,895	179					
Total	401	25,300	1,209					
1971								
Regular route intercity	305	20,315	1,020					
Other operations	90	5,185	182					
Total	395	25,500	1,202					
1972								
Regular route intercity	304	19,887	988	162.7		1,140		1,260
Other operations	89	5,713	194	32.0		700		870
Total	393	25,600	1,182	194.7	22,850	1,050	25,450	1,180
1973								
Regular route intercity	293	20,523	975	160.6		1,090		1,210
Other operations	88	5,877	203	33.4		790		880
Total	381	26,400	1,178	194.0	22,840	1,020	25,450	1,140
1974								
Regular route intercity	289	21,431	978	157.2		1,020		1,130
Other operations	97	6,269	217	34.9		770		860
Total	386	27,700	1,195	192.1	22,300	960	24,840	1,070
1975								
Regular route intercity	271	18,946	914	146.8		1,070		1,200
Other operations	80	6,454	212	34.1		730		820
Total	351	25,400	1,126	180.9	22,280	990	24,820	1,100
1976								
Regular route intercity	261	18,244	897	146.3		1,110		1,240
Other operations	79	6,856	221	36.0		720		800
Total	340	25,100	1,118	182.3	22,620	1,010	24,190	1,120
1977								
Total	NA	25,700	1,102	181.9	22,890	980	25,500	1,090

NA — Not available.

[a] Includes statistics of Class I, II, III carriers reporting to the ICC and Intrastate Carriers.

[b] All intercity buses are assumed to use diesel fuel. Prior to 1974, fuel consumption was not reported to the ICC and the fuel consumption data for those years are based on estimates from the American Bus Association.

[c] All great-circle-based energy intensity values are derived utilizing the passenger-mile-weighted systems circuity of 1.114 (see page).

Source: American Bus Association, *America's Number 1 Passenger Transportation Service*, Washington, D.C., 1977; supplemented by private communications with the American Bus Association.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 5-9.

5. PERSONAL RAPID TRANSIT

Table 5-1 PERSONAL RAPID TRANSIT (LIGHT MASS TRANSIT) FUEL CONSUMPTION

System	Seats (Standing) per car		Rated Hp/Seat	Wt/Seat Tons (Metric T)		Avg. Speed MPH (Km/hr)		Energy Consumption
N. Railbus (San Diego Zoo)	75		1.33	0.13	(0.11)	25	(40)	N.A.
Airtrans (Dallas Airport)	16	(24)	4.69	0.34	(0.31)	12	(19)	1.4 Kw/veh-mi (0.87 Kw/veh-Km)
Minirail (Montreal)	12		0.78	0.05	(0.05)	8	(13)	N.A.
K Monorail (Lancaster, PA)	12		0.42	N.A.		25	(40)	N.A.
Skybus (Tampa Airport)	12	(90)	8.33	1.06	(0.96)	15	(24)	N.A.
Jetrail (Dallas Airport)	6	(4)	1.67	N.A.		30	(48)	N.A.
Peoplemover (Disneyland)	4		2.5	0.08	(0.07)	4	(6)	N.A.
ACT (Ford Motor Co.)	10	(20)	12.0	0.64	(0.58)	20	(32)	N.A.
StaRRcar (Morgantown, WV)	8	(13)	12.5	0.43	(0.39)	22	(35)	2 Kw/veh-mi (1.2 Kw/veh-Km)
Speedwalk* (Moving sidewalk) (L. A. Airport)		(200±)	0.23*	30**	(44.6)**	1.4	(2.25)	N.A.
Escalator* (Moving stairway)		(N.A.)	0.3*	N.A.		1.4	(2.25)	N.A.

* Standees only in this system
** Values are: 30 plf (44.6 Kg/m)

From _Energy Factor Handbook--Appendix A_, Caltrans, 1977, pp. A-79 - A-80.

6. TRUCK TRANSPORTATION

Table 6-1 Weight Class Distribution for Light-Duty Trucks, 1975–1978

Weight class (lb)	Model Year 1975	1976	1977	1978
2750	.1284	.2349	.1554	.1321
3000	.0739	.1319	.1044	.1293
3500	.0274	.0663	.0404	.0599
4000	.2684	.3057	.3247	.3528
4500	.4466	.2332	.3587	.3093
5000	.0552	.0279	.0165	.0166

[a]Data based on manufacturers' sales estimates.

Source: J. D. Murrell, *Light Duty Automotive Fuel Economy — Trends Through 1978*, SAE Paper 780036.

Table 6-2 Sales-Weighted[a] Fuel Economy[b] for Light-Duty Trucks, 1975–1978

Inertia weight (lb)	Fuel economy (mpg) 1975	1976	1977	1978
2750	22.3	24.3	25.6	25.9
3000	18.8	20.2	25.5	25.0
3500	20.6	17.7	18.2	18.3
4000	15.6	17.3	19.0	18.3
4500	14.1	14.8	16.7	15.8
5000	11.5	13.1	12.5	18.2
All	15.4	18.0	19.1	18.7

[a]Data based on manufacturers' sales estimates.

