and ton miles. But, since both rail revenues and ton miles would decline by approximately the same amount and given the high fixed costs of the railroad industry, it is likely that there would be less revenue to cover the fixed costs. In this case, rail profits would likely decline. In the short run, it may be possible to raise rates 20 percent in the winter when the Mississippi River is frozen and still maintain total corn and soybean rail shipments and increase rail profits. In the long run, however, higher winter rates would encourage elevator operators and farmers to sell more grain at harvest or build more storage or both so that corn and soybean sales could be shifted to spring and summer shipments. If one railroad company raised its rates independently in the Eastern District, enough corn and soybean revenue and ton miles would be lost to result in lower rail earnings.

In the Western District, the probability is higher that railroad companies would more fully exercise their rail-rate freedom. Rail rate increases would result in substantially higher rail revenues, whereas ton miles would decline slightly. This would increase rail profits sharply. However, if one railroad company independently raises its rail rates while all other rail rates and variables remain constant, the company that raised its rates would lose more than 80 percent of its gross revenues and rail ton miles of corn and soybean shipments. Thus, it would seem to be unprofitable for one railroad company to raise its rates independently. This conclusion must be tempered somewhat, because some of the rail competition that existed in both study areas in 1977-1978 no longer exists. The Chicago, Rock Island and Pacific Railroad Company has ceased operation in both areas since the analysis. One method of preventing railroad-company abuse of market power under deregulation is to remove antitrust exemption from railroad rate bureaus, which would prevent railroad companies from simultaneous rate-making activities. Railroad companies would be required to publish rates only on independent action. Joint rates on end-to-end line-haul movements would need to be negotiated on a one-to-one basis. In a deregulated environment, however, railroad rate bureaus could still have the function of mechanically printing and distributing railroad price lists. The Staggers Rail Act of 1980 prevents rate-bureau discussion or voting on single-line rates except for general rate increases and precludes the latter after 1983.

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Fuel Efficiency in Freight Transportation

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Barge transportation is the most fuel-efficient method of moving the raw materials and semifinished products needed by the nation's economy. This study reviews the record of extensive research on this vital issue and provides findings that lend new perspective to energy efficiency in transportation. A number of studies of fuel efficiency have been sponsored over the past several years by the U.S. Departments of Transportation and of Energy. These studies show that shallow-draft water transportation consumes considerably less energy in producing equivalent freight transportation than do alternative modes. Even when circuity (the lack of straight-line water routes between cities) is taken into account, the energy efficiency of the barge and towing industry is superior. These analytical findings are confirmed by a survey of barge operators and reinforced by specific examples—grain movements from Minneapolis to the Gulf Coast and a total of 25 million tons in coal movements to steam-generating plants of the Tennessee Valley Authority. All bulk-transport modes make significant contributions to the nation's distribution system in a highly fuel-efficient manner. Any transportation energy policy must recognize and promote the use of the inherent advantages of all the fuel-efficient modes of transportation.

Nearly 25 percent of domestic freight traffic and more than 16 percent of all intercity freight moves by water (1, p. 8; 2, p. 91). An analysis of published studies, carrier filings with the Interstate Commerce Commission (ICC), and data from railroad and waterway companies shows that, on the average, after both rail and water circuity have been taken into account, domestic water carriers consume less energy in producing equivalent work than does the rail mode. In this analysis, the facts on fuel efficiency in freight transportation are reviewed. Particular attention is paid to the rail and water modes.

A wealth of data on efficiency in the use of energy has been developed in recent years, mostly under contracts for the U.S. Department of Energy (DOE) and the U.S. Department of Transportation (DOT) (3, p. 9). Rising cost of fuel, occasional uncertainties of supply, and possibility of catastrophic interruption of fuel supplies from the Middle East have concentrated the attention of transportation companies on improved efficiency.

One major conclusion of a review of the available information is that the vital task of distributing the production of industry and agriculture (thus keeping farms and factories running) is accomplished by using a fraction of the nation's total fuel supplies. It is well understood that more than half the nation's petroleum is consumed by transportation. It is not so well understood that most of this goes for passenger transportation.

