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AN ENERGY STUDY OF THE MARINE TRANSPORTATION INDUSTRY

Executive Summary. Volume I

June 1978

Work Performed Under Contract No. EY-76-C-03-1175

Booz, Allen and Hamilton, Incorporated
Bethesda, Maryland

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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Division of Transportation Energy Conservation

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EXECUTIVE SUMMARY
AN ENERGY STUDY OF THE MARINE TRANSPORTATION INDUSTRY.
VOLUME I

for

Division of Transportation Energy Conservation
Non-Highway Transport Systems
U.S. Department of Energy
20 Massachusetts Avenue
Washington, D.C. 20545

June 1978

Contract No. EY-76-C-03-1175

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EXECUTIVE SUMMARY OF AN ENERGY STUDY OF THE MARINE TRANSPORTATION INDUSTRY

This report covers the conclusions and recommendations resulting from an examination of energy use in the marine transportation industry. The work was performed for the Transportation Energy Conservation Division of the U.S. Department of Energy (DOE) by Booz, Allen & Hamilton. The conclusions and recommendations developed during the course of this research are intended to assist DOE in formulating research and development programs that will promote energy conservation in the marine transportation industry.

The results of the analysis determined that the maritime transportation industry consumed approximately 2.9 quads in 1974. This consumption is expected to rise to 6.7 quads by the year 2000. In response to the need to reduce energy consumption below the projected level for the year 2000, conservation-oriented research and development programs were investigated. Fifteen program areas were identified and evaluated with respect to their energy conservation potential. Of these, two program areas were recommended for funding by the Department of Energy:

- Diesel bottoming cycles
- Adiabatic diesels.

The assignment was structured around the following four tasks:

- Task I - Industry Summary - To define the current marine transportation industry in terms of population, activities and energy use; to develop a Marine Transportation Energy Model (MTEM) to assist in the analysis of industry energy consumption and financial performance

- Task II - Regulations and Tariffs - To define the regulatory structure surrounding the marine transportation sector and evaluate the energy use impact

- Task III - Efficiency Improvements - To identify conservation-related research and development programs and evaluate their impacts in terms of costs, energy savings potential and technological risk

- Task IV - Industry Future - To project a future industry scenario, evaluate the energy use implications and recommend specific courses of action to be pursued by DOE.

The methodology used in this assignment is discussed in the following section. The final report has been organized into five volumes. This first volume contains the Executive Summary. Volumes II and III cover Tasks I and II, respectively. Volume IV combines Tasks III and IV. A fifth volume, which is available upon request from DOE, contains documentation of the Marine Transportation Energy Model (MTEM).

1. OUR APPROACH TO THE ASSIGNMENT

The methodology used in this assignment closely followed the four major tasks. The industry was first divided into seven major sectors and current levels of activity. Energy use and operating parameters were identified. Second, the regulatory structure was defined and the energy consumption impacts of specific regulatory actions were estimated. Third, specific research and development programs were identified and evaluated with respect to their potential for energy conservation, given the existing energy use patterns identified in Task I. Fourth, levels of activity and operating patterns for each of the seven industry sectors were postulated for the year 2000. The research and development programs, identified in Task III, were again evaluated with respect to their potential for energy conservation during that future period.

Conclusions were then drawn and specific recommendations for DOE action in funding research and development programs were made. These conclusions and the recommendations are summarized in the following sections.

2. SUMMARY OF RESULTS AND CONCLUSIONS

The marine transportation industry can be broadly defined as being composed of seven individual industry sectors:

- The Foreign Trade Sector or those U.S. and foreign flag general cargo ships, dry bulk carriers and tankers that participate in the foreign commerce of the United States

- The Great Lakes sector or those U.S. and Canadian vessels that participate in the U.S. and Canadian Great Lakes trade

- The coastal shipping sector or those U.S. flag vessels that participate in our coastwise and intercoastal trade

- The offshore sector consisting of drill rigs and ships, pipe laying barges and workboats that are employed in the discovery and production of offshore oil

- The inland waterway sector consisting of towing vessels and barges engaged primarily in the transportation of bulk products on our inland river systems

- The fishing and miscellaneous sector include those special purpose service craft operating predominantly in local harbor areas

- The pleasure boat sector consisting of small noncommercial craft used exclusively for recreational purposes.