[b]EPA urban/highway mpg.

Source: J. D. Murrell, *Light Duty Automotive Fuel Economy — Trends Through 1978*, SAE Paper 780036.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 4-17.

7. RAIL TRANSPORTATION

Table 7-1 Summary of Rail Energy Intensities, 1972-1977

Year	Rail transit (Btu/VM)	Rail transit (Btu/PM)[a]	Commuter rail (Btu/PM)[b]	Amtrak (Btu/PM)[c]
1972	66,090	2,540	4,680	4,110
1973	60,460	2,480	4,710	3,590
1974	65,170	2,830	4,400	3,050
1975	67,100	2,960	3,900	3,410
1976	68,240	2,960	3,500	3,230
1977	68,350	2,700	3,790	3,410

[a]The values are estimated based on the assumption that the average trip length of 6.82 miles as estimated for 1975 holds for other years.

[b]Includes a small number of intercity operations.

[c]The values are based on route-passenger-miles. For intermodal comparisons they should be multiplied by the lower-bound passenger-mile weighted circuity ratio of 1.325 to yield great-circle-mile energy intensity values.

Source: American Public Transit Association, *Transit Fact Book, '77-'78 ed.*, Washington, D.C., 1978; Association of American Railroads, *Statistics of Railroads of Class I, Years 1967 to 1977*, Washington, D.C., September 1978; National Railroad Passenger Corporation, *Annual Report to the Interstate Commerce Commission*, Washington, D.C., 1972-1977; Stanford Research Institute, *Energy Study of Rail Passenger Transportation, Volume 2: Description of Operating System*, Menlo Park, Calif., August 1977.

From <u>Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements</u>, A. B. Rose, Department of Energy, January 1979, p. S-9.

Table 7-2 CALCULATED ENERGY INTENSITY OF URBAN RAIL SYSTEMS

Heavy Rail

BTU/VEHICLE MILE			BTU/PASSENGER MILE		
Distance Between Stops Miles	Maximum Occupancy Including Standees	All Seats Occupied	Maximum Occupancy Including Standees	All Seats Occupied	30% Seats Occupied
.5	93,000	84,000	669	1,040	3,130
1.0	66,000	60,000	472	750	2,250
1.5	50,000	45,000	351	560	1,670
2.0	39,000	36,000	284	450	1,350
2.5	34,000	30,500	246	390	1,170

Total load: 140 passengers; seats: 80
Maximum load weight: 122,100 lbs
Empty weight: 91,920 lbs
Maximum speed: 55 mph

Light Rail

BTU/VEHICLE MILE			BTU/PASSENGER MILE		
Distance Between Stops Miles	Maximum Occupancy Including Standees	All Seats Occupied	Maximum Occupancy Including Standees	All Seats Occupied	30% Seats Occupied
.5	90,000	67,000	309	883	2,652
1.0	61,000	43,000	192	558	1,696
1.5	45,000	32,500	140	429	1,304
2.0	37,500	26,000	114	351	1,087
2.5	31,500	23,000	98	299	913

Total load: 320 passengers; seats: 77
Maximum load weight: 109,400 lbs
Empty weight: 55,815 lbs
Maximum speed: 55 mph

Source: The Aerospace Corporation, Characterization of the U.S. Transportation System - Urban Rail Transit, Los Angeles, Calif., July 1976, p. 21. (Draft)

From Transportation Energy Conservation Data Book: Edition 2, D. B. Shonka, A. S. Loebl, P. D. Patterson, Energy Research and Development Administration, October 1977, p. 201.

Table 7-3 DIRECT FUEL CONSUMPTION OF RAIL MASS TRANSIT

System	Seats [Standing] per car	Rated Hp/Seat	Wt/Seat Tons	Wt/Seat (Metric T)	Energy Consumed** BTU/Seat-Mi	Energy Consumed** (Joules/Seat-Km)
Std. Commuter	127 [123]	9.5	.47	(.43)	N.A.	(N.A.)
Lindenwold	84	7.6	.39	(.36)	N.A.	(N.A.)
Toronto	83 [N.A.]	1.9	.35	(.32)	860	(5.62x10^5)
San Francisco*	72 [72]	7.4	.40	(.36)	850	(5.62x10^5)
Philadelphia	56 [N.A.]	5.8	.43	(.39)	1075	(7.02x10^5)
Cleveland	54 [N.A.]	3.4	.51	(.46)	686	(4.54x10^5)
Chicago	51 [N.A.]	3.4	.41	(.38)	952	(6.26x10^5)
New York	47 [N.A.]	7.3	.84	(.76)	1208	(7.88x10^5)
Montreal	40 [120]	3.9	.75	(.68)	N.A.	(N.A.)
Tokyo "Alweg"	35 [65]	13.3	.39	(.35)	N.A.	(N.A.)

