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DRAFT REPORT
ENERGY USE IN THE MARINE TRANSPORTATION INDUSTRY
TASK IV - INDUSTRY FUTURE

for

Division of Transportation Energy Conservation
Non-Highway Transport Systems
Energy Research and Development Administration
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I. INTRODUCTION

I. INTRODUCTION

This report covers the work accomplished under the fourth task of a four-task assignment, entitled "Energy Study of Ship Transportation Systems." This fourth task projects future industry scenarios and evaluates the energy savings potential of the research and development programs identified in Task III against these scenarios. The objectives of the four tasks are:

- Task I — Industry Summary - to define the current marine transportation industry in terms of population, activities and energy use

- 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 ERDA.

The approach used in Task IV is discussed in the following section.

1. METHODOLOGY USED IN THE EVALUATION OF THE POTENTIAL FUTURE ENERGY SAVINGS OF RESEARCH AND DEVELOPMENT PROGRAMS

The work accomplished under this task drew heavily from the results of the first three tasks. In this fourth task, levels of activity, operating patterns, regulatory profiles and growth in vessel sizes were postulated for the year 2000. These future scenarios were based on the information developed in Tasks I and II. After the future scenarios were defined, the research and development programs identified in Task III were evaluated with respect to their potential for energy conservation during that future period.

Key to the analysis is the use of the Marine Transportation Energy Model (MTEM), developed in Task I. This model simulates the United States maritime transportation industries activities for two years, 1974 and 2000. Cargo movements are specified for 27 foreign and 16 domestic trade routes. A series of 35 generic vessels was developed and are contained in the model. Each of these vessels is described in terms of application to trade routes, speed, horsepower, fuel consumption, and cargo carrying capacity, as shown in Chapters II and III.

Each program area to be analyzed can be introduced into this generic U.S. flag fleet by varying the appropriate operating parameters. The operations of this "new" fleet were then simulated with the model and changes in the energy consumption patterns determined.

2. ORGANIZATION OF THIS REPORT

This report consists of four chapters. The introduction is contained in Chapter I. In Chapter II, the operational, regulatory and vessel size scenarios for the year 2000 are developed. In Chapter III, future cargo flows and expected levels of energy use for the baseline 2000 projection are determined. In Chapter IV, the research and development programs are introduced into the future U.S. flag fleet and the energy savings potential associated with each is determined.

II. THE INDUSTRY FUTURE, PROJECTED OPERATING, REGULATORY AND TECHNOLOGICAL SCENARIOS FOR THE YEAR 2000

II. THE INDUSTRY FUTURE, PROJECTED OPERATING, REGULATORY AND TECHNOLOGICAL SCENARIOS FOR THE YEAR 2000

The current levels of activity, regulatory scenarios and technology base that defines the marine transportation industry are described in Volumes II, III and IV of this final report. The purpose of this chapter is to project a new baseline for the year 2000 against which the potential research and development programs identified in Chapter IV can be evaluated.

The projected technology base for the year 2000 will be limited to expected growth in vessel sizes and changes in shipping technology. The research and development programs identified in Volume IV will then be evaluated against this baseline. The expected scenarios for each of the seven industry segments are described in the following sections:

1. THE FOREIGN TRADE SECTOR

The oceangoing merchant fleet serving U.S. foreign trade is defined as those steel-hulled, self-propelled vessels over 1,000 gross registered tons capable of operating in the U.S. - foreign trade. There are five primary types of service offered by the foreign trade sector:

- Liner
- Nonliner or tramp
- Dry bulk
- Tanker
- Passenger.

Each is discussed below.

(1) Liner Vessels

Liner vessels operate as common carriers and provide a regularly scheduled service between specified ports. This portion of the ocean shipping sector is characterized by fast ships moving relatively high value cargo.

1. Growth of Intermodalism

There are a variety of vessel types employed in liner service that differ primarily in their method of cargo handling. This variety has resulted from the growth of various types of intermodal transportation systems. The intermodal vessels call on fewer ports and minimize their port time due to more efficient cargo handling techniques and links to other transportation modes. Liner vessels have been classified according to ship type in the following four categories:

- Break-bulk and partial container
- Container
- Roll-on/Roll-off
- Barge carriers.

The increasing trend towards intermodalism in international shipments that has been evident over the past 15 years is expected to continue. Container vessels were the first intermodal concept and first introduced by Sea-Land Services, Inc. in the North Atlantic/Puerto Rico trade during the 1950's. The growth of intermodalism is shown by the fact that by 1974, 43 percent* of all liner cargo was being carried in containers. Other intermodal vessels are also gathering an increasing share of the world's liner market.

This growth of intermodalism is expected to grow. For the purposes of this analysis, the distribution of liner cargo by vessel type and essential trade route is shown in Table II-1.

2. Growth in Vessel Size

A recent MarAd funded study** has projected liner vessels to grow, as shown in Table II-2.

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* "Containerized Cargo Statistics, Calendar Year 1974," Department of Commerce, Maritime Administration.

** "A Study of the Future Requirements for Ships That Will Be Engaged in the U.S. World Trade for Both the Short and Long Term," Temple, Barker and Sloane, Inc., for the Office of Maritime Technology, U.S. Maritime Administration, 1977.

TABLE II-1
Distribution of Liner Cargo by Vessel Type - 2000

Essential U.S. Trade Routes	Percent Distribution by Vessel Type			
	Container Vessel	Ro/Ro	Barge Carrier	Break-bulk and Partial Container
1	25		25	50
2	25		25	50
4	40	40		20
5-7-8-9	90	9		1
6	90			10
10	40	20		40
11	95			5
12	60			40
13	40	20		40
14	20			80
15A	20			80
15B	20			80
16	80			20
17			40	60
18		40	40	20
19	20	20	30	30
20	25		25	50
21	80			20
22	30		30	40
23	20	20		60
24	25		25	50
25	25		25	50
26	90			10
27	80		10	10
28	20	30	30	20
29	80	10		10
31	25		25	50

Source: Booz, Allen & Hamilton.

TABLE II-2
Growth (Reduction) in Liner Vessel Parameters 1975 - 2000

Vessel Type	Percent Increase in DWT/Ship	Percent Increase in Horsepower	Percent Increase in Speed
Break-bulk	91	74	16
Containerships	23	30	10
Barge carriers	17	(6)	(1)
Ro/Ro	not addressed		

Based on these projections, generic liner vessels for the year 2000 were defined, as shown in Table II-3. The procedure used to develop Table II-3 utilized the percentage increase in DWT and speed as calculated in the MarAd study and shown in Table II-2. The horsepower levels required by that deadweight and speed were taken from Figure II-1.

3. U.S. Flag Share

U.S. flag liner vessels are expected to benefit from flag preference legislation.

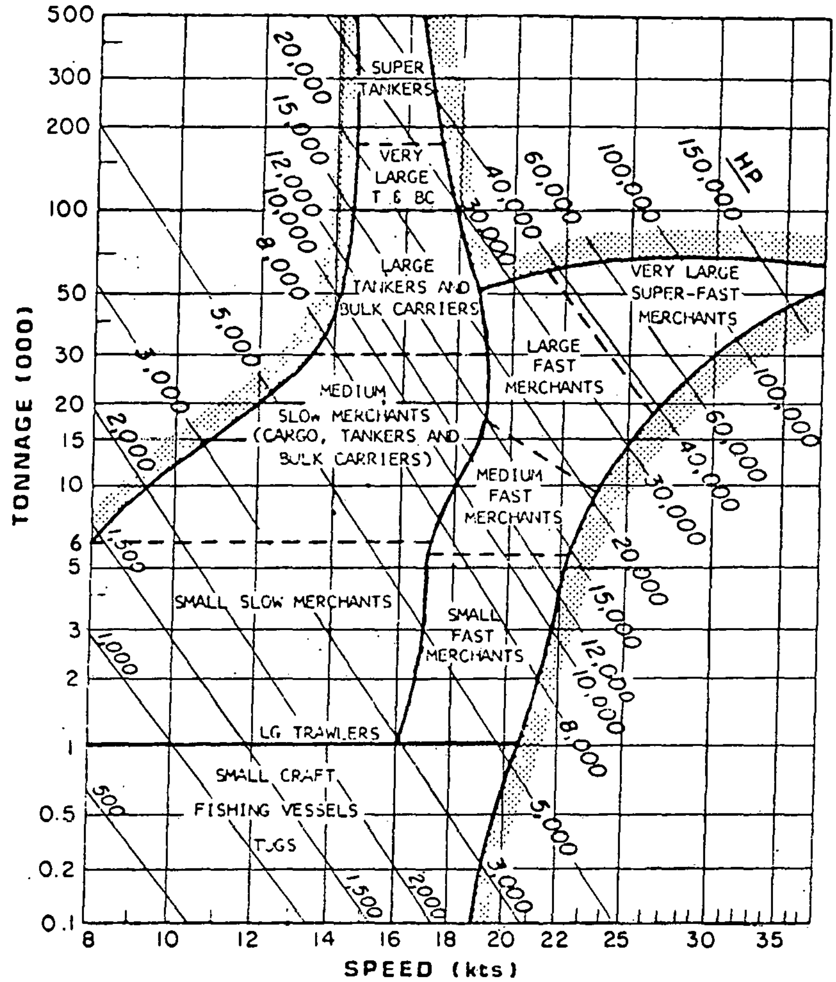
This flag preference scenario assumes that the trend of national flag preference actions on the part of individual countries working through bilateral trade agreements or countries working through international forums such as the United Nations, will continue. The proposed United Nations code of conduct for liner conferences (UNCTAD) would reserve cargo on a 40-40-20 basis, with 40 percent of all cargo reserved for the fleets of the two trading partners and 20 percent for ships flying a third flag. This cargo sharing formula has been under consideration by United Nations members for the past few years. Although still far from being accepted, the UNCTAD code is illustrative of the trend towards national flag preference for liner trades that is already a reality in the bulk trades.