Each of these seven industry sectors was examined in detail and defined in terms of:

- Population and vessel types

- Productivity in terms of tons moved or hours operated

- Operating profiles

- Regulatory impacts

- Potential for energy conservation

for the baseline case (1974) and a projected future scenario (2000). The results of this analysis and the conclusions that were drawn are presented below. Following this presentation, specific recommendations have been made concerning research and development actions that appear to offer the greatest conservation potential for the industry.

(1) In 1974 the Maritime Industry Was Estimated to Have Consumed 2.9 Quads and Is Forecasted to Require 6.7 Quads by the Year 2000

Utilizing the latest annual trade statistics available (1974), it is estimated that the marine transportation industry consumes 2.9 quads annually. Table 1 provides a summary of the industry's productive activity and energy consumption by sector.

This energy consumption figure reflects the fuel or energy estimated by Booz, Allen to be required (regardless of purchase point), by all vessels (regardless of flag) when engaged in the foreign and domestic commerce of the United States.

The energy consumption figures for the year 2000 were based on two trade forecasts developed by the U.S. Maritime Administration and an analysis of future energy requirements completed by the Massachusetts Institute of Technology.[1]

TABLE 1
Productivity and Energy Consumption of the Marine Transportation Industry

Industry Sector	1974 (estimate)			2000 (forecast)		
	Long Tons of Cargo Moved (millions)	Energy Consumed (quads)	%	Long Tons of Cargo Moved (millions)	Energy Consumed (quads)	%
Foreign trade						
Foreign flag	609.9	2.145	73	1384.8	4.821	72
U.S. flag	45.0	0.215	7	188.0	0.771	12
Great Lakes	175.3	0.052	2	334.8	0.100	2
Inland waterways	535.8	0.089	3	704.5	0.100	2
Coastal	213.0	0.112	4	403.0	0.300	4
Offshore	-	0.064	2	-	0.200	3
Pleasure craft	-	0.225	8	-	0.300	4
Fishing and miscellaneous	-	0.032	1	-	0.100	2
Total	1,579.0	2.934	100.0	3015.9	6.692	100.0

Source: Booz, Allen & Hamilton. See Volumes II and IV of this report.
Note: Percentages may not add to 100 percent due to rounding.

Prior to the Arab oil embargo in 1974, which led to large increases in world fuel prices, the question

1 See Volume IV for detailed references and discussion of methodology.

of fuel consumption rates and their reduction potential were either not addressed by operators or given a relatively low priority due to the minor impact that changes in the rate of fuel consumption had on total transportation costs. Consequently, a shortage of data exists concerning energy consumption in the industry, and until recently, few comprehensive studies have been initiated to determine the industry's energy intensiveness. As a result, these estimates of the energy consumption of the industry include an element of uncertainty. The methodology developed to calculate energy consumption for both 1974 and the year 2000 required a number of assumptions. The major assumptions are:

- In the foreign trade shipping sector a generic vessel was defined and chosen to represent all vessels of that type operating on a given trade route, as defined by the Maritime Administration. The degree to which all vessels reflect the performance of the generic vessels is unknown.

- In all sectors a generic vessel was applied to historical and projected trade flows. The degree to which these generic vessels accurately represent a cross section of each trade and sector is unknown. However, they are representative of actual vessels employed on these trades.

- In the maritime industry, vessel capacity is generally measured in deadweight[2] tons or cubic feet and trade flows are measured in tons. A deadweight utilization factor, based on historical averages was applied to each generic vessel type in order to compensate for variations in both cargo densities and vessel utilization. In reality the amount of a vessel's weight carrying capability actually used varies significantly based on factors such as:

    - Vessel operator
    - Type of cargo carried
    - Industry sector

2 Deadweight — A term describing the weight carrying capacity of a cargo ship, it includes the weight of cargo, crew, stores, and fuel and is measured in long tons of 2240 pounds.

- Season of the year
- Direction of the trade flow
- Shipping technology used
- Depth of water in harbor areas served.

- In almost all bulk trades, and to a lesser degree liner trades, the trade flows are not balanced in terms of tonnages moving in both directions. In the bulk trades, vessels typically spend half their life in ballast.

- The analysis of the recreational boating sector relied on 1973 U.S. Coast Guard data describing populations, sizes and operating patterns. These 1973 operating patterns were applied to 1975 recreational boating population statistics.