*BART System

**Standee capacity is not included in computations

From <u>Energy Factor Handbook--Appendix A</u>, Caltrans, 1977, p. A-78.

Table 7-4 ENERGY INTENSITY OF HEAVY RAIL TRANSIT SYSTEMS, 1970-1977

Year	Vehicle miles (10^6)	Energy use (10^6 kWhr)	Energy intensity	
			kWhr/VMT[a]	Btu/VMT[b]
1970	407.1	2,261	5.55	63,170
1971	407.4	2,262	5.55	63,150
1972	386.2	2,149	5.56	63,290
1973	407.3	2,098	5.15	58,580
1974	431.9	NA	NA	NA
1975	423.1	2,352	5.56	63,290
1976	407.0	NA	NA	NA
1977[c]	361.3	NA	NA	NA

NA — Not available.

[a] Electricity in kWhr, not including generation losses.

[b] Calculated assuming 30% efficiency for electrical generation and distribution.

[c] Preliminary data.

Source: American Public Transit Association, *Transit Fact Book, 1976-1978 Edition*, Washington, D.C., May 1978; K. Chomitz, C. Lave, *A Survey and Analysis of Energy Intensity Estimates for Urban Transportation Modes*, Irvine, Calif., 1978.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 6-11.

Table 7-5 OPERATIONAL STATISTICS AND ENERGY INTENSITIES OF COMMUTER RAILROADS, 1972-1977

	1972	1973	1974	1975	1976	1977
Rail motor cars						
VMT (10^6)	88.07	91.51	99.42	103.3	102.98	98.43
Energy use (10^{12} Btu)	8.61	10.71	10.24	10.36	9.69	11.57
Energy intensity (Btu/VMT)	97,800	117,100	103,000	100,300	94,100	117,600
Locomotive hauled trains						
Passenger car miles (10^6)	72.91	67.70	70.34	67.02	68.23	65.36
Energy use (10^{12} Btu)	16.50	14.27	15.29	12.89	10.22	10.36
Energy intensity (Btu/VMT)	226,300	210,800	217,400	192,300	149,800	163,300
Total passenger miles[a] (10^9)			5.80	5.92	5.76	5.87
Overall energy intensities						
Btu/VMT	156,000	156,900	150,400	136,500	116,500	135,800
Btu/PM			4,400	3,900	3,500	3,790

Source: Association of American Railroads, *Statistics of Railroads of Class I*, Years 1967–1977, Washington, D.C., September 1978; Auto-Train Corporation, *Annual Report to the Interstate Commerce Commission*, Washington, D.C., 1972–1977; National Railroad Passenger Corp., *Annual Report to the Interstate Commerce Commission*, Washington, D.C., 1972–1977.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 6-16.

Table 7-6 FUEL CONSUMPTION OF PASSENGER TRAINS

(SHORT TRIPS)

Electric Energy	Diesel Fuel Equivalent
0.17 KWH/seat-mile	0.013 gal/seat-mile
(0.11 KWH/seat-Km)	(0.030 litre/seat-Km)

Data from Energy Factor Handbook--Appendix A, Caltrans, 1977, p. A-74.

Table 7-7 FUEL CONSUMPTION OF SELECTED PASSENGER TRAINS

(LONG TRIPS)

Route	Distance Miles(Km)	Propulsion Type	Diesel Fuel Gal/seat-mile (Lit/seat-Km)	
Seattle-Havre	903 (1453)	Diesel-Elec.	.009	(.022)
Atlanta-Wash.	633 (1019)	Diesel-Elec.	.012	(.029)
New York-Wash.	284 (457)	Gas Turbine	.010	(.024)
Chicago-St. Louis	227 (365)	Electric	.013*	(.031)

*Equivalent diesel fuel

From Energy Factor Handbook--Appendix A, Caltrans, 1977, p. A-74.

Table 7-8 OPERATING STATISTICS AND ENERGY EFFICIENCIES OF THE AMTRAK INTERCITY RAIL SYSTEM, 1972-1977

Equipment	Year					
	1972	1973	1974	1975	1976	1977
Rail motor cars						
VMT (10^6)	11.77	12.55	13.67	15.53	16.35	18.79
Energy use (10^{12} Btu)	1.39	1.11	1.17	2.00	2.36	2.92
Energy intensity (Btu/VMT)	117,900	89,000	85,600	128,800	144,100	155,300
Locomotive hauled trains:						
Passenger car miles (10^6)	200.6	226.0	245.9	237.6	246.5	242.1
Energy use (10^{12} Btu)	11.09	12.55	11.82	10.80	11.38	11.41
Energy intensity (Btu/VMT)	55,280	55,520	48,050	45,460	46,250	47110
Total passenger miles (10^9)	3.039	3.807	4.259	3.753	4.268	4.204
Percent commutation			3.7	3.7	3.1	3.0
Route-mile–based energy intensity						
Btu/VMT	58,760	57,270	50,020	50,570	52,270	54,900
Btu/PM	4,110	3,590	3,050	3,410	3,230	3,410
Lower-bound great-circle mile–based energy intensity[a]						
Btu/VMT	77,860	75,880	66,280	67,010	69,260	72,740
Btu/PM	5,450	4,760	4,040	4,520	4,280	4,520