Between 1965 and 1972, the U.S. flag participation in all liner movements was quite constant and varied between 22 and 24 percent. Starting in 1973, the U.S. flag share grew to 26 percent and then to 30 percent in 1974 and 1975. This increase in U.S. flag share was due to a complex interrelationship between three factors:

- The tendency of U.S. operators to employ more productive liner vessels than their foreign counterparts
- The increased effectiveness of MarAd's market development organization in assisting the U.S. flag operators to secure both commercial and government-sponsored cargo

TABLE II-3
Changes in Generic Liner Vessels
1974 to 2000

Liner Vessel Type	Year	Deadweight (long tons)	Horsepower	Speed (knots)	Fuel Rate (lb/SHP-hr)	Deadweight Utilization Factor (percent)
Break-bulk	1974	13,500	14,500	19.0	.47	40
	2000	25,800	26,000	22.0	.37	40
Containership	1974	12,000	8,000	16.0	.47	50
	2000	14,800	9,000	17.6	.37	50
	1974	16,500	17,000	20.0	.47	50
	2000	20,000	24,000	22.0	.37	50
	1974	18,500	18,000	20.0	.47	50
	2000	23,000	25,000	22.0	.37	50
	1974	23,000	28,000	23.0	.47	50
	2000	28,000	40,000	25.0	.37	50
Ro/Ro	1974	10,000	11,000	24.0	.47	33
	2000	12,500	22,000	25.0	.37	33
	1974	16,500	22,000	22.5	.47	33
	2000	20,000	35,000	25.0	.37	33
	1974	18,000	25,000	22.5	.47	33
	2000	22,000	36,000	25.0	.37	33
Barge carriers	1974	33,000	33,000	22.0	.47	60
	2000	38,000	35,000	22.0	.37	60
	1974	42,000	38,000	22.0	.47	60
	2000	49,000	39,000	22.0	.37	60



Source: "Trends In Merchant Shipping," Donald Ross, Tetratech Report to Naval Undersea Center.

FIGURE II-1
Operating Diagram for Major Ship Types

- The leadership of several U.S. flag companies in the area of innovative liner services such as minibridge

For the purpose of this analysis, it is expected that the U.S. maritime community will continue to maintain its technological lead through the year 2000, and together with increased world-wide emphasis on national flag cargo preference, the U.S. flag share of liner movements will rise to 40 percent.

(2) Passenger Vessels

Cruise volume projections have been based on past U.S. Army Corps of Engineer passenger statistics. Table II-4 presents recent passenger statistics at the five major east coast cruise ports for the 1965 through 1974 period.

TABLE II-4
Number of Passengers Passing Through
Major Cruise Ports
(in thousands)

Year	Major Cruise Ports					
	New York	Baltimore	Charleston	Port Everglades	Miami	Total
1965	893	14	453	336	535	2,231
1966	822	13	535	345	495	2,210
1967	725	9	576	433	345	2,088
1968	631	10	514	483	454	2,092
1969	663	3	391	527	707	2,291
1970	573	176	261	459	608	2,077
1971	567	98	255	571	695	2,186
1972	1,075	128	263	557	710	2,733
1973	1,154	183	258	356	759	2,710
1974	405	177	234	323	569	1,708

Source: "Waterborne Commerce of the United States," 1974, U.S. Army Corps of Engineers.

As can be seen, the total number of passengers passing through all east coast ports fell from a level of 2.23 million in 1975 to a low of 2.09 million in 1967 and then had an increasing trend from 1967 through 1973. 1974 saw a 37 percent drop from the high set in 1973. Growth rates over selected periods are:

- 1965 to 1974 - average of -3 percent per annum
- 1965 to 1973 - average of 2.5 percent per annum
- 1967 to 1973 - average of 4.4 percent per annum.

Due to the great variations in growth rates over the recent historical past, selection of a growth rate for cruise activity is extremely difficult. The decline and cessation of regularly scheduled passenger traffic on the North Atlantic is reflected in these figures, as well as the growth of the cruise industry. Based on the fact that the period shown in Table IV-4 includes the decline of one marine transportation service and the growth of another plus an anticipated higher growth rate for air fare versus cruise fares, due to the higher energy intensiveness of air travel, a 2 percent annual growth of cruise travel is projected for the 1974-2000 period. All cruise traffic is expected to be foreign flag service.

(3) Nonliner or Tramp Vessels

Tramp vessels, in contrast to liner vessels, offer irregular service and are available for hire to a shipper under either a time or voyage charter, to load and discharge specified cargo between such ports as the charter stipulates. In some cases, foreign flag operators move their vessels between liner and tramp service. Another perturbation occurs when an operator offers berth service in one direction on a trade route and tramp service in the other direction. A typical tramp vessel is generally of the break-bulk variety, but is different in that it is a generally older and slower vessel with a smaller cargo carrying capacity than a break-bulk liner vessel.

1. Growth in Tramp Vessel Size

Tramp vessels are typically chartered to transport small lots of traditional bulk commodities such as grains or sugar and low value neobulk commodities such as:

- Animal feed
- Wood (primary and rough)
- Wood pulp and wastepaper
- Scrap
- Iron and steel products.

The previously cited MarAd report (see page II-2) projected a growth in the typical neobulk carrier between 1974 and 2000 of:

- 40 percent in deadweight
- 41 percent in horsepower
- 8 percent in speed.

Based on these projected growth rates, the deadweight of the generic tramp vessel was increased 40 percent and the speed increased 8 percent. Power levels were taken from Figure II-1. A comparison of the generic tramp vessel in 1974, with that postulated to be in service during the 2000 time frame, is shown in Table II-5.

TABLE II-5
Changes in Generic Tramp Vessel
1974 - 2000

Year	Deadweight (long tons)	Horsepower	Speed (knots)	Fuel Rate (lb/SHP-hr)	Deadweight Utilization Factor
1974	8,400	5,000	14	.37	40%
2000	11,760	7,000	15	.37	40%

2. U.S. Flag Share

For the purpose of this analysis, no major regulatory changes are anticipated in the tramp sector, and U.S. flag share of the tramp trades is expected to remain at the current level of 4 percent.

(4) Dry Bulk Vessels

Dry bulk carriers are designed to carry such bulk cargoes as grains and ores. This group also includes ore/bulk/oil (OBO) vessels suited for both the liquid and dry bulk trades. Like tramp vessels, dry bulk carriers are chartered on a time or voyage basis, and are drawn from the world pool.

Dry bulk carriers are engaged in importing such commodities as sugars, fertilizers, iron ore, and exporting such commodities as grain, coal, and fertilizers in the United States' foreign trade. Dry bulk shipments primarily originate or terminate on the east and gulf coasts. These vessels typically call at one or two ports on each leg of the voyage and rarely spend more than one or two days in port. The typical operating profile of a dry bulk carrier is loaded in one direction and return in ballast. There is generally little opportunity for backhaul cargo.

1. Growth in Dry Bulk Vessel Size

The previously cited MarAd report (see page II-2) projects a growth in the average dry bulk vessel of:

- 49 percent in deadweight
- 42 percent in horsepower
- 3 percent in speed.

Based on these projected growth rates for deadweight, speed and power levels from Figure II-1, the generic dry bulk carriers were changed, as shown in Table II-6, on the following page.

2. U.S. Flag Share

The dry bulk trades are expected to show increased U.S. flag participation due to:

- Increased national awareness of the national security implications of continued reliance on foreign flag vessels to carry over 95 percent of our dry bulk trades

TABLE II-6
Changes in Generic Dry Bulk Vessels
1974 - 2000

Year	Deadweight (long tons)	Horsepower	Speed (knots)	Fuel Rate (lb/SHP-hr)	Deadweight Utilization Factor
1974	20,000	8,000	15	.37	96%
2000	30,000	10,000	15	.37	96%
1974	30,000	10,000	15	.37	96%
2000	45,000	12,000	15	.37	96%
1974	40,000	11,000	15	.37	96%
2000	60,000	13,500	15	.37	96%

- Increased government sponsorship of U.S. flag dry bulk shipping programs.

Recent legislation has been enacted that will reserve 9.5 percent of all U.S. petroleum imports for U.S. built, manned and registered tankers. For the purposes of this analysis, the U.S. dry bulk fleet is expected to benefit from this action. By the year 2000, 10 percent of our dry bulk trade will be carried by U.S. flag vessels.

(5) Tank Vessels

Tankers are designed for the carriage of liquid bulk cargoes such as crude oil, refined petroleum products, chemicals and edible oils. These vessels are also used to move dry bulk cargoes that can be handled using pumping or suction systems. They have been employed extensively in the U.S. foreign grain trade.

Crude petroleum destined for the United States generally originates in South America, Africa, and the Arabian Gulf, while clean petroleum products move primarily from the Caribbean area to the U.S. east coast.

As with dry bulk carriers, tankers typically call at only one port on each leg of the voyage, spend a minimum amount of time in port, and carry no backhaul cargo.