Trucks, railroads, and water carriers perform more than 76 percent of intercity freight transportation, but in 1978 they consumed less than 6 percent of the nation's total domestic demand for petroleum (excluding residual fuel oil used mainly in bunkering vessels engaged in foreign trade) (4, p. I-5) and less than 3 percent of the nation's fuel supply. Barging alone consumed about one-half of 1 percent of the nation's fuel supply (5, p. 2-8; 6, p. 32). Petroleum demand for trucks is estimated based on 602 trillion ton miles at 2.343 Btu/ton mile. The Transportation Association of America's value for diesel fuel and distillate is taken as the water and barge petroleum energy demand. Rail passenger demand was taken to be 5.6 x 10^6 bbl (5, p. 2-13). These facts reinforce the wisdom of policies that assure 100 percent of the fuel requirements for the freight transportation modes in the event that fuel allocation becomes a necessity, so that disruption in the distribution of the products of farms and factories will be minimized.

In an extreme emergency, it is possible to conceive that fuel efficiency will become an important criterion for allocating the work of transporting freight. Some truck traffic could be diverted to rail and some rail traffic diverted to water. Measures that had a similar effect were introduced during World War II to conserve fuel and rubber (7).

COMPARISON OF TON-MILE PRODUCTION AND ENERGY CONSUMPTION

Special studies of relative energy efficiency--or energy intensity as it is often called--were conducted for DOE and DOT in the 1970s (3). These studies use the number of British thermal units consumed in the production of a net ton mile of transportation services as a measure of energy efficiency. This provides a common standard for gasoline, diesel, and residual fuel oil. For example, 1 gal of number 2 diesel fuel yields 138 700 Btu (5).

Most of the government studies are quite detailed and are built around models from which conclusions are calculated. These conclusions have been confirmed from independent data filed with the ICC or from company reports. For example, one study of railroads uses equations that report rolling resistance plus aerodynamic drag plus resistance on curves and grades plus assumptions on percentage of fuel lost or spilled, percentage spent in idling, and, finally, percentage spent on switching and assembling trains. The conclusion is an estimate of 670 Btu/ton mile as an average for rail (8, pp. 5-1, S-9). This is further confirmed by dividing out the reported ton miles of 12 railroads and their total fuel consumed as recorded by the ICC. The resulting figure is 644 Btu/ton mile, which is close to the aggregate or average value based on the analytical model (data are for 1976) (9, p. 220).

A further confirmation comes from the most recent DOT study of the different modes and may be used to illustrate the arithmetic. Dividing fuel consumed (in trillions of Btu) by ton miles [Table 1 (10, pp. 31, 33, and 34)] shows that rail consumes 686 Btu/ton mile compared with 270 Btu/ton mile for barge. This would suggest that for total work performed, barge is two and a half times more energy efficient than rail in a comparison of route miles of service.

A method frequently used by the railroad industry for comparing fuel efficiency of the several modes is to calculate the miles that 1 ton of freight can be carried per gallon of fuel. Figure 1 (which is based on the data in Table 1) shows this relationship and adds the barge dimensions as well.

UPDATING RAIL AND BARGE DATA

As shown in Table 2, the values from several different studies that give an average energy intensity for railroads vary within a narrow range. Those for the water carriers, also shown in Table 2, have a somewhat greater spread, due in part to different technologies employed in inland, Great Lakes, and coastwise water transportation. For both modes the values from the different studies and answers to surveys are remarkably consistent. There have been some incorrect characterizations of water transport and misuse of data in articles and advertisements. For example, an article by D.S. Paxson (13) based on a study by the U.S. Department of Commerce (14) reports the value of 495 Btu/ton mile for barge compared with 396 Btu/ton mile for unit train. The following comments may be made:

1. The article compares "best" (unit train) by rail with "average" for water; "best" by barge would be 103 Btu/ton mile downstream on the Mississippi River (12, Tables II.9 and II.10, pp. II.28 and II.29);
2. A later study by F.H. Leilich reports 272 Btu/ton mile for "average" barge (12); and
3. The value for barge in the U.S. Department of Commerce study (14) seems high; this is explained by the study definition of "water" to include "domestic deep sea".

The Southern Railway System, in advertisements in various publications for 1979-1980, reported values of 670 Btu/ton mile for railroads versus 680 Btu/ton mile for waterways. [Southern Railways gives a study by Hirst (15) as its source.] The following comments apply:

1. None of the various studies has confirmed this finding;
2. For 1965, Hirst determined the figure to be 450 Btu/ton mile for barge; no explanation is offered to justify the 1970 figure; and
3. Hirst regards the 1970 figure as "particularly open to question"; his footnote "e" attached to the figure reads (15):

> This research effort was complicated by data inconsistencies, different definitions used by various agencies, missing data, and unexplained temporal variations in data. Therefore, we often found it necessary to approximate, extrapolate, interpolate, and even guess values. Those numbers in the tables that are particularly open to question have an "e" following the number. Because of these data limitations, results presented here should be used cautiously.