[a] Because the average trip length for years after 1972 is greater than that for 1972, the year for which the circuity of 1.35 was calculated, these figures must be considered lower bounds.

Source: National Railroad Passenger Corporation, *Annual Report to the Interstate Commerce Commission*, Washington, D.C., 1972–77, Supplemented by personal communications with the National Railroad Passenger Corporation.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 6-9.

Table 7-9 CLASS I RAILROAD FREIGHT ENERGY INTENSITIES, 1970-1977

Year	Route-mile-based energy intensities: Btu per revenue ton-mile: Line haul	Additional	Total	Btu per gross ton-mile	Great circle mile-based energy intensities: Btu per revenue ton-mile	Btu per gross ton-mile
1970	577	78	650	272	860	360
1971	615	81	760	286	920	380
1972	630	76	710	284	930	380
1973	597	71	670	274	880	360
1974	594	71	660	276	870	360
1975	609	72	680	278	900	370
1976	604	72	680	275	890	360
1977	594	73	670	274	880	360

Source: Association of American Railroads, *Statistics of Railroads of Class I in the United States, Years 1967 to 1977*, Washington, D.C., Sept. 1978; Association of American Railroads, *Yearbook of Railroad Facts, 1978 Edition*, Washington, D.C., 1978.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, A. B. Rose, Department of Energy, January 1979, p. 5-12.

8. AIR TRANSPORTATION

Table 8-1 JET AIRCRAFT FUEL CONSUMED ASSUMING BEST CRUISING SPEED

Aircraft Type	Approx. Seats	Best Cruise Speed MPH	(Km/Hr)	FUEL CONSUMPTION: Cruise Gal/Seat-Mile*	(Lit/Seat-Km)	Non-Cruise** (per trip) Gal/Seat	(Lit/Seat)
Jumbo Jet	315	575	(925)	.020	(.047)	7.2	(27.3)
Long-Range Jet	140	565	(909)	.024	(.056)	10.1	(38.2)
Medium-Range Jet	90	565	(909)	.022	(.052)	10.1	(38.2)
Air Carrier Turboprop	85	360	(579)	.019	(.045)	3.0	(11.4)
S.T.O.L. Commercial	19	190	(306)	.028	(.066)	1.8	(6.8)
Gen.Aviation Turboprop	10	300	(483)	.020	(.047)	3.0	(11.4)
Gen.Aviation Piston	5	105	(169)	.023	(.054)***	0.3	(1.1)***

*Great Circle miles

**Non-Cruise mode includes: Taxi-Idle at both ends of trip, takeoff, climbout, and approach-landing.

***Aviation Gasoline Fuel

From <u>Energy Factor Handbook--Appendix A</u>, Caltrans, 1977, p. A-83.

Table 8-2 SUMMARY OF CERTIFICATED AIR CARRIER ENERGY INTENSITY FOR PASSERGER MOVEMENTS, 1971-1976

	Domestic	International	Composite
1971			
Btu/pm	8920	6540	8290
Btu/sm	4550	3700	4180
% load factor	48.6	56.6	50.5
1972			
Btu/pm	8130	6080	7590
Btu/sm	4280	3670	4130
% load factor	52.6	60.3	54.5
1973			
Btu/pm	8200	6020	7650
Btu/sm	4280	3520	4100
% load factor	52.2	58.4	53.6
1974			
Btu/pm	7240	5630	6870
Btu/sm	4050	3200	3860
% load factor	55.9	56.8	56.1
1975			
Btu/pm	7180	5730	6870
Btu/sm	3950	3120	3770
% load factor	55.0	54.4	54.9
1976			
Btu/pm	6760	5230	6440
Btu/sm	3800	3060	3650
% load factor	56.2	58.6	56.7
1977[a]			
Btu/pm	6580	5070	6260
Btu/sm	3720	3040	3590
% load factor	58.6	59.9	57.2

[a]Data for first 3 quarters only.

Source: National ARchives and Records Service, Machine Readable Archives Division, *CAB Form 41 Schedule T-2*, Washington, D.C., 1970-1977.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Passenger Movements, A. B. Rose, Department of Energy, January 1979, p. 3-9.