1. <u>Growth in Tank Vessel Size</u>

One major technological advance is expected in the U.S. - foreign tanker trade by the year 2000. Deepwater ports, such as LOOP and SEADOCK, currently proposed for the gulf coast are expected to be operating on all three coasts by the year 2000. The State of Washington has sufficient water depth in Puget Sound to handle the largest tankers currently in existence. Exxon is currently constructing a single point mooring buoy for the Santa Barbara channel that will be located in 440 feet of water. It is expected that the current regulatory problems associated with the gulf coast deepwater ports will soon be resolved and by the year 2000, deepwater ports will be in existence on the Atlantic coast as well.

Based on this expected growth in vessel size, the tankers involved in the importation of crude oil will grow to the maximum size available. Those tankers involved in the exportation of chemical and petroleum products are expected to remain at approximately the same size, however, they will become increasingly more specialized. The expected change in generic tank vessels is shown in Table II-7.

TABLE II-7
Changes in Generic Tank Vessels
1974 - 2000

Year	Deadweight (long tons)	Horsepower	Speed (knots)	Fuel Rate (lb/SHP-hr)	Deadweight Utilization Factor
1974	20,000	7,000	14	.37	96%
2000	same	-	-	-	80%
1974	40,000	9,000	14	.37	96%
2000	same	-	-	-	80%
1974	65,000	14,000	15	.37	96%
2000	same	-	-	-	80%
1974	80,000	16,000	15	.37	96%
2000	150,000	20,000	15	.37	80%
1974	150,000	20,000	15	.37	96%
2000	300,000	36,000	15	.37	80%

2. Expected Environmental Impacts

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) and will reduce the deadweight utilization of tankers from approximately 96 percent to 80 percent by the year 2000.

It is expected that new hull forms will be developed over the next few years, such as the cut-away hull form now under investigation by the Gulf Oil Corporation, that will reduce the penalty associated with segregated ballast requirements. These research and development options are discussed in greater detail in Volume IV.

3. U.S. Flag Share

The Administration has recently given its approval to cargo preference legislation reserving 9.5 percent of all petroleum imports for U.S. flag tankers. This measure is expected to pass both houses of Congress and be signed into law. The Administration's approval of the 9.5 percent quota is a compromise position, as the maritime lobby has actively advocated a 30 percent cargo preference reservation for the past few years. For the purposes of this analysis, U.S. flag share in the year 2000 was taken as 10 percent of the total tanker trade.

2. THE GREAT LAKES SECTOR

The Great Lakes sector of the U.S. merchant fleet has been defined as those vessels operating within the Great Lakes/St. Lawrence Seaway system. The system stretches for more than 2,300 miles from the Atlantic Ocean to mid-America, with a controlling depth of 27 feet. There are 16 locking points and more than 155 miles of channels and canals in the system. Traditionally, the Great Lakes operating season has been cut short by the winter season, as icing on the lakes has rendered navigation virtually impossible. In recent years, successful attempts have been made in extending the operating season in certain sections from 10 to 12 months.

Waterborne commerce in the Great Lakes can be divided into the following categories:

- Domestic interlake and intralake movements or trade between U.S. ports within a specific lake or between lakes
- Trans-lakes movements between the United States and Canada
- Overseas foreign movements.

In 1974, the distribution of the tonnage involved in these categories is shown in Table II-8.

TABLE II-8
Great Lakes Trade During 1974

Service	Total Trade in Millions of Long Tons	Percent
Domestic	138.2	75
Trans-lake	37.7	20
Overseas foreign	8.1	5
Total	184.0	100%

Source: "Domestic Waterborne Trade of the United States 1967-1974," Maritime Administration, U.S. Department of Commerce:

(1) <u>Growth in Great Lakes Vessels</u>

The growth in size of vessels involved in the domestic and trans-lake Great Lakes trade categories is not expected to be as dramatic as that expected in the foreign trade sector. This is due to a number of constraining factors:

- Size limitations imposed by existing lock and channel width and draft constraints

- Size limitations imposed by loading facilities
- Liquid bulk storage capacities
- Extremely long life spans for Great Lakes vessels.

The last point is quite important. Approximately 70 percent of the current U.S. Great Lakes fleet is over 30 years old. Some existing vessels date to 1897. With an expected life span of 40 to 50 years, the average size of Great Lakes bulk freighters is expected to change slowly. Currently, the older vessels in the Canadian and U.S. dry bulk fleets are slowly being replaced. The vessels being replaced are the older, coal fired reciprocating steam engined vessels. As of December 1975, there were 11 Great Lakes bulk carriers on order ranging in size from 6,700 DWT to 59,000 DWT, as shown in Table II-9.

Table II-9 underscores the trend towards larger vessels and the limiting factor of the locks and entrance channels. Currently, the vessel size limit at the "Soo" Locks is 1,000-foot length overall, by 105-foot beam.

TABLE II-9
Great Lakes Dry Bulk Carriers on Order
December 1975

Shipyard	DWT	Overall Length	Horsepower	Delivery
American Ship Building	59,000	1,000'	16,000	1976
American Ship Building	59,000	1,000'	16,000	1977
American Ship Building	59,000	1,000'	16,000	1978
Port Weller Dry Docks	33,000	730'	10,000	1976
Bay Shipbuilding	42,400	770'	10,500	1976
Collingswood Shipyards	31,250	730'	unknown	1976
Collingswood Shipyards	6,700	355'	4,000	1976
Bay Shipbuilding	36,000	728'	7,000	1976
Bay Shipbuilding	unknown	1,000'	unknown	1977
Bay Shipbuilding	unknown	1,000'	unknown	1978
Bay Shipbuilding	unknown	730'	unknown	1976

Source: "Greenwood's Guide to Great Lakes Shipping," 1975.

Based on the projected increases in shipments of iron ore, coal, and other mining products, and the current trends in new buildings, it is expected that the average size of the domestic Great Lakes dry bulk carrier will increase to 30,000 DWT by the year 2000.

At all other locks in the Great Lakes-St. Lawrence Seaway System, the maximum size limit is shown in Table II-10.

TABLE II-10
Maximum Dimensions for Vessels Transiting the St. Lawrence Seaway

Length	-	730 feet
Beam	-	75 feet, 6 inches
Draft	-	25 feet, 9 inches (fresh water)

These dimensions effectively limit the maximum size of vessels able to serve the Great Lakes to approximately:

- General cargo vessels - 14,000 DWT
- Bulk carriers - 25,000 DWT

As a result the ships in the Great Lakes Overseas Service are expected to grow at a much lower rate than the domestic trades. The expected changes in the generic vessels on the Great Lakes is shown in Table II-11.

TABLE II-11
Changes in Generic Great Lakes Vessels
1974-2000

Vessel Type	Year	Deadweight (long tons)	Horsepower	Speed (mph)	Fuel Rate (lb/SHP-HR)	Deadweight Utilization Factor
Dry Bulk Carrier	1974 2000	15,000 30,000	4,000 10,000	11 11	.37 to .50 .37	.96 .96
Tanker	1974 2000	4,000 none	1,500	11	.37 to .47	.96
Tug	1974 2000	5,143 11,000	900 3,000	11 11	.37 .37	.96 .96

(2) Expected Regulatory Impacts

Increased environmental concerns and the establishment of a zero discharge criteria on the Greak Lakes is expected to eliminate almost all tanker traffic.

It is expected that by the year 2000, the majority of the petroleum distribution occurring on the Great Lakes will be done by barge, with very little carried by self-propelled tanker. The current U.S. flag tanker fleet consists of 15 vessels with a capacity greater than 10,000 bbls. Of these only three have been built since 1950. The U.S. tank barge fleet consists of 47 units of which 40 have been constructed since 1950. The total capacity of the barge fleet is approximately three times that of the self-propelled fleet. In addition, the Great Lakes Tanker fleet will also be subjected to segregated Ballast Requirements that will make barging operations more attractive. Based on these expected scenarios, all forecasted petroleum distribution was allocated to tug/barge operations.

The generic tug/barge was estimated to increase in size by 120 percent, which is the same percentage increase that was forecasted for the growth in marine tonnage, as discussed in Chapter III.

3. THE COASTAL SHIPPING FACTOR

The coastal shipping sector of the U.S. merchant fleet was defined as those vessels transporting cargo in the U.S. domestic deep-sea trade, which is protected from foreign competition by the Jones Act. This sector includes the non-contiguous trades with Puerto Rico, Hawaii, and Alaska.

Nearly all of the cargo movements in the domestic deep-sea trade consist of bulk commodities transported by either tanker or barge. In 1974, nearly 213 million long tons of cargo was carried in this trade, 90 percent of which was bulk commodities. Movements of non-bulk commodities are handled predominantly by coastwise container feederships and Ro/Ro ships. The coastal fleet was divided into the following three categories:

- Tanker
- Tug/barge
- Other coastal.

(1) Growth in Vessel Size

Growth in the size of the three generic vessel types involved in the coastwise trade will be constrained by:

- Tankers — coastal petroleum trade is predominately distribution of fuel and other refined products (approximately 87 percent). Size is restricted by available water depth and storage capacity at discharge points.
- Tug/barge — coastal trade is predominately petroleum products and dry bulk commodities. Depth of water and storage capacity at discharge points will constrain growth.
- Other coastal — the size of coastal feeder vessels are expected to be constrained only by the growth of the market.

The prime inhibitors of growth in size for the tanker and tug/barge are physical limitations of the current harbors. For this reason, a modest growth in size of 10 percent is projected for these two generic vessel types for the year 2000. Cargo forecasts for the coastal feeder services are based on an expected developing market. The vessels most likely to be deployed in a feeder service will most likely be older liner vessels that are currently employed in the foreign trade sector. Table II-12 gives the expected changes in the generic coastal vessels for the year 2000.