Last, in an article by M.L. Smith (16), barge miles are alleged to exceed rail miles by 55 percent in a study of 36 origins and 35 destinations--a combination of 1260 city pairs--on selected movements. The comments on this source are as follows:

1. Rail route mileage is understated; Missouri Pacific shows the "logical" rail route to be 8.3 percent greater than the rail short-line distance; the ICC study (11, p. 13) from its sample shows actual routings to be 16.4 percent greater than short-line routings;
2. Proper comparison would be (a) to compare circuity on actual movements and relate it to traffic density and (b) to use the common basis of the Great Circle distance for both rail and barge circuity; and
3. The city pairs chosen are far from representative; the U.S. Army Corps of Engineers, for example, reports average haul on the inland system to be 381.7 miles; the average haul in the Missouri Pacific compilation is 1124.7 miles, which is nearly three times greater (2, Table 3, p. 94).

The Oak Ridge National Laboratory (ORNL) calculation for all inland water modes, 440 Btu/ton mile (8), seems somewhat high. The same method was used for inland barge as for the Great Lakes. The "generic ship" chosen was of 1350 hp; this compares unfavorably with the 4000- to 10 000-hp towboats now ordinarily used, which are much more energy-efficient than their smaller counterparts. L.E.

Sutton of Dravo Mechling reported in a speech at the International Trade Mart in New Orleans on May 5, 1980, that from 1967 to 1977, barge demand went up 60 percent (from 174 billion ton miles to 277 billion ton miles), that the number of towboats increased only 10 percent (from 4000 to 4400), but that the total towboat horsepower doubled (from 3 million hp to a little more than 6 million hp) (10).

There are additional difficulties with the ORNL estimate of 440 Btu/ton mile. In the 1979 ORNL study (8), an earlier study is relied on (4). In the earlier study, it is stated that energy consumption for inland waterways was calculated by using the Great-Lakes-sector methodology, yet ORNL reports using coastal-sector methodology to compute inland water energy intensity. In addition, estimates for tug or barge (278 Btu/ton mile) and tanker (355 Btu/ton mile) are reversed from the earlier study to the later ORNL study [compare Table IV-4, p. IV-4 (4), with Table 4.9, p. 4-11 (8)]. The effect of these seeming inconsistencies on the estimate of 440 Btu/ton mile for all inland water modes is not known.

Nevertheless, data on average barge energy intensiveness both from analytic models and supplied by questionnaire from the operators show a range of 270 Btu/route ton mile to 350 Btu/route ton mile, which is well below the range of 650 Btu/route ton mile to 750 Btu/route ton mile for rail.

Table 1. Work performed compared with fuel consumed.

	Work Performed		Fuel Consumed	
Mode	Ton Miles (billions)	1 Ton of Freight Moved per Gallon (miles)	Trillion Btu	Btu per Ton Mile
Rail	784	202	538	686
Highway	470	59.2	1101	2343
Waterway[a]	178	514	48	270
Pipeline	476	492	134	282

[a] Excludes Great Lakes and domestic deep-draft shipping.

COMPARING CIRCUITY

A relevant question in making comparisons of energy efficiency is whether the water route is significantly more circuitous than the rail route between the same city pairs. The answer is that sometimes it is and sometimes it is not. Towboats follow winding rivers, but railroads are built along the easiest grades. These are seldom straight lines and even sometimes follow what the railroads call the "water-level route" along the riverbanks. The best way through a mountain range is that which follows the easiest grade. It is seldom "the way the crow flies."

Whereas barges always follow rivers, railroads do not necessarily route their traffic over the shortest possible rail route. More than 70 percent of all rail traffic is interlined with other railroads. The average shipment moves on the trackage of more than three railroads (17, p. 183). There is a strong economic incentive for a railroad to keep a given shipment for as long a distance as possible before turning it over at an interchange point, since the longer the distance that freight travels on a single railroad's lines, the greater the revenue is to that railroad. As a practical matter, therefore, the rail short-line distance must be adjusted to take into account the way in which the traffic actually moves.

All these variables can be accommodated in order to arrive at a comparison of distances actually traveled by the freight that uses the Great-Circle distance as the common measure for comparison purposes. A Great-Circle distance is that measured between origin and destination, and the degree of circuity is calculated from that for each mode. The values in Table 2 show that, on the average, barge is somewhat more circuitous than rail but not nearly enough for rail to overcome barge's superior route-mile energy efficiency.