Table 8-3 ALL-CARGO AIRCRAFT OPERATING STATISTICS CARRIER TYPE, 1976

Carrier type	Aircraft miles (10^6)	Jet fuel consumed (10^6 gal)	Cargo ton-miles (10^6)	Ton load factor (%)	Mean stage length (miles)	Cargo energy intensity (Btu/TM)	Portion of energy intensity due to non-revenue operations (%)
All carriers	119.4 (100.0)	578.8 (100.0)	3235.4 (100.0)	59.1	1409	24,150	2.9
All-cargo	47.5 (39.8)	252.0 (43.5)	1560.6 (48.2)	63.9	1484	21,800	3.0
Trunks	70.8 (59.4)	324.5 (56.1)	1665.4 (51.5)	55.0	1256	26,310	2.8
Other carriers	1.0 (0.9)	2.2 (0.4)	9.4 (0.3)	61.1	NA	31,460	4.3
All domestic	54.5 (65.04)	247.6 (42.8)	1318.2 (40.7)	56.1	1142	25,360	1.1
Trunks	38.8 (32.5)	170.9 (29.5)	845.6 (26.4)	53.8	1149	27,280	1.2
Big 4	33.4 (27.9)	143.7 (24.8)	722.9 (22.3)	55.3	NA	26,830	1.2
Other	5.42 (4.5)	27.21 (4.7)	122.7 (3.8)	46.3	NA	29,950	1.4
All-cargo	14.7 (12.3)	74.5 (12.9)	463.3 (14.3)	60.8	1119	21,720	0.6
All international	64.9 (54.3)	331.1 (57.2)	1917.1 (59.3)	61.2	1736	23,310	4.3
Trunk	32.1 (26.9)	153.6 (26.5)	819.8 (25.3)	56.3	1435	25,300	4.6
All-cargo	32.78 (27.5)	177.44 (30.7)	1097.3 (33.9)	65.3	2115	21,830	4.0

NA – Not available.

Source: Civil Aeronautics Board, *Aircraft Operating Cost and Performance Report*, Washington, D.C., July 1973 and 1977 Editions. National Archives and Records Service, Machine Readable Archives Division, *CAB Form 41 Schedule T-2*, Washington, D.C., 1971-77.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, A. B. Rose, Department of Energy, January 1979, p. 3-10.

9. PIPELINES

Table 9-1 DIRECT ENERGY CONSUMPTION OF PIPELINES

	Btu/Ton-mile	Joules/Metric T-Km
Coal Slurry Transport	300	1.78×10^5
Natural Gas Transport	2637	1.57×10^6
Oil Transport	660	3.92×10^5

From Energy Factor Handbook--Appendix A, Caltrans, 1977, p. 91.

Table 9-2 ENERGY EFFICIENCY OF THE NATURAL GAS PIPELINE SYSTEM, 1970-1976

Year	Natural gas consumed for transmission ($10^6 \times ft^3$)	Natural gas delivered[a] ($10^9 \times ft^3$)	Energy intensity ratio (10^{-3})
1970	722,166	19,417	39.1
1971	742,592	19,969	39.1
1972	766,156	20,015	40.3
1973	728,177	20,267	37.8
1974	668,792	19,161	36.7
1975	582,963	17,902	34.3
1976	548,323	17,716	32.6

[a]Natural gas delivered to customers plus net change in underground storage.

Source: American Gas Association, *Gas Facts 1976*, Arlington, Va., 1977.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, A. B. Rose, Department of Energy, January 1979, p. S-5.

10. MARINE TRANSPORTATION

Table 10-1 Estimated Energy Intensities for the Lakewise Shipping Sector, U.S. Vessels

Vessel	Percentage of ton-miles carried	Energy intensity	
		Btu/route-TM	Btu/GC-TM[a]
Dry bulk	94.0	540	580
Tanker	3.3	650	690
Tug/barge	2.8	300	320
Total	100.0	510	540

[a] The route-mile-based energy intensity multiplied by the lower bound circuity ratio of 1.068 from Section 4.2.

TM — Ton-mile.

GC — Great-circle.

Source: Booz, Allen, and Hamilton, *Energy Use in the Marine Transportation Industry, Task I-Industry Summary*, Washington, D.C., 1977.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, A. B. Rose, Department of Energy, January 1979, p. 4-13.

Table 10-2 Energy Intensity of Domestic Waterborne Commerce, 1970-1977

Year	Fuel consumed		Energy used	Route-ton miles	Energy intensity	
	Distillate (10^6 gal)	Residual (10^6 gal)	(10^{12} Btu)	(10^9)	Btu per route TM	Btu per great-circle TM[a]
1970	525	1683	324	596.2	540	870
1971	592.9	1454.8	299	593.2	500	810
1972	666.6	1487.2	315	603.5	520	840
1973	817.9	1493.8	337	584.7	580	920
1974	696.3	1246.9	283	586.3	480	770
1975	786.8	1294.8	302	566.0	530	850
1976	760.7	1147.8	227	591.9	470	750
1977	818.3	995.6	263	599.0	440	700

[a]Calculated using the aggregate circuity ratio of 1.601 from Section 4.2.