TABLE II-12
Changes in Generic Coastal Vessels
1974 - 2000

Vessel Type	Year	Deadweight (long tons)	Horsepower	Speed (knots)	Fuel Rate (lb/SHP-hr	Deadweight Utilization Factor
Tanker	1974	40,000	12,000	16	.47	.96
	2000	44,000	12,500	15	.37	.80
Tug/ Barge	1974	11,430	2,000	8	.37	-
	2000	13,000	2,250	8	.37	-
Other	1974	7,800	6,000	15.5	.47	.50
	2000	16,500	22,000	22.5	.47	.33

(2) Operational and Regulatory Changes

Expected changes in the existing operational practices and regulatory constraints are:

- As liner vessels get larger and faster, there exists a need to minimize the nonproductive port time that a large container vessel spends on each round trip. The easiest way to accomplish this is to eliminate all but one port call on each leg of the voyage and utilize a feeder system to distribute cargo to outlying ports. These systems currently exist throughout Europe and have been introduced to the U.S. coastwise trade by Sea-Land and Seatrain using self-propelled vessels and McAllister using a 300-foot deck barge. The growth of these systems is expected to continue.

- As fuel costs continue to climb, there exists a good potential for a coastwise Ro/Ro service, either by self-propelled vessel or tug/barge system, providing transportation between the northeast and Florida.

- Increased environmental concerns will extend the segregated ballast requirement for tankers discussed under the foreign trade shipping sector to tankers in the coastal shipping trades resulting in a decrease in their deadweight utilization factor from .96 to .80.

4. THE OFFSHORE SECTOR

The offshore sector is expected to show the most dramatic technological changes of all of the marine transportation sectors. New activities, such as:

- Offshore thermal energy conversion (OTEC)
- Deep ocean mining

are anticipated by the year 2000, plus increased activity in offshore oil exploitation.

Current activities in the offshore sector were categorized as:

- Exploration
- Drilling and production
- Service and supply
- Pipelaying and construction.

The expected new activities of offshore thermal energy conversion and deep ocean mining will place additional demands on the service and supply and construction categories. Increased activity in the offshore oil exploitation is expected to require more semisubmersible drilling rigs and dynamically positioned drillships as the search for oil moves further offshore. Supply craft are expected to increase in size and the number required to service a drilling rig is expected to increase as the distances from supply bases increases. Table II-13, which is shown on the following page, gives the expected changes in the generic offshore vessel types for the year 2000.

5. THE INLAND WATERWAY SECTOR

The inland waterways sector of the U.S. Merchant Marine is defined as those vessels operating between ports in the United States where the movement takes place entirely in rivers, canals, ports, channels, and other inland waters. Vessels operating within the U.S. Great Lakes system were discussed previously.

Most of the vessels operating upon the U.S. inland waterway system fall into the following categories:

- Towboats
- Tugboats
- Barges.

The towboat is a virtually flat-bottomed vessel which serves as the power unit for "push-towing" barges, in waterways that are protected or relatively calm in their natural state. Barges are lashed together by cables and ropes to form a single unit for push-towing. The towboat pushing from the rear of the tow is capable of handling a greater number of barges under better control than in the "pull-towing" method. These diesel powered vessels are capable of pushing barges carrying as much as 50,000 tons of cargo. The use of multiple rudders and kort nozzles allows maximum control in forward, backing, and flanking movements; all necessary to navigate the winding channels of the inland rivers and canals.

TABLE II-13
Changes in Offshore Generic Vessels
1974 - 2000

Activity	Vessel Type	Year	Length (water depth)	Horse-Power	Fuel Rate (lb/SHP-hr)	Level of Activity 2000
Drilling	Submersible	1974 2000	(80') none	- -	50 bbl/day -	1974=174 rig years projected increase of 2.5%/year; 331 rig years by 2000
	Drillship & barges	1974 2000	(20,000') (30,000')	- -	100 bbl/day -	
	Jack-up's	1974 2000	(600') (600')	- -	100 bbl/day -	
	Semisubmersible & tension leg	1974 2000	(6,000') (10,000')	- -	100 bbl/day 100 bbl/day	
Logistics	Crewboats	1974 2000	90' 100'	1800 2000	.37 .37	3 boats per rig year
	Tug	1974 2000	100' 150'	4000 7200	.37 .37	
	Tug/supply	1974 2000	190' 200'	3300 8000	.37 .37	
	Supply	1974 2000	170' 200'	3300 7000	.37 .37	
Other	Mining vessels	1974 2000	none 700'	- 7000	- .37	Energy consumption is equivalent to 30% of logistic activity
	Offshore construction and thermal energy conversion					

Over the past 40 years, the productivity of the inland towing industry has increased tremendously. The output of a typical barge tow has risen from 150,000 ton-miles per day to over 3 million and the average length of haul has increased from 50 to 375 miles. Large tows on the lower Mississippi are now on the order of 50,000 tons with towboats reaching 10,500 horsepower and the amount of cargo moved on the inland waterways of the United States has more than tripled since the 1930's.

This rate of growth is expected to slow dramatically over the next 20 years. Increasing environmental pressures and competitive railroad lobbying are currently stalling major public works projects such as the upgrading of Locks and Dam 26 on the Mississippi River and the Tennessee-Tombigbee project.

The capacity of the inland river system is expected to grow slowly. Major changes in the current operating constraints, such as maximum lock sizes of 1200 feet x 110 feet and minimum project depth of 9 feet are not expected.

Inland waterway user charges will become a reality by the year 2000. Impacts could result in a shift of up to 10 percent of the total ton-miles carried on the system to competing modes. However, it is felt that current barge rates have served to restrain the rise of competing rail rates. An inland waterway user charge will force a rise in barge rates which will be matched by a corresponding rise in competing rail rates. The overall impact of inland waterway user charges will, in all probability, be well within the range of error associated with cargo movement forecasts for the year 2000.

The current average tow, representing all cargo movements on the inland river systems was defined as:

- 1,350 horsepower towboat
- 7,714 tons of cargo
- 358 miles average haul.

Based on the expected slowdown in the growth of productivity on the inland rivers, the growth rates, shown in Table II-14, were used to project the average tow for the year 2000.

TABLE II-14
Expected Growth Rates for the Inland Rivers

Parameter	Parameter Value 1974 to 1976	Recent Historical Growth Rate Per Annum	Growth Rate 1974 - 2000 Per Annum	Parameter Value 2000
Average towboat	1,350 HP	2.9 %	2.00%	2,171 HP
Required HP/ton	.175 HP/ton	unknown	0.0%	0.175 HP/ton
Average haul distance	358 miles	0.83%	0.42%	396 miles

6. THE FISHING AND MISCELLANEOUS SECTOR

The U.S. commercial fishing fleet can be characterized as fragmented and dominated by single family, one boat operations. According to the National Marine Fisheries Service, the U.S. fishing fleet consists of over 15,000 vessels with capacities in excess of 5 net tons and more than 72,000 boats with capacities less than 5 net tons. The U.S. Coast Guard listing of fishing craft includes approximately 22,000 craft. Many fishing craft are registered with municipal or state agencies, and most small craft are not required to register at all. In 1973, the U.S. fishing fleet landed a catch of nearly 5 billion pounds of seafood.

According to the U.S. Coast Guard, there are approximately 300 miscellaneous or harbor service craft registered with that organization. This classification includes such craft as fireboats, ice breakers, pilot boats, police and patrol boats. Miscellaneous service craft were judged to be insignificant in determining energy consumption because these vessels are generally small in size and see limited duty in local harbor areas.

An examination of that portion of the U.S. fishing fleet that is registered with the U.S. Coast Guard resulted in the following average characteristics:

- Average engine size - 224 horsepower
- Average age - 22.6 years.

A further analysis produced the age distribution given in Table II-15.

TABLE II-15
Age Distribution of the U.S. Fishing Fleet

Horsepower Range	0 to 50	51 to 100	101 to 500	501 to 1000	1001 to 5000	5001 to 10,000
No. of vessels	695	3,402	17,424	677	237	2
Average horsepower	35	82	215	679	2,100	5,875
Average age	37.7	33.0	20.4	15.8	14.4	3.0
Percent age 0-19 years	13	17	53	64	69	100
Percent age 19-39 years	41	52	35	31	30	0
Percent age over 40	46	31	12	5	1	0

Source: U.S. Coast Guard, Vessel Registry File.

The analysis shown in Table II-15 underscores the fact that the U.S. fishing fleet is composed of older smaller vessels with vessels 19 years or older dominating the under 100 horsepower class. Caution must be exercised, however, as the U.S. Coast Guard vessel file contains approximately half the fishing vessels estimated by the National Fisheries Service, U.S. Department of Commerce.

Expected technological changes in the character of the fleet will be driven by the extension by the United States of its territorial claims to fishing privileges from 12 to 200 miles. Expected changes will include:

- Scrapping of the older, smaller vessels that are unable to work and maintain station out to 200 miles
- Replacement of the older vessels with larger vessels, capable of maintaining station for months and equipped with processing plants and refrigerated cargo holds.

It is expected that these projected changes will increase the amount of energy consumed by the U.S. fishing fleet by a factor of 3.

7. THE RECREATIONAL BOATING SECTOR

This sector consists of those small craft used exclusively for recreational purposes. The U.S. Coast Guard estimated that there were over 9 million recreational boats owned by Americans in 1975. Of these, more than 7 million were motor-powered boats.

Recreational boating statistics were subdivided into the following types of motorized boats:

- Canoe
- Houseboat
- Inboard
- Inboard/outboard
- Outboard
- Rowboat/jonboat
- Sailboat
- Other.