It is of course perfectly possible to imagine water circuities that are much greater than those shown in Table 3. One railroad made a list of such possible routings, which included Sioux City, Iowa, to Brownsville, Texas, via the Missouri River, New Orleans, and the Gulf Intracoastal Waterway, and

Figure 1. Relative energy efficiencies: truck, rail, and barge.

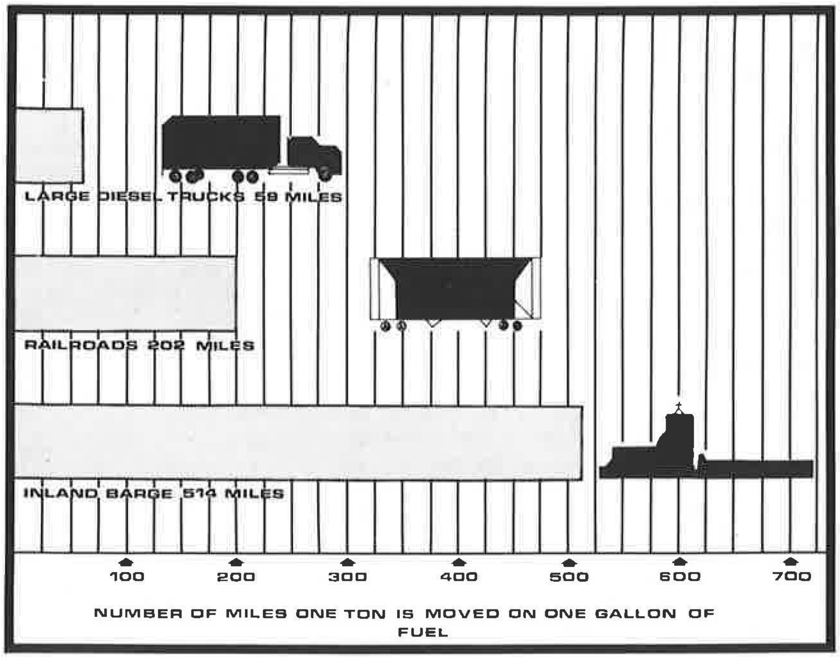

Table 2. Energy intensity: rail and domestic water transportation.

Study and Mode	Btu per Route Ton Mile	Miles 1 Ton Moved per Gallon
Rail		
Oak Ridge National Laboratory (ORNL) (1979)[a]	670	207
ICC adjustment[b]	780	178
DOT (1976)[c]	687	202
Twelve railroads from ICC reports (1976)[d]	644	215
DOT (1979)[e]	686	202
Domestic Water Transportation		
ORNL (1979), all domestic water[f]	440	315
DOT (1976)[g]		
Barge average	272	510
Lower Mississippi		
Upstream	276	503
Downstream	103	1347
One inland barge operator Lower Mississippi downstream[h]	141	984
Inland barge operators		
27, 1977 avg[i]	352	394
2[j]		
All waterways	326	425
Lower Mississippi	278	499
Ohio	329	421
Illinois	366	379
DOT (1979)[k]	270	514
Thirty samples: Great Lakes self-unloading[l]		
Lake Superior, lower lakes	261	531
Lake Michigan	240	578
General trades	215	645

[a] Data are for 1977 (8, Table S.8, p. S-9).
[b] Rail routing adjusted by ICC study (11, p. 13).
[c] Data are for 1972 (12, Table II-8, p. II.21).
[d] Study by Eastman (9, p. 220).
[e] Data are for 1972 (10, Tables 4-1, 4-2, and 4-3, pp. 31, 33, and 34).
[f] Data are for 1977 (8, Table S.4, p. S-4).
[g] Data are for 1972 (12, Tables II.9 and II.10, pp. II.28 and II.29).
[h] According to American Commercial Lines, Inc., Sept. 21, 1979.
[i] From responses to American Waterways Operators, Inc., questionnaire to members, Dec. 17, 1979. Approximately 36 percent of inland barge traffic is reported.
[j] From responses to Water Transport Association (WTA) questionnaire to members, Nov. 30, 1979.
[k] Data are for 1972 (10, Tables 4-1, 4-2, and 4-3, pp. 31, 33, and 34) but exclude Great Lakes and domestic deep-draft vessels.
[l] From responses to WTA questionnaire, Nov. 30, 1979. Data are for 1979. Miles 1 ton moved per gallon based on distillate fuel oil; based on residual fuel oil (149 700 Btu/gal), values are 573, 624, and 696 miles 1 ton moved per gallon, respectively.

added up all the possible barge routings to compare barge circuity with that of rail. Needless to say, not much traffic moves from Sioux City to Brownsville. This study is also flawed because the average barge length of haul calculated was 1125 miles, whereas the U.S. Army Corps of Engineers reported the average length of haul on the inland waterway system in 1977 to be about one-third that distance, or 382 miles. Therefore, the model could not be used as representative of the manner in which barge traffic actually moves (16; 2, Table 3, p. 94).