TM — Ton-mile

Sources: U.S. Department of Army, Corps of Engineers, 1970 to 1977 editions, *Waterborne Commerce of the United States*, New Orleans, La.; U.S. Department of Commerce, *Bunker Fuels Annual*, 1970-1977 editions, Washington, D.C.; U.S. Department of the Interior, Bureau of Mines, *Mineral Industry Surveys*, "Fuel Oil Sales, Annual," 1970-1975 editions, Washington, D.C.; U.S. Department of Energy, Energy Information Administration, *Energy Data Reports*, "Fuel Oil Sales, Annual," 1976-1977 editions, Washington, D.C.

From Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movements, A. B. Rose, Department of Energy, January 1979, p. 4-8.

APPENDIX

Table A-1
Nomenclature and Powers of Ten

	Value	Prefix	Symbol
One million million millionth	10^{-18}	atto	a
One thousand million millionth	10^{-15}	femto	f
One million millionth	10^{-12}	pico	p
One thousand millionth	10^{-9}	nano	n
One millionth	10^{-6}	micro	µ
One thousandth	10^{-3}	milli	m
One hundredth	10^{-2}	centi	c
One tenth	10^{-1}	deci	d
UNITY	10^{0}		
Ten	10^{1}	deca	da
One hundred	10^{1}	hecto	h
One thousand	10^{3}	kilo	k
One million	10^{6}	mega	M
One billion[a]	10^{9}	giga	G
One trillion[a]	10^{12}	tera	T
One quadrillion[a]	10^{15}	peta	P
One quintillion[a]	10^{18}	exa	E

[a]Care should be exercised in the use of this nomenclature, especially in foreign correspondence, as it is either unknown or carries a different value in other countries. A "billion," for example signifies a value of 10^{12} in most other countries.

Table A-2
Standard Metric Units and Abbreviations

Parameter	Base unit name	Preferred unit and prefix
Energy	Megajoule	MJ
Specific energy	Megajoule/kilogram	MJ/kg
Specific energy consumption	Megajoule/kilogram·kilometer	MJ/kg·km
Energy consumption	Megajoule/kilometer	MJ/km
Energy economy	Kilometre/kilojoule	km/KJ
Power	Kilowatt	kw
Specific power	Watt/kilogram	W/kg
Power density	Watt/metre^3	W/m^3
Speed	Kilometer/hour	km/h
Acceleration	Meter/second^2	m/s^2
Range (distance)	kilometre	km
Weight	Kilogram	kg
Torque	Newton·metre	N·m
Volume	Metre^3	m^3
Mass; payload	Kilogram	kg
Length; width	Metre	m
Brake specific fuel consumption	Kilogram/megajoule	kg/MJ
Fuel economy (heat engine)	Kilometer/litre	km/l

From Transportation Energy Conservation Data Book: Edition 3, Department of Energy, February 1979, p. A-4.

Table A-3
Energy Unit Conversions

1 Btu = 778.2 ft-lb	1 kWhr = 3412 Btu
= 107.6 kg-m	= 2.655×10^6 ft-lb
= 1055 J	= 3.671×10^5 kg-m
= 39.30×10^{-5} hp-hr	= 3.60×10^6 J
= 39.85×10^{-5} metric hp-hr	= 1.341 hp-hr
= 29.31×10^{-5} kWhr	= 1.360 metric hp-hr
1 kg-m = 92.95×10^{-4} Btu	1 J = 94.78×10^{-5} Btu
= 7.233 ft-lb	= 0.7376 ft-lb
= 9.806 J	= 0.1020 kg-m
= 36.53×10^{-7} hp-hr	= 37.25×10^{-8} hp-hr
= 37.04×10^{-7} metric hp-hr	= 37.77×10^{-8} metric hp-hr
- 27.24×10^{-7} kWhr	= 27.78×10^{-8} kWhr
1 hp-hr = 2544 Btu	1 metric hp-hr = 2510 Btu
= 1.98×10^6 ft-lb	= 1.953×10^6 ft-lb
= 2.738×10^6 kgm	= 27.00×10^4 kg-m
= 2.685×10^6 J	= 2.648×10^6 J
= 1.014 metric hp-hr	= 0.9863 hp-hr
= 0.7475 kWhr	= 0.7355 kWhr