The latest comprehensive recreational boating survey* performed by the U.S. Coast Guard in 1973, identifies powerboats by type and region of the country.

In Volume II, an analysis of the operational parameters of the recreational sectors contained in the latest Coast Guard survey of recreational boating indicated that the average motor driven pleasure boat:

- Operated a total of 186.2 hours during 1973
- Consumed an average of 1.46 gallons of fuel per hour of use in 1973.

The total number of motor driven pleasureboats was estimated at 7.3 million units in 1975 with the percentage distribution of type of propulsion of 48 percent gasoline and 52 percent diesel.

The following trends are anticipated in the recreational boating sector through the year 2000:

- Increasing leisure time will tend to hold the amount of boat-hours per boat-year at current levels
- Increasing standards of living and personal disposable income will perpetuate the recent historical growth of the number of recreational boats.
- Greater emphasis on energy conservation and higher energy costs will lower both the average power levels and hence the average amount of fuel consumed per boat-hour and hold down any increase in the number of operating hours per boat-year.

Table II-16 gives the expected growth rates for the recreational boating sector.

TABLE II-16
Expected Growth Rates for the Recreational Boating Sector

Parameter	Parameter Value 1975	Recent Historical Growth Rate	Growth Rate 1974-2000	Parameter Value 2000
Number of boats	7.3 million	2.80%	2.00 %	12.0 million
Operating hrs/boat	142.6 hrs/hr	unknown	0.00 %	142.6 hrs/hr
Fuel consumption/hr	1.46 gal/hr	unknown	(1.00)%	1.12 gal/hr

* The National Boating Survey, U.S. Coast Guard, 1973.

III. CARGO MOVEMENTS AND ENERGY CONSUMPTION IN THE YEAR 2000

III. CARGO MOVEMENTS AND ENERGY CONSUMPTION IN THE YEAR 2000

The general method used to determine the amount of the energy required by the marine transportation sector relies on:

- Defining typical or generic ships
- Identifying cargo flows on various trade routes
- Calculating the amount of cargo carried and energy required by each generic ship making one round trip on each trade route
- Calculating the number of round trips required to carry the level of trade flowing on each trade route.

This chapter presents the development of cargo movements in the year 2000 for the following four shipping sectors:

- The foreign trade sector
  - Liners
  - Tramp
  - Dry bulk
  - Tankers
  - Passenger
- The Great Lakes sector
- The Coastal shipping sector
- The Inland sector.

Energy consumption calculations for the offshore, fishing and miscellaneous and pleasure sectors are based more on levels of activity rather than cargo movements.

The forecasted activity levels are described in Chapter II, however, the energy consumption calculations for all industry sectors are given below.

1. THE FOREIGN TRADE SECTOR

Cargo movements in the foreign trade sector were based on a U.S. Maritime Administration trade forecast.* This forecast contained specific projections, at the 3-digit schedule A and B commodity level, for each of MarAd's 63 trade routes. Many of these trade routes are quite minor, with insignificant amounts of tonnage moving over them. Forty-six of the 63 trade routes had projected total cargo movements for the year 2000 in excess of 1,000,000 long tons per year. Of the 46 trade routes with major cargo flows, 31 have been combined by the Maritime Administration into 27 essential trade routes, as described in Appendix B, Volume II.

The tonnage moving on the remaining 15 trade routes with significant cargo flows were then combined with one of the 27 essential trade routes having a similar round trip distance.

(1) Tonnage Movements for Liner, Tramp, Dry Bulk and Tankers

Each 3-digit commodity for the 46 trade routes was then classified according to the type of service that would normally carry the bulk of that commodity. Table III-1 presents this classification scheme for tanker, dry bulk and tramp classifications. All other commodities were classified as liner cargo. Total tons carried were then developed for each service classification and used as the expected level of cargo movement for each trade route for the year 2000.

For tanker crude imports, the MarAd forecast allocated approximately 100 percent of the cargo to 11 trade routes. Based on this percentage distribution, the level of imports projected by a recent MIT study** were substituted for the MarAd forecasts.

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* "The Long-Term Forecast of U.S. Foreign Waterborne Trade," by the 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 III-1
Classification of Three-Digit Schedule A & B
Commodity Codes by Service Type

Service	Commodity	
Tanker	331	Crude oil
	332	Petroleum products
	341	Natural gas
	512	Organic chemicals
Dry bulk	041	Wheat unmilled
	042	Rice milled & unmilled
	043	Barley unmilled
	044	Corn or maize unmilled
	045	Cereals NEC
	061	Sugar
	271	Fertilizers crude
	273	Stone sand & gravel
	274	Sulfur & unroasted iron pyrits
	276	Crude materials NEC
	281	Iron ores & concentrates
	283	Ores concentrates nonferrous
	321	Coal coke briquets
	513	Inorganic chemicals
	561	Fertilizers manufacturing
	661	Lime - cement
Tramp	081	Feeding stuff for animals
	221	Oilseeds, oil nuts
	242	Wood in the rough
	243	Wood shaped or simply worked
	251	Wood pulp or wastepaper
	282	Iron & steel scrap
	286	Uranium & thorium ores & conc.
	599	Chemical products NEC
	631	Wood veneers
	641	Paper, paperboard
	671	Pig iron
	672	Iron & steel primary forms
	673	Iron & steel shapes
	674	Iron & steel plates
	675	Iron & steel hoop strip
	676	Iron & steel rails
	677	Iron & steel wire
	678	Iron & steel tubs
	679	Iron & steel castings, forgings
	732	Passenger cars, trucks, buses

The annual tonnage derived for the year 2000 by service type, is shown in Table III-2.

TABLE III-2
Projected Cargo Movements for the Foreign Trade Sector by Service

Service	Cargo Movements (thousands of long-tons)			
	Year 2000	U.S. Flag Share	Year 1974	U.S. Flag Share
Liner	148,900	40.0%	51,500	30.0%
Tramp	219,000	4.0%	169,000	3.8%
Dry bulk	502,400	10.0%	147,900	1.4%
Tanker	703,300	10.0%	297,500	7.1%
Total	1,573,600	12.0%	665,900	6.8%

Source: U.S. Maritime Administration Cargo Projections and Booz, Allen & Hamilton.

(2) Energy Consumption in the Foreign Trade Sector

The cargo flows for each of the 27 trade routes developed above were coded and substituted in the Marine Transportation Energy Model, developed in Task I, to simulate cargo movements and calculate energy required for the marine transportation industry. The generic ships developed in Chapter II were substituted for those 1974 vessels contained in the model and the energy required by the foreign trade sector was calculated. The results are presented in Table III-3 on the following page.

2. THE GREAT LAKES SECTOR

Cargo flows in the Great Lakes for the year 2000 were developed for each of the following ship types:

- U.S. flag dry bulk (diesel)
- U.S. flag dry bulk (steam)
- Canadian flag dry bulk (diesel)
- Canadian flag dry bulk (steam)
- U.S. flag tug/barge
- Canadian flag tug/barge.

TABLE III-3
Energy Consumption in the Foreign Trade Sector
1974 - 2000

Service Type	Energy Requirements (quads)			
	1974		2000	
Liner	0.530	22%	1.245	22.3%
Tramp	1.080	46%	2.469	44.2%
Dry bulk	0.330	14%	0.932	16.6%
Tanker	0.330	14%	0.812	14.5%
Passenger	0.080	4%	0.134	2.4%
Total	2.360	100%	5.592	100.0%
U.S. flag consumption	0.215	9%	0.771	13.8%

Source: Booz, Allen & Hamilton.

Domestic cargo movements for the year 2000 were based on a 1974 MarAd funded report* and translake movements (between the United States and Canada) were developed from the previously cited 1977 MarAd foreign trade forecasts.

(1) Tonnage Movements for the Great Lakes Sector

The domestic cargo movements from Table III-4 were then allocated as follows:

- U.S. flag dry bulk movements - 97 percent** of all coal, mining products, cash grains and iron ore. These were further allocated on a 50/50 basis to steam and diesel powered Great Lakes bulk carriers.

- U.S. flag tug/barge movements - 3 percent of all coal, mining products, cash grains and iron ore, plus all other movements.

* "Domestic Waterborne Shipping Market Analysis," A.T. Kearney, Inc., February 1974, prepared for the U.S. Maritime Administration.

** Historical split, based on "Domestic Waterborne Trade of the United States," U.S. Department of Commerce, Maritime Administration, 1975.

TABLE III-4
Great Lakes Tonnage Movements
1974 - 2000

Commodity	Projections Great Lakes
Coal	69,000
Mining products	63,000
Fuels & lubricants	11,000
Durable manufactures	15,000
Chemicals	2,000
Crude oil & natural gas	-
Cash grains	4,000
Primary iron & steel	3,000
Agricultural products	-
Grain mill products	-
Iron ore	152,000
Nondurable manufacturing	1,000
Paper	4,000
Fabricated metal products	-
Metal ores	-
Lumber	1,000
Nonferrous primary metals	-
Raw & refined sugar	-
Canned fruits & vegetables	-
Total 2000	325,000
Total 1974	175,310

Translake movements were projected at the 3-digit schedule A and B commodity level and were grouped into three types:

- Dry bulk movements - 42,036,960 short tons
- Liquid bulk movements - 3,106,000 short tons
- All other - 4,837,000 short tons.

These movements were allocated as follows:

- Dry bulk - 90 percent Canadian flag and 10 percent U.S. flag dry bulk carriers and split 50/50 between diesel and steam propulsion

- Liquid bulk and all other movements were allocated to the U.S. and Canadian flag tugs on a 50/50 basis.