- The fishing and miscellaneous, and offshore sectors are so diverse that meaningful operating profiles could not be developed. As a result, the analysis used for these sectors differs from that developed for the other sectors. Energy consumption for this sector was estimated subjectively by allocating a portion of domestic fuel oil sales in the United States to these vessels.

These factors affect the calculated marine transportation energy consumption figure of 2.9 quads for 1974. It is believed that the uncertainty associated with our estimate of total industry energy consumption could result in an estimate 25 percent higher or lower than 2.9 quads. The projected energy consumption figure of 6.7 quads is also subject to the same qualifications and in addition is only as accurate as the cargo forecasts and the future operating and technological scenarios upon which it is based. These scenarios are described in detail in Volume IV.

(2) <u>Energy Consumption in the Marine Transportation Sector Currently Represents 15 Percent of the Energy Consumed for Transportation Services</u>

The Energy Research and Development Administration estimates that the nonmaritime transportation services consume 16.126 quads as shown in Table 2. Adding the

2.94 quads calculated for the marine sector yields 19.060 quads used by all transportation modes. The marine transportation industry represents approximately 15 percent of this total.

TABLE 2
Energy Consumed for Transportation Services
(1974)

Trade	Energy Consumed (quads)	Percent of Total Energy Consumed
Highway	13.417	71
Air	1.393	7
Pipeline	0.685	4
Rail	0.631	3
Marine	2.934	15
Total	19.060	100

Source: Marine consumption represents estimates provided by Booz, Allen & Hamilton. All other estimates are provided by the "Transportation Energy Conservation Data Book," October 1977, Table 2-11, p. 171, published by the Oak Ridge National Laboratory.

(3) The Foreign Trade Sector is Expected to Continue to Be the Major Energy User

As indicated by Table 1, the foreign trade sector is expected to continue to account for the majority of the energy consumed by the marine transportation industry. Its overall share is expected to increase from 82 to 84 percent of the total between 1974 and 2000.

(4) U.S. Flag Share of the Foreign Trade Sector's Energy Consumption Is Expected to Increase Between Now and the Year 2000

In 1975, U.S. flag vessels carried 7 percent of the cargo in the U.S. foreign trade and consumed 9 percent of the energy. By the year 2000 it is projected that U.S. flag vessels will carry 12 percent of the cargo and consume 14 percent of the energy, as shown in Tables 3 and 4.

TABLE 3
Cargo Movements in the Foreign Trade Sector

Service Type	Cargo Movements (thousands of long tons)			
	1974		2000	
Liner	51,500	7.9%	148,900	9.5%
Tramp	159,000	24.3%	219,000	13.9%
Dry bulk	147,900	22.6%	502,400	31.9%
Tanker	296,500	45.3%	703,300	44.7%
Total	654,900	100.0%	1,573,600	100.0%
U.S. flag share	45,000	6.9%	188,800	12.0%

Source: "The Long-Term Forecast of U.S. Foreign Waterborne Trade," Division of Economic and Operational Analysis, Office of Policy and Plans, U.S. Maritime Administration, April 14, 1977.

"Energy: Global Prospects 1985-2000," by the Massachusetts Institute of Technology, May 1977.

TABLE 4
Energy Consumption in the Foreign Trade Sector
1974 - 2000

Service Type	Energy Requirements (quads)			
	1974		2000	
Liner	0.530	22.4%	1.345	22.3%
Tramp	1.080	45.8%	2.469	44.2%
Dry bulk	0.337	14.3%	0.932	16.6%
Tanker	0.333	14.1%	0.812	14.5%
Passenger	0.080	3.4%	0.134	2.4%
Total	2.360	100.0%	5.592	100.0%
U.S. flag consumption	0.215	9.1%	0.772	13.8%

Source: Booz, Allen & Hamilton.

The estimated U.S. flag share of the cargo movements in the foreign trade sector for 1974 and 2000 are presented in Volume IV of this report.

(5) A Minimum of 28 Percent of the Energy Currently Required by the Marine Transportation Industry Is Purchased in the U.S.

Table 5 presents a summary of all the marine fuels purchased in the United States. This total of .81 quads represents 28 percent of the total energy requirements, of 2.93 quads presented earlier in Table 1.

TABLE 5
Reported U.S. Purchases of Marine Fuel, 1974
(quads)

Trade	Residual	Distillate	Gasoline	Total
Domestic	0.19	0.09	0.09	0.37
Foreign trade	0.39	0.05	-	0.44
Total	0.58	0.14	0.09	0.81

Sources: "Bunker Fuel," U.S. Department of Commerce, Bureau of the Census, 1974.