Table A-4
Distance and Velocity Conversions

1 in. = 83.33×10^{-3} ft	1 ft = 12.0 in.
= 27.78×10^{-3} yd	= 0.333 yd
= 15.78×10^{-6} milc	= 189.4×10^{-3} mile
= 25.40×10^{-3} m	= 0.3048 m
= 0.2540×10^{-6} km	= 0.3048×10^{-3} km
1 mile = 63360 in.	1 km = 39370 in.
= 5280 ft	= 3281 ft
= 1760 yd	= 1093.6 yd
= 1609 m	= 0.6214 mile
= 1.609 km	= 1000 m

1 ft/sec = 0.3048 m/sec = 0.6818 mph = 1.0972 km/hr

1 m/sec = 3.281 ft/sec = 2.237 mph = 3.600 km/hr

1 km/hr = 0.9114 ft/sec = 0.2778 m/sec = 0.6214 mph

1 mph = 1.467 ft/sec = 0.4469 m/sec = 1.609 km/hr

From _Transportation Energy Conservation Data Book: Edition 3_, Department of Energy, February 1979, p. A-8.

Table A-5
Force Conversions

From \ To	Horsepower	Kilowatts	Metric horsepower	Ft-lb per sec	Kilocalories per sec	Btu per sec
Horsepower	1	0.7457	1.014	550	0.1781	0.7068
Kilowatts	1.341	1	1.360	102.0	737.6	0.9478
Metric horsepower	0.9863	0.7355	1	542.5	0.1757	0.6971
Ft-lb per sec	1.82×10^{-3}	1.356×10^{-3}	1.84×10^{-3}	1	0.3238×10^{-3}	1.285×10^{-3}
Kilocalories per sec	5.615	4.187	5.692	3088	1	3.968
Btu per sec	1.415	1.055	1.434	778.2	0.2520	1

Table A-6
Energy Intensity and Efficiency Conversions

1000 Btu/mile = 621.5 Btu/km
= 66.86×10^3 kg-m/km
= 655.6 kJ/km
= 1.53 km/MJ
= 0.2931 kWhr/mile
= 0.1822 kWhr/km
= 125.0 mpg[a]
= 1.882 liter/100 km

1000 Btu/km = 1609 Btu/mile
= 107.6×10^6 kg-m/km
= 1055 kJ/km
= 0.9479 km/MJ
= 0.4716 kWhr/mile
= 0.2931 kWhr/km
= 77.67 mpg[a]
= 3.028 liter/100 km

10 mpg[a] = 12,500 Btu/mile
= 7767 Btu/km
= 835.8×10^3 kg-m/km
= 8195 kJ/km
= 0.1220 km/MJ
= 3.664 kWhr/mile
= 2.277 kWhr/km
= 23.52 liter/100 km[a]

10 liter/100 km[a] = 5315 Btu/mile
= 3302 Btu/km
= 355.4×10^3 kg-m/km
= 3484 kJ/km
= 0.2870 km/MJ
= 1.558 kWhr/mile
= 0.9683 kWhr/km
= 23.52 mpg[a]

1000 kJ/km = 1525 Btu/mile
= 947.8 Btu/km
= 102.0×10^3 kg-m/km
= 1 km/MJ
= 0.4469 kWhr/mile
= 0.2778 kWhr/km
= 81.97 mpg[a]
= 2.869 liter/100 km[a]

1 kWhr/mile = 3412 Btu/mile
= 2120 Btu/km
= 228.1×10^3 kg-m/km
= 2237 kJ/km
= 0.4470 km/MJ
= 0.6214 kWhr/km
= 36.64 mpg[a]
= 6.419 liter/100 km[a]

[a]Assuming automotive gasoline at 125,000 Btu/gal.

From Transportation Energy Conservation Data Book: Edition 3, Department of Energy, February 1979, p. A-9.

Table A-7 PROPERTIES OF SELECTED FUELS

	Density	Thermal Energy
1. AMMONIA (Liquid)	5.73 lb/gal	2.5×10^{5} BTU/gal
	(0.69 kg/litre)	(7.0×10^{7} Joules/litre)
2. BUTANE (Liquid)	N.A.	1.0×10^{5} BTU/gal
		(2.8×10^{7} Joules/litre)
3. COAL (Composite all grades)	78 pcf	1.07×10^{4} BTU/lb
	(1250 kg/m^3)	(2.49×10^{7} Joules/kg)
3.1 Anthracite	97 pcf	1.44×10^{4} BTU/lb
	(1554 kg/m^3)	(3.35×10^{7} Joules/kg)
3.2 Bituminous	84 pcf	1.28×10^{4} BTU/lb
	(1346 kg/m^3)	(2.98×10^{7} Joules/kg)
3.3 Lignite	78 pcf	6.6×10^{3} BTU/lb
	(1250 kg/m^3)	(1.5×10^{7} Joules/kg)
3.4 Sub-Bituminous	N.A.	8.5×10^{3} BTU/lb
		(2.0×10^{7} Joules/kg)
4. ETHANOL (Ethyl Alcohol)	8.02 lb/gal	1.75×10^{5} BTU/gal
	(0.96 kg/litre)	(4.88×10^{7} Joules/litre)