These cargo movements were then combined, as shown in Table III-5.

TABLE III-5
Cargo Projections Great Lakes Sector (2000)
(short tons)

Flag	Vessel Type	Tons Moved
United States	Dry bulk (steam)	141,000,000
	Dry bulk (diesel)	141,000,000
	Tug/barge	51,000,000
Canadian	Dry bulk (steam	19,000,000
	Dry bulk (diesel)	19,000,000
	Tug/barge	4,000,000

(2) Energy Consumption for the Great Lakes Sector

Based on these cargo movements, an average haul distance of 540 miles* and the generic vessels defined in Chapter II, the energy consumption of the Great Lakes sector is given in Table III-6.

TABLE III-6
Energy Consumption in the Great Lakes Sector
1974 - 2000

Vessel Type	Flag	Energy Requirements (quads)			
		1974		2000	
Dry bulk	United States	0.036	69%	0.080	80%
	Canadian	0.008	15%	0.010	10%
Tanker	United States	0.002	4%	0.000	0%
	Canadian	0.003	6%	0.000	0%
Tug	United States	0.001	2%	0.010	10%
	Canadian	0.002	4%	0.001	0%
Total		0.052	100%	0.101	100%

* U.S. Army Corps of Engineers, "Waterborne Commerce of the United States," 1974.

3. THE INLAND WATERWAYS SECTOR

Cargo movements for the year 2000 were based on the 1974 MarAd funded domestic trade forecast* and the changes in the operating profiles were drawn from Chapter II.

(1) Tonnage Movements for the Inland Waterways Sector

The cargo movements, shown in Table II-7, are taken from the A.T. Kearney report referenced below. This growth in tonnage is equivalent to a compound annual growth rate of 5 percent. Based on the waterborne commerce statistics, the Army Corps of Engineers reports a recent (1972 to 1974) growth rate of 3 percent per annum. For the purposes of this analysis, the growth rate for total inland tonnage is taken as one-half of the recent historical growth rate, or 1.5 percent per annum. The rational for limiting the growth to 1.5 percent per annum is due to the inherent constraints placed on tow size by channel depths and lock dimensions, as discussed in Chapter II.

(2) Energy Consumption for the Inland Waterway Sector

Based on the tonnage movements from Table III-7, and the generic vessel and operational profile given in Table II-14, the expected energy consumption is shown in Table III-8.

TABLE III-8
Energy Consumption in the Inland Waterways Sector
1974 - 2000

Energy Requirements (quads)			
1974		2000	
Energy	Percent of Total Industry Consumption	Energy	Percent of Total Industry Consumption
.089	3.1	.100	1.5

* "Domestic Waterborne Shipping Market Analysis," A.T. Kearney, Inc., February 1974, prepared for the U.S. Maritime Administration.

TABLE III-7
Inland Waterway Tonnage Movements
1974 - 2000
(in thousands of short-tons)

Commodity	Inland
Coal	319,020
Mining products	380,055
Fuels & lubricants	114,893
Durable manufactures	181,502
Chemicals	275,742
Crude oil & natural gas	61,058
Cash grains	122,740
Primary iron & steel	116,420
Agricultural products	46,017
Grain mill products	34,978
Iron ore	45,861
Nondurable manufacturing	24,915
Paper	51,129
Fabricated metal products	22,667
Metal ores	10,533
Lumber	18,006
Nonferrous primary metals	13,396
Raw & refined sugar	8,254
Canned fruits & vegetables	5,926
A.T. Kearney projected total 2000	1,853,112
Total 1974	599,000
Implied annual growth rate	4.4%
Recent annual growth rate	3.0%
Growth rate selected 1974-2000	1.5%
Annual tonnage 2000	789,000

4. THE COASTAL SHIPPING SECTOR

Coastal tonnage is expected to grow significantly due to shipments of Alaskan crude oil. In addition, as mentioned in Chapter II, the growth of coastal feeder systems is also expected. The 1974-2000 projections of tonnages by A.T. Kearney, as shown in Table III-9, has an implied annual growth rate of approximately 8 percent. Even with the expected growth of the Alaskan crude trade, this rate of growth was considered excessive. By the year 2000, distribution of Alaskan crude is expected to be by pipeline from the west coast with the marine leg from Valdez to either Washington or California.

TABLE III-9
A.T. Kearney Coastal Tonnage Projections
1974 - 2000
(in thousands of short-tons)

Commodity	Coastal
Coal	56,152
Mining products	37,082
Fuels & lubricants	1,065,031
Durable manufactures	94,492
Chemicals	66,840
Crude oil & natural gas	162,381
Cash grains	2,946
Primary iron & steel	3,017
Agricultural products	1,805
Grain mill products	851
Iron ore	10
Nondurable manufacturing	3,885
Paper	1,517
Fabricated metal products	1,445
Metal ores	25
Lumber	6,659
Nonferrous primary metals	309
Raw & refined sugar	6,906
Canned fruits & vegetables	3,794
A.T. Kearney projected total 2000	1,515,147
Total 1974	213,000
Implied annual growth rate	7.8%

The A.T. Kearney report also projected an average annual capacity growth rate for the various vessel types of:

- Tankers - 1.7 percent
- Tug/barges - 2.6 percent
- Other - 3.2 percent

over the 1971 to 2000 time period. Updating the growth rates to 1974 in order to account for scrapings and new constructions in the 1971 to 1974 period, yields expected annual capacity growth rates of:

- Tankers - 2.4 percent
- Tug/barge - 2.8 percent
- Other - 2.0 percent.

For the purpose of this analysis, these annual growth rates were applied to the annual ton-miles carried by these vessel types. The average length of haul was kept constant. Tonnage movements in the coastal sector for the year 2000 are given in Table III-10.

TABLE III-10
Coastal Tonnage Movements
1974 - 2000
(in millions of long tons)

Vessel Type	Tonnage Movements	
	1974	2000
Tanker	144	267
Tug/barge	53	109
Other	16	27
Total	213	403

(1) <u>Energy Consumption for the Coastal Shipping Sector</u>

Based on the tonnage movements from Table III-10, and the generic vessels and operating profiles developed in Chapter II, the expected energy consumption for the coastal shipping sector in the year 2000 is shown in Table III-11.

TABLE III-11
Energy Consumption for the Coastal Shipping Sector

Vessel Type	Energy Requirements (quads)			
	1974	Percent	2000	Percent
Tanker	.071	63	.140	57
Tug/barge	.020	18	.040	16
Other	.021	19	.066	27
Total	.112	100%	.246	100%

5. THE OFFSHORE SECTOR

Based on the generic vessels and operating profiles developed in Chapter II and shown in Table II-13, the energy consumption of the offshore industry sector for the year 2000 is given in Table III-12.

TABLE III-12
Energy Consumption in the Offshore Sector

Vessel Type	Energy Consumption (quads)	
	1974	2000
Drilling rigs	.027	.070
Crew boats Tugboats Tug/supply boats Supply boats	.026	.095
Construction, offshore thermal energy conversion & deep ocean mining	.011	.028
Total	.064	.200

6. THE FISHING, MISCELLANEOUS AND PLEASURE CRAFT SECTORS

In Chapter II, it was estimated that the fishing and miscellaneous sectors would increase their energy consumption by a factor of three by the year 2000. The pleasure craft sectors operating profiles were estimated to change to:

- Number of craft - 12 million
- Operating hours per year per craft - 142.6 hours
- Fuel consumption - 1.12 gal/hour
- Fuel type - 50/50 split between gasoline and diesel.

Based on these parameters, the expected energy consumption for these sectors is shown in Table III-13.

TABLE III-13
Energy Consumption in the Fishing, Miscellaneous and Pleasure Craft Sectors
1974 - 2000

Industry Sector	Energy Consumption (quads)	
	1974	2000
Fishing and miscellaneous	0.032	0.100
Pleasure craft	0.225	0.300

7. ENERGY CONSUMPTION OF THE MARINE TRANSPORTATION INDUSTRY

Utilizing the latest annual trade statistics available (1974), it was estimated that the marine transportation industry currently consumes 2.9 quads annually. Table III-14 summarizes the industry's productive activity and energy consumption developed above. These energy consumption figures reflect 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.

TABLE III-14
Productivity and Energy Consumption of the Marine Transportation Industry

Industry Sector	1974			2000		
	Long Tons of Cargo Moved (millions)	Energy Consumed (quads)	%	Long Tons of Cargo Moved (millions)	Energy Consumed (quads)	%
Foreign trade	654.9	2.360	82.1	1,570.0	5.600	84.3
Great Lakes	175.3	0.052	1.8	320.0	0.100	1.5
Inland waterways	535.8	0.089	3.1	790.0	0.100	2.2
Coastal	213.0	0.112	3.9	400.0	0.300	3.8
Offshore	-	0.006	0.2	-	0.200	2.9
Pleasure craft	-	0.225	7.8	-	0.300	3.8
Fishing and miscellaneous	-	0.032	1.1	-	0.100	1.5
Total	1,579.0	2.876	100.0	3,080.0	6.700	100.0

Source: Booz, Allen & Hamilton

Prior to the Arab oil embargo in 1974, which led to large increases in world fuel prices, the question of fuel consumption rates and their reduction 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, our estimates of the energy consumption of the industry carry a degree of uncertainty. The methodology developed to calculate energy consumption for both 1974 and the year 2000 required a number of assumptions. These major assumptions were:

- 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. In reality, vessels frequently deviate from these assumptions.