"Mineral Industry Survey," U.S. Department of Interior, Bureau of Mines, 1974.

"Private and Commercial Nonhighway Use of Gasoline — 1974," U.S. Department of Transportation, FHA.

1. Nineteen Percent of the Energy Consumed by the Ocean Shipping Sector Is Purchased in the United States

Further inspection of Table 5 shows that 0.37 quads were reported purchased by the domestic sectors and 0.44 quads were reported purchased in the U.S. by the ocean shipping sector. This 0.44 quads represents 19 percent of the ocean shipping sector's estimated energy requirements. Table 6 displays the percentage of fuel required by the ocean shipping sector by flag of registry and purchase point.

TABLE 6
Foreign Trade Sector Fuel Requirements

Vessels	Point of Purchase			
	United States		Overseas	
	Quads	Percentage	Quads	Percentage
U.S.	.090	42%	.125	58%
Foreign flag	.350	16%	1.795	84%
All vessels	.440	19%	1.920	81%

Note: Based on "Bunker Fuels," published by U.S. Department of Commerce, Bureau of Census, 1974.

2. The Present Energy Reporting Systems Account for 64 Percent of the Estimated Domestic Requirements

The "Mineral Industry Survey" published by the U.S. Department of Interior, Bureau of Mines, and the "Private and Commercial Non-highway Use of Gasoline - 1974," published by the Federal Highway Administration, report fuel representing 0.37 quads as purchased for domestic marine use in 1974. This represents 64 percent of the 0.574 quads estimated for the six domestic shipping sectors, as shown in Table 1. Table 7 provides a comparison of the fuel reported sold by the Bureau of Census with the requirements estimated by Booz, Allen in this report

TABLE 7
Comparison of Fuel Reported Sold for Marine Use Vs. Estimated Requirements (1974)

Trade	Reported Sold (quads)[3]	Estimated Requirements (quads)[4]	Percent to Which Reported Sales Represent Estimated Requirement
Foreign	0.440	2.360	19%
Domestic	0.370	0.574	64%
Total	0.810	2.934	28%

3 From Table 5, ex sum.
4 From Table 1.

The low percentage that is shown for our foreign trade has been previously explained as being caused by foreign purchases. The rationale for the relatively low percentage that domestic purchases represent of domestic requirements is difficult to explain. A partial explanation for the differential may be due to:

- The purchase of fuel by commercial and pleasure craft at nearby foreign locations

- The nonreporting of consumption by vessels under charter to the major petroleum production and refining companies in support of offshore drilling and production activities or petroleum product distribution efforts.

3. <u>Domestic Energy Supplies Will Be Required to Produce 2.44 Quads by the Year 2000 for the Marine Transportation Industry</u>

If it is assumed that the relationship between foreign to domestic purchases of fuel oil in the foreign trade sector will remain constant between now and the year 2000, domestic energy supplies will be required to supply 2.44 quads to the marine transportation industry. Of this, 1.1 quads represents the demand of the six domestic industry sectors and 1.34 quads represents domestic purchases of the foreign trade sector.

(6) <u>Thirty-Three Federal, State, International and Private Organizations Were Identified That Either Impact or Have Regulatory Jurisdiction Over the Commercial Marine Transportation Industry</u>

Thirty three organizations representing the following categories:

- Federal
- State
- International
- Private, nonprofit

were identified that impact the operations of the commercial marine transportation industry. These organizations and their areas of impacts are shown in Table 8.

These organizations may have an impact on either the design and construction or operational aspects of commercial marine transportation. These two major areas of impact were subdivided into 16 areas as follows:

- Design and construction - 6 subcategories
  - Propulsion machinery
  - Hull
  - Habitability
  - Environment and safety
  - Manning and licensing
  - Financial assistance
- Operational - 10 subcategories
  - Itinerary
  - Entry restrictions
  - Tariff review and filing
  - Monopoly control
  - Financial assistance
  - Cargo allocation
  - Fuel price and availability
  - Traffic control
  - Maintenance and repair standards
  - Environment and safety.

The 33 organizations impact the commercial marine transportation industry either directly through regulatory jurisdiction and approval authority or indirectly by generating a requirement for U.S. flag shipping services through U.S. Government impelled cargoes. Twelve of the 33 organizations were judged to have direct and 21 were judged to have indirect impacts on the commercial marine transportation industry.