	Density	Thermal Energy
5. GAS-NATURAL	.038 pcf	$1.0x10^3$ BTU/cf
	(0.609 kg/m^3)	($37.26x10^6$ Joules/m^3)
6. GASOLINE (Automotive)	5.57 lb/gal	$1.25x10^5$ BTU/gal
	(0.67 kg/litre)	($3.48x10^7$ Joules/litre)
7. GASOLINE (Aviation)	5.57 lb/gal	$1.08x10^5$ BTU/gal
	(0.67 kg/litre)	($3.01x10^7$ Joules/litre)
8. HYDRAZINE	7.08 lb/gal	$2.05x10^5$ BTU/gal
	(0.85 kg/litre)	($5.71x10^7$ Joules/litre)
9. HYDROGEN (Liquid)	1.67 lb/gal	$4.88x10^5$ BTU/gal
	(0.20 kg/litre)	($13.60x10^7$ Joules/litre)
10. HYDROGEN+OXYGEN (Liquids)	4.32 lb/gal	$7.12x10^5$ BTU/gal
	(0.52 kg/litre)	($19.84x10^7$ Joules/litre)
11. JET AIRCRAFT FUEL	6.6 lb/gal	$1.23x10^5$ BTU/gal
	(0.79 kg/litre)	($3.42x10^7$ Joules/litre)
12. KEROSENE	6.71 lb/gal	$1.35x10^5$ BTU/gal
	(0.80 kg/litre)	($3.76x10^7$ Joules/litre)
13. MAGNESIUM HYDRIDE	7.20 lb/gal	$5.12x10^5$ BTU/gal
	(0.86 kg/litre)	($14.27x10^7$ Joules/litre)

	Density	Thermal Energy
14. METHANE (Liquid)	5.61 lb/gal	2.0×10^5 BTU/gal
	(0.67 kg/litre)	(5.57×10^7 Joules/litre)
15. METHANOL (Methyl Alcohol)	5.57 lb/gal	2.25×10^5 BTU/gal
	(0.67 kg/litre)	(6.27×10^7 Joules/litre)
16. OIL-CRUDE		
16.1 Alaskan sources	N.A.	N.A.
16.2 California sources	7.88 lb/gal	1.38×10^5 BTU/gal
	(0.95 kg/litre)	(3.85×10^7 Joules/litre)
16.3 Other USA sources	7.03 lb/gal	1.38×10^5 BTU/gal
	(0.84 kg/litre)	(3.85×10^7 Joules/litre)
16.4 Outside USA sources	7.50 lb/gal	1.38×10^5 BTU/gal
	(0.90 kg/litre)	(3.85×10^7 Joules/litre)
17. OIL-FUEL OIL		
17.1 No. 1 (API 42 deg.)	6.790 lb/gal	1.35×10^5 BTU/gal
	(0.815 kg/litre)	(3.76×10^7 Joules/litre)
17.2 No. 2 Diesel (API 35)	7.076 lb/gal	1.39×10^5 BTU/gal
	(0.849 kg/litre)	(3.87×10^7 Joules/litre)

	Density	Thermal Energy
17.3 No. 3 (API 28 deg.)	7.387 lb/gal	1.43×10^5 BTU/gal
	(0.886 kg/litre)	(3.99×10^7 Joules/litre)
17.4 No. 4 (API 20 deg.)	7.778 lb/gal	1.485×10^5 BTU/gal
	(0.933 kg/litre)	(4.14×10^7 Joules/litre)
17.5 No. 5 (API 14 deg.)	8.099 lb/gal	1.52×10^5 BTU/gal
	(0.972 kg/litre)	(4.24×10^7 Joules/litre)
17.6 No. 6 Bunker C (API 10)	8.328 lb/gal	1.54×10^5 BTU/gal
	(0.999 kg/litre)	(4.29×10^7 Joules/litre)
18. PROPANE (Liquid)	N.A.	9.70×10^4 BTU/gal
		(2.70×10^7 Joules/litre)
19. SULFUR	124 pcf	4.0×10^3 BTU/lb
	(1987 kg/m^3)	(9.3×10^6 Joules/kg)
20. WOOD		
20.1 Hardwoods		8.6×10^3 BTU/lb
		(20.0×10^6 Joules/kg)
20.2 Softwoods		9.2×10^3 BTU/lb
		(21.40×10^6 Joules/kg)
20.3 Resin	67 pcf	1.74×10^3 BTU/lb
	(1074 kg/m^3)	(4.05×10^6 Joules/kg)

From Energy Factor Handbook--Appendix A, Caltrans, 1977, pp. A-1 - A-4.