- 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* 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
  - Season of the year
  - Direction of the trade flow
  - Shipping technology used
  - Depth of water at pier side

- In almost all bulk trades and to a lesser degree, liner trades, the trade flows are not balanced as far as tonnages moving in both directions. In the bulk trades, vessels typically spend half their life in ballast. The extent to which the search for back haul cargoes effect operating profiles and energy consumption is unknown.

- 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

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* 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.

extent to which operating profiles identified in 1973 accurately represent those occurring in 1975, is unknown.

- 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.

These factors effect the calculated marine transportation energy consumption figure of 2.9 quads for 1974. It is estimated that the uncertainty associated with the estimate of total industry energy consumption could reach plus or minus 25 percent. The projected energy of 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.

IV. IDENTIFICATION AND EVALUATION OF POTENTIAL RESEARCH AND DEVELOPMENT PROGRAMS

IV. IDENTIFICATION AND EVALUATION OF POTENTIAL RESEARCH AND DEVELOPMENT PROGRAMS

The energy-related technology base of the commercial marine transportation industry is composed of the following five generic technology areas:

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

The analysis described in this chapter focuses on the identification and evaluation of programs in the first four areas. Programs addressing alternative and contingency fuels for the commercial maritime transportation industry are the subject of two other studies and are discussed only briefly in this report.

Fifteen existing and proposed research and development program areas were identified in the four generic technology areas. Due to the diversity of vessel types and operational profiles that exist in the commercial marine transportation industry, none of the programs identified has across-the-board applications. As a result, the economic and energy impact and technology risk assessment was structured around five separate steps:

- Step 1 — Identify potential program areas and applications for each from among the generic ships contained in the maritime transportation energy model

- Step 2 — Determine changes in first costs and operational expenses associated with the introduction of each program area into the existing U.S. flag fleet and determine the impact on required freight rates using current dollars

- Step 3 — Calculate the energy impact associated with the introduction of each program area in the U.S. flag fleet for activity levels and cargo movements estimated for 1974 and 2000

- Step 4 — Determine the category of technological risk associated with each program area

- Step 5 — Estimate costs of ERDA program actions in each of the program areas based on current dollars.

Key to the analysis in steps one through 3 is the use of the Marine Transportation Energy Model (MTEM), developed in Task I. This model simulates the United States maritime transportation industries activities for two years, 1974 and 2000. Cargo movements are specified for 27 foreign and 16 domestic trade routes. A series of 35 generic vessels was developed and are contained in the model. Each of these vessels is described in terms of application to trade routes, speed, horsepower, fuel consumption, and cargo carrying capacity, as shown in Chapter II.

Each program area to be analyzed can be introduced into this generic U.S. flag fleet by varying the appropriate operating parameters. The operations of this "new" fleet were then simulated with the model and changes in the energy consumption patterns and economic performance determined.

1. STEP 1 — FIFTEEN PROGRAM AREAS WERE IDENTIFIED AND THEIR AREA OF APPLICATIONS DETERMINED

Fifteen program areas were identified in the four generic technology categories:

- Main propulsion plants
  - High pressure/temperature reheat steam plants (HPTRS)
  - Slow speed diesels (SSD)
  - Diesel bottoming cycles (DBC)
  - Adiabatic diesels (AD)
  - Heavy duty gas turbines and combined cycles (GTCC)
  - Closed cycle gas turbines (CCGT)

- Propulsors
  - Contra-rotating propellers (CR)
  - Propellers in nozzels (PIN)
- Hydrodynamics
  - Submerged air cushions (SAC)
  - Cutaway hulls (CH)
  - Tunnel sterns (TS)
  - Hull maintenance and smoothing (HMS)
- Vessel operations
  - Vessel routing (VR)
  - Plant tuning (PT).

These 15 program areas were then applied to the series of 35 generic vessels described in Tables IV-1 and IV-2. These tables also identify the application of each program area by industry sector and generic vessel type for 1974 and 2000, respectively.

The applicability of each program area was based on engineering and technical considerations. These considerations are discussed in the appendices in Volume IV that address each program area. Each program area is briefly discussed in the following sections.

(1) <u>High Pressure/Temperature Reheat Steam Plants (HPTRS)</u>

Reheat steam main propulsion plants offer a potential for energy conservation. The current state-of-the-art will allow production of reheat steam plants with steam conditions of 1450 PSIG and 950^{o}F with one stage of reheat to 950^{o}F. Fuel rates ranging from .46 lb/SHP-Hr to .41 lb/SHP-Hr of residual fuel are possible with this type of plant.

Reheat steam plants with initial steam conditions of 2400 PSIG and 1050^{o}F with one stage of reheat to 1050^{o}F are now being proposed. Fuel rates of .42 lb/SHP-Hr to .37 lb/SHP-Hr using residual fuel are possible with these plants. As shown in Table IV-2, the 2400 PSIG/1050^{o}F/1050^{o}F reheat steam plants were applied to all generic U.S. flag vessels having installed horsepower levels greater than 30,000 SHP. A more detailed

TABLE IV-1
Application of Research and Development Programs to Generic U.S. Flag Vessels for the Year 1974

Industry Sector	Vessel Type	DWT	HP	Speed Knots (mph)	Main Propulsion Plants: HPTRS	SSD	DBC	AD	NAHBE	GTCC	CCGT	Propulsors: CR	PIN	Hydrodynamics: SAC	CH	TS	HMS	Vessel Operations: VR	PT
Foreign Trade	Container	12,000	8,000	16													•	•	•
	Container	16,500	17,000	20		•				•							•	•	•
	Container	18,500	18,000	20		•				•							•	•	•
	Container	23,000	28,000	23		•				•	•	•					•	•	•
	Ro/Ro	10,000	11,000	24															
	Ro/Ro	16,500	22,000	22.5						•	•	•					•	•	•
	Ro/Ro	18,000	25,000	22.5															
	Barge	33,000	33,000	22	•					•	•	•					•	•	•
	Carriers	42,000	42,000	22	•					•	•	•					•	•	•
	Break Bulk	13,500	14,500	19		•											•	•	•
	Tramp	8,400	5,000	14													•	•	•
	Dry Bulk	20,000	8,000	15												•	•	•	•
	Dry Bulk	30,000	10,000	15												•	•	•	•
	Dry Bulk	40,000	11,000	15												•	•	•	•
	Tanker	20,000	7,000	14												•	•	•	•
	Tanker	40,000	9,000	14												•	•	•	•
	Tanker	65,000	14,000	15		•										•	•	•	•
	Tanker	80,000	16,000	15		•				•						•	•	•	•
	Tanker	150,000	20,000	15	•	•				•			•	•	•	•	•	•	•
Inland Rivers	Tow Boat		1,350	(7.2)			•	•	•										
Coastal	Tanker	40,000	12,000	15		•										•	•		•
	Tug		2,000	8			•	•	•										
	Freighter	7,800	6,000	15.5															•
Great Lakes	Tug		900	(9)			•	•	•										
	Dry Bulk	16,700	4,860	(12)															
	Dry Bulk	14,900	4,180	(12)			•	•											
	Dry Bulk	13,100	2,550	(12)															
	Tanker	6,576	1,925	(12)															
	Tanker	2,676	1,410	(12)			•	•	•										
Offshore	Tug		4,000	14			•	•	•										
	Tug/supply		3,300	15			•	•	•										
	Supply		3,300	13			•	•	•										
	Crewboat		1,800	25			•	•	•										
Pleasure	None							•	•										
Fishing & Misc.	None							•	•										

TABLE IV-2
Application of Research and Development Programs to Generic U.S. Flag Vessels for the Year 2000

Industry Sector	Vessel Type	DWT	H.P.	Speed Knots (mph)	Fuel Rate (16/SHP-HR)	Deadweight Utilization Factor	Program Areas														
							Main Propulsion Plants							Propulsors		Hydrodynamics				Vessel Operations	
							HPTRS	SSD	DBC	AD	NAHBE	GTCC	CCGT	CR	PIN	SAC	CH	TS	HMS	VR	PT
Foreign Trade	Container	14,800	9,000	17.6	.37	.50			●										●	●	
	Container	20,000	24,000	22	.37	.50			●				●	●					●	●	
	Container	23,000	25,000	22	.37	.50			●				●	●					●	●	
	Container	28,000	40,000	25	.47	.50	●	●				●							●	●	●
	Ro/Ro	12,500	22,000	25	.37	.33			●			●	●	●					●	●	
	Ro/Ro	20,000	35,000	25	.47	.33	●	●				●	●	●					●	●	●
	Ro/Ro	22,000	36,000	25	.47	.33	●	●				●	●	●					●	●	●
	Barge	38,000	35,000	22	.47	.33	●	●				●	●	●					●	●	●
	Carriers	49,000	39,000	22	.47	.60	●	●				●	●	●					●	●	●
	Break Bulk	25,800	26,000	22	.37	.40			●				●	●					●	●	
	Tramp	11,760	7,000	15	.37	.40			●										●	●	
	Dry Bulk	30,000	10,000	15	.37	.96			●										●	●	
	Dry Bulk	45,000	12,000	15	.37	.96			●										●	●	
	Dry Bulk	60,000	13,500	15	.37	.96			●										●	●	
	Tankers	20,000	7,000	14	.37	.80			●										●	●	
	Tankers	40,000	9,000	14	.37	.80			●										●	●	
	Tankers	65,000	14,000	15	.37	.80			●										●	●	
	Tankers	150,000	20,000	15	.47	.80		●				●	●	●	●	●	●	●	●	●	●
	Tankers	300,000	36,000	15	.47	.80	●	●				●	●	●	●	●	●	●	●	●	●
Inland Rivers	Tug	12,061	2,171	(7.2)	.37	1.00			●	●	●										
Coastal	Tanker	44,000	12,500	(15)	.37	.80			●								●	●	●		
	Tug	13,000	2,250	(8)	.37	1.00			●	●	●										
	Other	16,500	22,000	(22.5)	.47	.33		●						●					●		
Great Lakes	Dry Bulk	30,000	10,000	(11)	.47	.96	●	●													
	Dry Bulk	30,000	10,000	(11)	.37	.96			●	●	●										
	Tug	11,000	3,000	(9)	.37	1.00			●	●	●										
Offshore	Tug				.37				●	●	●								●		
	Tug/Supply				.37				●	●	●								●		
	Supply				.37				●	●	●								●		
	Crewboat				.37				●	●	●								●		
Pleasure	None									●	●										
Fishing & Misc.	None				.37					●	●								●		

discussion of this program area is contained in Appendix A, Volume IV.