(7) <u>Seven Existing or Proposed Regulations Were Found to Have a Quantifiable Impact on Energy Consumption in the Marine Transportation Industry</u>

The analysis of the organizations identified above resulted in the identification of seven specific regulations that impact or could impact commercial marine transportation energy consumption.

TABLE 8
Agencies and Their Areas of Jurisdiction in the Commercial Marine Transportation Industry

	Construction Aspects						Operational Aspects									
	PROPULSION MACHINERY	HULL	HABITABILITY	ENVIRONMENTAL AND SAFETY	MANNING & LICENSING	FINANCIAL ASSISTANCE	ITINERY	ENTRY RESTRICTIONS	TARIFF REVIEW AND FILING	MONOPOLY CONTROL	FINANCIAL ASSISTANCE	CARGO ALLOCATION	FUEL PRICE AND AVAILABILITY	TRAFFIC CONTROL	MAINTENANCE & REPAIR STANDARDS	ENVIRONMENTAL AND SAFETY
1. UNITED STATES COAST GUARD	●	●	●	●	●									●	●	●
2. DEPARTMENT OF ENERGY													●			
3. MARITIME ADMINISTRATION	●	●	●	●		●	●				●	●			●	
4. FEDERAL MARITIME COMMISSION							●	●	●	●						
5. CLASSIFICATION SOCIETIES	●	●	●	●	●										●	
6. ENVIRONMENTAL PROTECTION AGENCY				●												●
7. INTERGOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION	●	●	●	●	●											●
8. INTERSTATE COMMERCE COMMISSION							●	●	●	●						
9. ST. LAWRENCE SEAWAY DEVELOPMENT CORP.				●										●		
10. PANAMA CANAL COMPANY		●		●										●		
11. STATE GOVERNMENTS	●	●												●		●
12. ARMY CORPS OF ENGINEERS														●		
13. ACTION												●				
14. AGENCY FOR INTERNATIONAL DEVELOPMENT												●				
15. BONNEVILLE POWER ADMINISTRATION												●				
16. DEPARTMENT OF AGRICULTURE												●				
17. DEPARTMENT OF COMMERCE												●				
18. DEPARTMENT OF DEFENSE												●				
19. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE												●				
20. DEPARTMENT OF STATE												●				
21. DRUG ENFORCEMENT ADMINISTRATION												●				
22. ECOLOGICAL SURVEY												●				
23. ENVIRONMENTAL PROTECTION AGENCY												●				
24. FEDERAL AVIATION AGENCY												●				
25. FEDERAL HIGHWAY ADMINISTRATION												●				
26. INTER-AMERICAN DEVELOPMENT BANK												●				
27. INTERNATIONAL EXCHANGE SERVICE												●				
28. NATIONAL AERONAUTICS & SPACE ADMINISTRATION												●				
29. SMITHSONIAN INSTITUTION												●				
30. TENNESSEE VALLEY ADMINISTRATION												●				
31. UNITED STATES INFORMATION AGENCY												●				
32. UNITED STATES TRAVEL SERVICE												●				
33. EXPORT-IMPORT BANK												●				

Source: U.S. Maritime Administration, Annual Report, 1975.

Note: The Environmental Protection Agency is listed twice, due to its dual role of regulatory agency and generator of government impelled cargoes.

The energy implications of these regulations are examined in separate case studies contained in Volume III of this report. A summary of the results of each of those analyses is given in Table 9. As shown in this table, three of the regulations identified have impacts greater than 1 percent of total industry consumption in 1974. Each of these three is discussed in greater detail below.

TABLE 9
Energy Impacts Due to Regulatory Actions

Case Study	Energy Impact Increase (Decrease) in Quads	Percent of Industry Consumption in 1974
		Low High
Puget Sound Tanker Regulations	0.0003 to 0.001	0.01 - 0.03
Foreign Sale of Alaskan Crude	0.066 to 0.103	2.25 - 3.51
Segregated Ballast	0.0 to 0.066	0.00 - 2.25
Inland Waterway User Charges	0.003 to 0.005	0.10 - 0.17
Cargo Pooling or Service Rationalization	(0.0) to (0.073)	(0.00) - (2.49)
Minibridge	(.005)	(0.17)
Lock and Dam 26	0.0 to 0.0007	0.00 - 0.02

Source: Booz, Allen & Hamilton.