A sounder approach is to use the Corps of Engineers' analysis of traffic densities by river segment as shown in Figure 2. There the width of the river segment shown portrays the tonnage carried on that segment, both upward and downward. About 69 percent of all waterway traffic is between Minneapolis and New Orleans, about 65 percent between St. Louis and New Orleans, and an additional substantial amount on the Lower Ohio River (based on ton miles, 1977) (2, pp. 25 and 28). The greatest future growth of waterway traffic is in grain and fuel on these same segments of the river (18, pp. 147 and 161). Circuities on these particular stretches of the river provide a useful guide to perhaps three-quarters of all river traffic. As shown in Table 3, the actual city-pair circuity for going by barge between Minneapolis and New Orleans (1.61) and that between St. Louis and Baton Rouge (1.59) are slightly lower than that reported by barge operators for these river segments whose calculations are for actual operations between their terminals on the river.

Rail and Water Grain Shipments to Gulf

How this all works out in actual practice is seen by comparing typical rail routings with those for barge on the heavy movements of grains for export from the upper Midwest to ports on the Gulf of Mexico. This comparison demonstrates that after circuity has been taken into account for both modes, barge is considerably more fuel-efficient than rail. As shown in Table 4, water is from 45.9 percent to 130.7 percent more energy-efficient than is rail, depending on the rail routing used.

Coal Supplies for Tennessee Valley Authority

A study of the routings of 25 million tons of coal supplied to the Tennessee Valley Authority (TVA) in 1976 showed average rail circuity of 1.736, somewhat less than the average barge circuity of 1.991 [Table 5 (9, p. 216)]. No attempt was made to determine how rail traffic actually moved; the railroads were given the benefit of the rail short-line distance in every case. By using these circuities and estimates of Btu/route ton mile energy intensities developed for DOE, barge energy efficiency was found to be superior to that of rail by 30 to more than 100 percent (9, p. 209).

ACCESS TO RAIL AND BARGE SYSTEMS

Attention has been called to the comparative energy efficiency of competitive rail and barge shipments, particularly energy used in other than the long-haul movement (16, p. 6). Grain does not grow either in the streets of St. Louis, where grain is loaded into barges, or in the streets of Kansas City, where grain is loaded into unit trains. For high-volume movements by barge and unit train, there is often a prior or subsequent haul by another mode.

For the barge industry, this is frequently the rail or pipeline mode. On coal shipments, which represent 25 percent of all barge tonnage moved on the inland waterways, there are 70 rail-water interchanges on the inland waterway system (20). For barge petroleum movements, which account for another 25 percent of water tonnage, access is frequently by pipeline. Trucks feed both rail and water modes and are more energy-intensive than either. From the analysis of Appalachian coal movements summarized below (21, p. 6-4), truck was used 57.7 percent by the rail mode compared with 42.9 percent by the water mode for gathering traffic.

Mode	Short Tons (000s)	Percentage of Total
Rail only	118 893	
Truck and rail	162 305	
Total rail	281 198	73.9
Water only	20 172	
Truck and water	15 137	
Total water	35 309	9.3
Truck only	43 692	11.5
Other	20 126	5.3
Grand total	380 325	

INDIRECT ENERGY USE

A recent study by ORNL for DOE calls attention to the energy consumed in the manufacture of vehicles, the construction of necessary facilities, and the maintenance and upgrading of such facilities by the various modes (8, p. 2-9). No precise definitions

Table 3. Circuity comparisons.