1. <u>Allowing Surplus West Coast Crude Oil Production to Be Sold to Japan Could Increase Transportation Energy Requirements by .066 to .103 Quads</u>

The recent proposals to allow surplus west coast crude oil production to be sold to Japan in exchange for Middle Eastern crude was evaluated by comparing the energy that would be consumed in the event the proposals were adopted with each of the following domestic transportation options:

- Ship surplus to Long Beach, California, and then by pipeline to the U.S. gulf coast
- Ship surplus to Puget Sound and then by pipeline to the northern tier states
- Ship surplus to U.S. gulf coast by way of the Panama Canal.

Of the four transportation alternatives evaluated, the two options that involved a combination marine and a pipeline system required the least amount of energy for transportation. A summary of the energy requirements associated with each option is presented in Table 10; details are provided in Volume III.

TABLE 10
Transportation Energy Requirements for Four Alternative Distribution Schemes for the Projected West Coast Crude Surplus

Option	Transportation Energy Requirements
Option 1: Ship surplus crude to Japan in exchange for Arabian Gulf crude delivered to U.S. gulf coast	0.136 quads
Option 2: Ship surplus to Long Beach, then by pipeline to U.S. gulf coast	0.057 quads
Option 3:* Ship surplus to Puget Sound, then by pipeline to northern tier states	0.033 quads
Option 4: Ship surplus to gulf coast by way of Panama Canal	0.070 quads

* Destination different than other options.

Source: Booz, Allen & Hamilton.

2. Imposition of Segregated Ballast Requirements Could Result in an Increase in Petroleum Transportation Energy Requirements by As Much As 0.068 Quads

Due to a series of 15 major incidents involving oil tankers off the U.S. coast or in U.S. harbors between December 15, 1976 and March 27, 1977, the United States Congress and the U.S. Coast Guard have under consideration a regulation that would require all tankers entering U.S. waters to be fitted with segregated ballast. A requirement to dedicate a certain percentage of the available cargo tank space of a tanker to ballast service only, impacts the energy efficiency (BTU's/ton-mile) in three ways:

- Dedication of cargo tanks to ballast service reduces the amount of space available to carry cargo
- Reduction of the amount of cargo carried while operating the main propulsion plant at design conditions will result in higher speeds
- Reduction of the level at which the main propulsion plant is operated in order to return to normal speed will reduce energy consumption, but increase specific fuel consumption.

In addition to these considerations, the speed/power relationship under which marine vehicles operate is nonlinear such that power requirements increase faster than speed. Conversely, as speed is reduced, power requirements drop such that a 2 percent decrease in speed could result in as much as an 8 percent reduction in power requirements. Seven cases of various combinations of speed and horsepower levels were evaluated to determine the point where the additional energy required, due to segregated ballast requirements, was matched by energy saved due to speed reduction.

The results of this case study indicate that the impact of segregated ballast requirements could increase the petroleum transportation energy requirements by as much as 0.068 quads. This increase could be avoided through a reduction in speed, as shown in Table 11. The details of this case study are presented in Volume III.

3. Energy Savings Due to Pooling or Service Rationalization in the Foreign Trade Container Service Could Reach .073 Quads

Cargo pooling or service rationalization refer to actions on the part of shipping lines to maximize space utilization through the elimination of duplications and redundancies in the services offered to shippers, while maintaining the level of service offered at or near the level of demand. The existing regulatory environment in the United States makes such rationalization difficult and often times leads to situations of excess capacity or ship capability. This situation in turn promotes malpractices in the industry.

The potential for significant energy savings exists on those highly developed trade routes where over-capacity appears to recur. A report[5] recently completed for the U.S. Maritime Administration indicated that a potential for energy savings on the order of 40 percent exists in the container trade on the North Atlantic (TR 5-7-8-9).

If it is assumed that a similar potential for energy reduction also exists on two other highly developed containerized trades, trade routes 29 and 12, and a potential for a 10 percent reduction exists on all other trade routes, then the energy savings existing under a service rationalization scenario could approach 0.73 quads. The details of this case study are given in Volume III.

5 "The Possible Effect of Rationalization on Maritime Fuel Consumption," John Brinkley, National Maritime Research Center Report No. NMRC-KP-147, dated October 1975.

TABLE 11
Energy Impact of
Segregated Ballast Requirements

Case	Operating DWT as % of Normal	Horsepower as % of Normal	Speed as % of Normal	Specific Fuel Consumption as % of Normal	Combined Impact on Energy Intensity (BTU's/ton-mile)	Potential for Increased Energy Use (QUADS)
1	80	100%	104%	100.0%	+20.2%	.068
2	80	88%	100%	101.0%	+11.1%	.037
3	80	95%	102%	100.3%	+15.8%	.056
4	80	85%	98%	101.5%	+10.0%	.034
5	80	80%	97%	102.5%	+ 5.7%	.019
6	80	75%	95%	103.6%	+ 2.2%	.008
7	80	70%	92%	105.1%	0.0%	.000

Note: Based on 1974 energy consumption of 1.333 quads for tankers engaged in U.S. - foreign trade, Booz, Allen & Hamilton Final Report - Volume II, "Energy Use in the Marine Transportation Industry - Task I Industry Summary."

(8) <u>Five Generic Technologies and Their Specific Energy Conservation Research and Development Program Areas Were Identified</u>

The technology base of the commercial marine transportation industry relating to energy usage, is made up of five generic technologies:

- Main propulsion plants
- Propulsors
- Hydrodynamics
- Vessel operations
- Fuels.

This study identified 15 specific program areas in four of these generic technologies, as shown in Table 12. Programs in the area of marine fuels are being evaluated under separate investigations.[6]

An economic and energy impact analysis and technological risk assessment were performed on the specific program areas and the results are summarized in Table 13. Two general conclusions were drawn:

- All programs identified show a net economic benefit when applied to the current U.S. merchant fleet
- Five program areas have energy reduction potentials greater than 5 percent in either 1974 or 2000.

Based on these conclusions and the results summarized in Table 13, it is recommended that the Department of Energy consider supporting research in the areas discussed in the next section of this report.

3. TWO PROGRAM AREAS ARE RECOMMENDED FOR FUNDING BY DOE

Based on the energy savings potentials calculated, the programs relating to:

6 "Evaluation of the Alternatives for Contingency Fuels in the Commercial Marine Transportation Industry," and "Study of Coal/Coke-Oil Emulsions for Use As Marine Contingency Fuels," DOE, Contract No. EY-76-C-03-1175.

TABLE 12
The Fifteen Maritime Energy Conservation
Program Areas Identified and Evaluated

Generic Technology	Program Area
Main Propulsion Plants	High Pressure/Temperature Reheat Steam (HPTRS)
	Slow Speed Diesels (SSD)
	Diesel Bottoming Cycles (DBC)
	Adiabatic Diesels (AD)
	Naval Academy Heat Balance Engine (NAHBE)
	Heavy Duty Gas Turbines & Combined Cycles (GTCC)
	Closed Cycle Gas Turbines (CCGT)
Propulsors	Contra-rotating Propellers (CR)
	Propellers in Nozzles (PIN)
Hydrodynamics	Submerged Air Cushions (SAC)
	Cutaway Hulls (CH)
	Tunnel Sterns (TS)
	Hull Maintenance & Smoothing (HMS)
Vessel Operations	Vessel Routing (VR)
	Plant Tuning (PT)

- Diesel bottoming cycles
- Adiabatic diesels

are recommended for funding. The specific program elements of each recommended program area are identified below.

(1) Recommended Program Elements in the Diesel Bottoming Cycle Program Area

Diesel bottoming cycles have advanced to the point where serious consideration should be given to funding a demonstration project. It is recommended that a program containing the following elements be initiated:

- Develop specifications and the design of a prototype exhaust heat recovery unit for installation on an inland river towboat be started. Such a program is estimated to cost $350 to $500 thousand.

- Construct, test and install the prototype. This program is estimated to require funding of $2 to $2.5 million.