Study and Mode	Btu per Route Ton Mile	Circuity[a]	Btu per Ton Mile[b]
ORNL (1979)			
Rail			
Short-line distance[c]	670	1.32	880
Actual distance moved[d]	670	1.54	1030
All domestic water	440	1.59	700
Two inland barge operators[e]			
All waterways	326	1.74	567
Lower Mississippi	278	1.74	484
Ohio	329	1.79	589
Illinois	366	1.59	582
Minneapolis to New Orleans, barge[f]		1.61	
St. Louis to Baton Rouge, barge[g]		1.59	
Thirty samples: Great Lakes self-unloading[h]			
Lake Superior, lower lakes	261	1.26	329
Lake Michigan	240	1.00	240
General trades	215	1.32	284

[a] No circuity, 1.0.
[b] Adjusted for circuity.
[c] Data are for 1977 (8, Table S.8, p. S-9). Data on rail short-line distance are as reported in ORNL report (8); Btu/ton mile adjusted for circuity for actual distance moved rounded to nearest ton, following ORNL report (8).
[d] Rail routing adjusted by ICC study (11, p. 13).
[e] From responses to WTA questionnaire to members, Nov. 30, 1979; Btu/route ton mile are for 1978; circuity data reported by only one carrier were applied to average for two carriers.
[f] Lambert's Landing at mile 839.0 (latitude 44° 57" north; longitude 93° 6" west) to St. Andrew's Street Wharf at mile 96.8 (latitude 29° 56" north; longitude 90° 4" west).
[g] Municipal Dock at mile 181.7 (latitude 38° 39" north; longitude 90° 11" west) to Greater Baton Rouge Port Commission docks at mile 229.0 (latitude 30° 25" north; longitude 91° 10" west).
[h] From responses to WTA questionnaire to members, Nov. 30, 1979. Data are for 1979.

or quantifications of these types of energy by mode are available. However, it would appear from the estimates shown in the study that the indirect energy required by the rail mode is greater as a percentage of their direct energy use than is the case for the water mode. Indirect energy use, shown below as the percentage of direct energy use, is 116.7 percent for rail and 85.7 percent for marine transportation (22, p. 2-9):

Mode	Indirect Energy Use (%)
Air	63.2
Automobile	37.9
Bus	100.0
Marine	85.7
Pipeline	7.1
Rail	116.7
Truck	42.9
Total	42.0

CONCLUSION

Whereas it seems clear that the water mode is more energy-efficient than the rail mode, it is also apparent that the rail, pipeline, and water modes, which account for 75 percent of the intercity freight load, are all remarkably efficient in their use of energy. By comparison, airplanes and trucks are less energy-efficient. The ORNL study (8) reports the route-mile energy intensity of all-cargo

Figure 2. Inland freight tonnage on Mississippi River system and Gulf Intracoastal Waterway.