TABLE 13
Results of Economic and Energy Impact Analysis

LEVEL OF TECHNOLOGICAL RISK	PROGRAM AREA	RANGE OF REDUCTION IN REQUIRED FREIGHT RATE (%) (1974)		ENERGY CONSERVATION POTENTIAL 1974 (% OF U.S. FLAG CONSUMPTION)	ENERGY CONSERVATION POTENTIAL 2000 (% U.S. FLAG CONSUMPTION)	POTENTIAL PROGRAM START	PROGRAM DURATION (YEARS)	ESTIMATED FUNDING REQUIREMENTS TO LOWER RISK CATEGORY (MILLIONS OF $)		
		MINIMUM	MAXIMUM					LOW TO COMMERCIALIZATION	MEDIUM TO LOW	HIGH TO MEDIUM
LOW	SSD	1.0	8.2	5.5	12.7	FY-78	2	0.500	–	–
LOW	PT	0.2	1.4	1.4	0.0	FY-78	–	0.000	–	–
LOW	VR	0.0	0.0	0.0	0.0	FY-78	–	0.000	–	–
MEDIUM	DBC	2.1	5.2	3.6	11.2	FY-78	2	UNKNOWN	3.000	–
MEDIUM	HMS	0.0	3.3	3.1	6.2	FY-78	1	"	0.250	–
MEDIUM	GTCC	0.0	5.18	1.2	2.9	FY-78	2-3	"	4.000	–
MEDIUM	TS	0.2	1.0	0.6	0.9	FY-78	1	"	0.300	–
MEDIUM	CR	0.9	1.6	0.5	3.1	FY-78	2-3	"	4.000	–
MEDIUM	HPTRS	3.7	5.9	0.4	2.8	FY-78	10	"	3.000	–
MEDIUM	PIN	0.7	0.7	0.0	0.3	FY-78	2-3	"	1.000	–
MEDIUM	CH	0.6	0.6	0.0	1.4	FY-78	1	"	0.300	–
HIGH	AD	0.0	0.0	10.2	6.7	FY-80	5	"	UNKNOWN	2.000
HIGH	NAHBE	2.4	3.6	5.4	2.9	FY-79	3	"	"	1.000
HIGH	CCGT	5.2	7.4	1.4	2.7	FY-80	6-7	"	"	50.000
HIGH	SAC	1.6	1.6	0.0	0.7	FY-78	1	"	"	0.400

Source: Booz, Allen & Hamilton.

- Operate the system for a year as a demonstration project to prove the savings potential. Costs associated with this element are estimated at $450 to $500 thousand.

It is expected that this demonstration project would span approximately two years and cost approximately $2.8 to $3.5 million.

(2) Recommended Program Elements in the Adiabatic Diesels Program Area

Basic research is currently being conducted in the adiabatic diesel program area by the U.S. Army and the Cummins Engine Company. The goal of the U.S. Army-sponsored program is to develop a smaller, lighter, and more efficient main battle tank engine.

Reliability and operating criteria for a military diesel and a commercial marine diesel are extremely different. Given the expected benefits of the adiabatic diesel, as discussed in Appendix A, the results of current research should be reviewed next fiscal year with an expected participation directed toward developmental research to determine the potential for marine applications.

Given the level of effort of the U.S. Army's program, costs are estimated at $2 million over a five year period to develop a prototype engine.

4. THE ENERGY STUDY OF THE MARINE TRANSPORTATION INDUSTRY IS ORGANIZED INTO FIVE VOLUMES

The work performed for the Transportation Energy Conservation Division of the Department of Energy (DOE) by Booz, Allen & Hamilton to examine energy use in the marine transportation industry is organized into the following volumes:

- Volume I - Executive Summary
- Volume II - Industry Summary
- Volume III - Regulations and Tariffs
- Volume IV - Efficiency Improvements and Industry Future

- Volume V - Marine Transportation Energy Model Documentation

Several related studies concerned with marine transportation energy conservation performed for DOE by Booz, Allen, include the following:

- Volume VI - Application of Organic Rankine-Cycle Heat Recovery Systems to Diesel Powered Marine Vessels

- Volume VII - Examination of Diesel Cooling Water Bottoming Cycles

- Volume VIII - Evaluation of the Alternatives for Contingency Fuels in the Commercial Marine Transportation Industry

- Volume IX - Study of Coal/Coke-Oil Emulsions for Use As Marine Contingency Fuels

- Volume X - The Impact of Government Regulations on Energy Consumption in Navy Ships.

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031 Sales/Marketing
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134 ALTERNATIVE FUELS
135 ELECTRIC & HYBRID VEHICLES
132 HEAT ENGINES
166 VEHICLE MANAGEMENT
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131 TECHNOLOGY ASSESSMENT
167 SYSTEMS MANAGEMENT
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TRANSPORTATION

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159 Hydrogen
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157 Gaseous Fuels (other than hydrogen)
156 Other (distillate fuels)
021 Fuels from Biomass
140 Toxicology

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