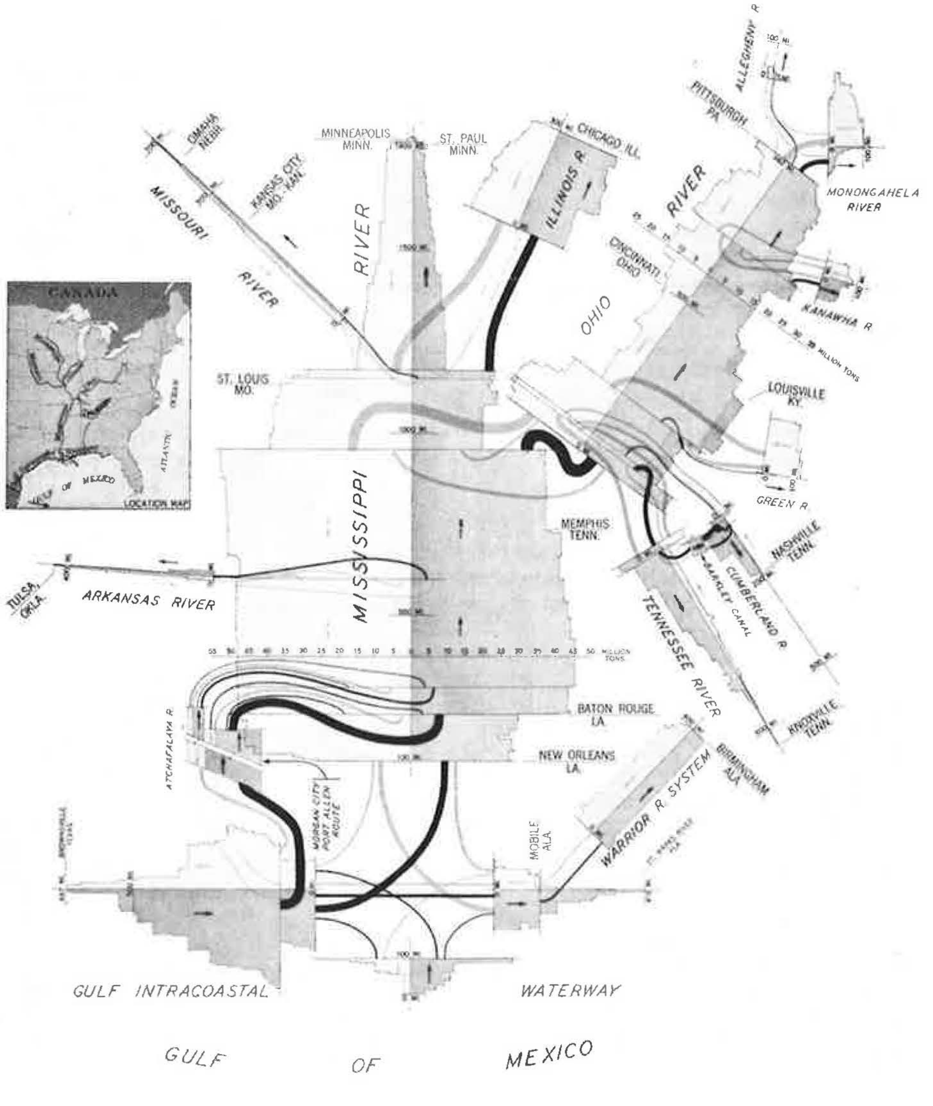

Table 4. Relative circuity and energy efficiency: rail and water grain shipments to Gulf of Mexico.

Route	Energy Intensity: Route Mile (Btu/ton mile)	Energy Intensity: Great Circle Mile (Btu/ton mile)	Mileage	Circuity	Higher Energy Efficiency of Water (%)
Minneapolis-New Orleans Great-Circle distance			1051	1.00	
Inland water	326[a]	525	1696	1.61	
Alternative rail routings[b]					
BN/MILW/SOO-ICG	644[c]	766	1250	1.19	45.9
CNW-MP	644	882	1441	1.37	68.0
MILW-KCS-LA	644	895	1467	1.39	70.5
CNW-MP	644	921	1504	1.43	75.4
CNW-MKT-LA	644	927	1517	1.44	76.6
CNW-SLSF-LA	644	959	1562	1.49	82.7
RI-LA	644	979	1602	1.52	86.5
MILW-MKT-TPMP	644	992	1621	1.54	88.9
RI-TPMP	644	1050	1716	1.63	100.0
MILW-MKT-TCT	644	1211	1976	1.88	130.7

[a] Average of two inland barge operators from all waterways, responses to WTA questionnaire to members, Nov. 30, 1979.
[b] Rail routings are taken from Upper Mississippi Waterway Association study (19, p. 75).
[c] Average of 12 railroads filing at ICC (9, p. 220).

Notes: Average inland water and rail energy intensities have been used because these estimates are supported by the most available data. Water would be downstream and grain would be in unit trains, both of lower energy intensity than the mode average. Railroad names are abbreviated as follows: BN, Burlington Northern, Inc.; MILW, Milwaukee Road; SOO, Soo Line Railroad Co.; ICG, Illinois Central Gulf Railroad; CNW, Chicago and North Western Transportation Co.; MP, Missouri Pacific Railroad Co.; KCS, Kansas City Southern Railway Co.; MKT, Missouri-Kansas-Texas Railroad Co.; LA, Louisiana and Arkansas Railway Co.; SLSF, St. Louis-San Francisco Railway Co.; RI, Chicago, Rock Island and Pacific Railroad Co.; TPMP, Texas Pacific-Missouri Pacific Terminal Railroad of New Orleans; and TCT, Toledo City Terminal Railroad Co.

Table 5. Circuity of all-water barge and rail coal shipments to TVA.

Mode and Facility	Tons (000s)	Straight-Line Ton Miles (000 000s)	Actual Ton Miles (000 000s)	Circuity
Barge				
Watts Bar	118.9	20.541	93.574	4.575
Johnsonville	2 788.0	529.770	992.732	1.874
Widows Creek	495.2	11.390	11.390	1.000
Colbert	31.7	5.801	15.691	2.705
Shawnee	185.1	30.165	55.830	1.851
Allen	2 576.7	672.516	1419.601	2.111
Cumberland	4 651.7	450.163	836.189	1.857
Total or avg	10 847.3	1720.256	3425.007	1.991
Rail				
Johnsonville	837.2	149.810	268.950	1.795
Widows Creek	2 594.6	520.051	803.212	1.544
Kingston	1 051.2	90.223	207.131	2.296
Shawnee	3 912.9	271.082	368.960	1.361
Gallatin	2 212.5	263.128	435.691	1.656
John Sevier	1 869.4	201.495	408.026	2.025
Bull Run	1 891.1	159.485	381.037	2.389
Total or avg	14 368.9	1655.274	2873.007	1.736

domestic aircraft in 1976 as 25.360 Btu/route ton mile and the energy intensity of large diesel trucks as 2.740 Btu/route ton mile. Needless to say, rail, water, and pipeline do not provide the type of transportation services offered by airlines and trucks.

The energy intensity for pipelines shown in Table 1 (282 Btu/ton mile) is for petroleum (both crude and product). Natural-gas pipelines are powered mostly by natural gas and petroleum pipeline mostly by electricity (5, p. 2-15). A recent study of two pipelines powered by electricity reports energy intensities of 283 Btu/ton mile for Colonial and 362 Btu/ton mile for Plantation (22, p. 38).

ACKNOWLEDGMENT

This study benefited in substantial measure from comments and suggestions on earlier drafts made by member carriers and staff of the American Waterways Operators, Inc., and the Water Transport Association. In addition, the member carriers' responses to questionnaires provided data on the energy efficiency of water transportation that would not otherwise have been available. Although all this assistance is appreciated and is hereby acknowledged, any errors or omissions are solely my responsibility.

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Transportation of Coal to Seaports via Mid-America Inland Waterway System

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The mid-America inland waterway system has long been recognized as one of the basic means for the movement of domestic coal. Yet, until the recent steam-coal export boom, insufficient attention had been paid to the economic advantages of shipping coal by river for export transshipment at Gulf Coast ports. The ports of Mobile in Alabama and New Orleans in Louisiana combined to handle 2.7 million tons of export coal in 1979, according to the U.S. Department of Commerce records. These two ports, however, offer much greater capacity than current demand requires. In addition, other Gulf Coast ports are exploring the potential for coal export, most notably Galveston, Texas.

The current congestion being experienced at the ports of Hampton Roads and Baltimore has dramatically altered the way in which the U.S. coal industry views itself within the context of world coal supply and demand. Hundreds of millions of dollars have been committed for the construction of new coal-loading terminals at these two ports and others located along the Atlantic Seaboard. Coal companies, previously involved with mining coal only, are now assisting financially in the development of new and/or expanded coal terminals. These commitments have received extensive documentation and will not be repeated here (1-3).

Likewise, the ports of Mobile and New Orleans and the entire mid-America inland waterway system are responding to the unprecedented demand for U.S. mined steam coal. In an effort to report the development of this portion of America's coal-handling capacity, this paper has three major objectives:

1. To place the mid-America inland waterway movement of coal for export in a broad domestic context of total U.S. coal movements for export;
2. To define the network of coal movement on mid-America inland waterways, including major points of origin; and
3. To describe the existing facilities and plans for expansion at the two leading Gulf Coast ports of New Orleans and Mobile, which receive a portion of their export coal via mid-American inland waterways.

RELATIONSHIP OF MID-AMERICA COAL EXPORTS TO TOTAL U.S. EXPORTS

Historically, the United States has exported a fairly stable level of bituminous coal since 1974 [Table 1 (4, pp. II-12 and II-16)]. With the exception of 1978, when a low of approximately 40 million tons was exported, a generally consistent level of between 54 million and 66 million tons of coal have left U.S. ports for consumption overseas. In 1977, approximately 78 percent of total coal exports was the metallurgical variety (met coal) processed into coke for use in steel production. The remaining 22 percent was steam coal used in the conversion of electricity, heat, steam, etc. (5). With the growing demand for U.S. steam coal, the relative shares of met coal and steam coal are expected to balance; steam coal will assume the larger share by the year 2000. The often-quoted Massachusetts Institute of Technology (MIT) text Coal: Bridge to the Future (5) offers two likely scenarios of future coal export demand. In scenario A, total exports are estimated at 125 million tons by the year 2000; steam coal accounts for 65 million tons, and met coal accounts for the remaining 60 million tons. In scenario B, a total of 200 million tons is forecast for export; steam coal represents 130 million tons and met coal, 70 million tons. Thus, in the minds of the MIT analysts, the volume of met coal could remain in a fairly well-defined range between 60 and 70 million tons for export by the year 2000. The steam-coal export market, on the