(2) Slow Speed Diesels (SSD)

Slow speed diesels are the predominant choice for main propulsion plants worldwide. The primary advantage offered by slow speed diesels is their low brake specific fuel consumption of .35 to .37 lb/BHP-Hr of residual fuel. Until recently, this type of main propulsion plant was not available in the United States. In this evaluation, slow speed diesels were applied to all generic U.S. flag vessels having installed horsepower levels greater than 12,000 SHP. A more detailed description of this program area is contained in Appendix A, Volume IV.

(3) Diesel Bottoming Cycles (DBC)

Diesel bottoming cycles offer a potential for energy conservation through the recovery of energy lost through the exhaust gases and cooling water. The energy recovery potential of diesel bottoming cycles is on the order of 15 to 18 percent. In our analysis, diesel bottoming cycles were applied to all generic U.S. flag vessels that currently use medium speed diesels for their main propulsion plants. A more detailed description of this area is contained in Appendix A, Volume IV.

(4) Adiabatic Diesels (AD)

The adiabatic diesel is an engine with true adiabatic (constant heat) compression of the fuel air mixture in a diesel cycle. The potential for energy conservation of this program is a brake specific fuel consumption of .28 lb/BHP-Hr of diesel fuel. Adiabatic diesels were applied to all generic U.S. flag vessels that currently use medium-speed diesels for their main propulsion plants. A more detailed description of this program area is contained in Appendix A, Volume IV.

(5) Naval Academy Heat Balance Engine (NAHBE)

The Naval Academy heat balance engine is based on nonadiabatic compression of the fuel air mixture in an Otto cycle. The concept is based on using retained heat and shock waves to enhance the combustion process. Improvements in the thermal efficiency of an internal combustion engine of 10 percent at full load have been claimed. The Naval Academy Heat Balance Engine was applied to all generic U.S. flag vessels that currently use medium speed diesels for their main propulsion plants and have installed horsepower levels of less than 4000 BHP. A more detailed description of this program area is contained in Appendix A, Volume IV.

(6) Heavy Duty Gas Turbines and Combined Cycles (GTCC)

Marine applications of industrial type heavy duty gas turbines capable of burning heavy residual fuels have recently been developed and installed in a few oceangoing vessels. Use of heavy duty gas turbines with steam bottoming cycles have a potential for specific fuel consumption rates of .40 lb/SHP-Hr to .36 lb/SHP-Hr. Heavy duty gas turbine and combined cycles were applied to all generic U.S. flag vessels whose installed horsepower level was greater than 45,000 SHP and all Ro/Ro vessels regardless of horsepower level. A more detailed description of this program area is contained in Appendix A, Volume IV.

(7) Closed Cycle Gas Turbines (CCGT)

Closed cycle gas turbines differ from the open cycles in that the combustion gases are not used in the power cycle. They are used to heat a working fluid that is expanded through a power turbine. This gives the closed cycle gas turbine a true multifuel capability. Specific fuel consumption rates of .36 to .35 lb/SHP-Hr of residual fuel are currently within the state-of-the-art. Closed cycle gas turbines were applied to all generic U.S. flag vessels having installed horsepower levels greater than 20,000 SHP. A more detailed discussion of this program area is contained in Appendix A, Volume IV.

(8) Contra-rotating Propellers (CR)

Contra-rotating propellers are two propellers, one located directly behind the other but rotating in the opposite direction. Increases in propulsive efficiencies of 7 to 9 percent are possible. Contra-rotating propeller systems were applied to all generic U.S. flag liner vessels having installed horsepower levels greater than 20,000 SHP. A more detailed discussion of this program area is contained in Appendix B, Volume IV.

(9) Propellers in Nozzels (PIN)

Locating a propeller within a nozzle increases the effective thrust of a highly loaded propeller. Increases in the propulsive efficiency of low speed full hull forms of 6 to 15 percent have been demonstrated. Propellers in nozzles were applied to generic U.S. flag tankers larger than 150,000 DWT. A more detailed discussion of this program area is contained in Appendix B, Volume IV.

(10) Submerged Air Cushions (SAC)

Submerged air cushions replace the hull/water interface on the bottom of a vessel's hull with an air/water interface. This effectively eliminates the frictional resistance associated with that portion of the hull. Reduction in required horsepower levels for full slow hull forms are on the order of 16 to 20 percent. Submerged air cushions were applied to generic U.S. flag tankers larger than 150,000 DWT. A more detailed discussion of this program area is contained in Appendix C, Volume IV.

(11) Cutaway Hulls (CH)

The cutaway hull decreases the displacement of a tanker's hull below the ballast waterline. The expected gains are either an increase in speed in the ballast condition or a decrease in required horsepower to maintain the same speed. The cutaway hull was applied to generic U.S. flag tankers larger than 150,000 DWT. A more detailed discussion of this program is contained in Appendix C, Volume IV.

(12) Tunnel Sterns (TS)

Tunnel sterns are used to entrain water and lift it up and over the top of a large slow turning propeller.

Net propulsive efficiency improvements on the order of 5 percent have been estimated for full slow hull forms. Tunnel sterns were applied to all generic U.S. flag bulk carriers. A more detailed discussion of this program area is contained in Appendix C, Volume IV.

(13) Hull Maintenance and Smoothing (HMS)

Inhibiting the degradation in propulsive efficiency that occurs with fouling and corrosion offers an energy conservation potential on the order of 6 percent for oceangoing vessels. Hull maintenance and smoothing programs were applied to all generic U.S. flag oceangoing vessels. A more detailed discussion of this program area is contained in Appendix C, Volume IV.

(14) Vessel Routing (VR)

Weather routing of vessels to minimize operational disruptions of those oceangoing vessels that are tied to schedules offers a modest energy use and cost reduction potential. A more detailed discussion of this program area is contained in Appendix D, Volume IV.

(15) Plant Tuning (PT)

A maintenance and propulsion plant performance monitoring program can reduce fuel consumption by operating a main propulsion plant at its design conditions and minimizing auxiliary loads. Fuel savings on the order of 5 percent have been demonstrated. Plant tuning programs were applied to all generic U.S. flag steam powered vessels for the 1974 cargo movements. Plant tuning programs were not applied to cargo movements for the year 2000, as plant upkeep programs not now existing were assumed to be part of the projected technology base. A more detailed discussion of this program area is contained in Appendix D, Volume IV.

2. STEP 2 — DETERMINATION OF ECONOMIC IMPACTS

Operating and cost parameters for 1974 were developed for each generic vessel type. These baseline parameters are given in Volume IV. Cost impacts associated with the implemention of each program area were assigned to the following two categories:

- Changes to acquisition costs
- Changes to daily operating costs
  - Wages
  - Stores and subsistance
  - Maintenance and repair
  - Insurance.

Specific changes to particular cost categories for each program area are contained in the appendices. The calculation of the economic impacts associated with these cost changes was accomplished by changing the baseline cost parameters of the MTEM.

3. STEP 3 — QUANTIFICATION OF ENERGY IMPACTS

Energy impacts were calculated using the MTEM. Parameters affecting the:

- Required horsepower
- Specific fuel consumption
- Fuel type

were modified to reflect changes occurring as a result of implementation of each program. Specific changes reflecting each program area are given in the appendices to Volume IV.

4. STEP 4 — CATEGORIZATION OF TECHNOLOGICAL RISK

The degree of technological risk associated with each program was determined based on a subjective analysis that included:

- The degree to which commercialization already exists
- Estimates by individuals involved in current research and development programs.

Each program was assigned one of the following risk factors: low, medium or high. A low risk category assignment was made when some degree of commercialization currently exists. A medium risk category assignment was made when the current state-of-the-art was judged to have advanced to that point where the next most logical step is the development of prototype components followed by an installation and demonstration project. A high risk category assignment was made when the current state-of-the-art was judged to be in the developmental engineering state, or where prototype equipment is currently being developed for land based installation and consideration of a marine application should wait until initial development work and land based demonstration projects are completed.

5. STEP 5 — ESTIMATE COSTS OF ERDA FUNDED PROGRAMS

Estimates of funding requirements, durations, and earliest possible start dates for each of the 15 program areas were made.

For those program areas classed as high technological risk items, the level of funding and time durations are those that would bring the technologies involved to a point where a decision could be made as to the feasibility of continuing to the demonstration project stage. For those program areas classed as medium technological risk items, the estimates reflect what is necessary to fund demonstration projects. Low risk program funding estimates reflect estimated funding requirements necessary to resolve operational questions that are currently inhibiting full acceptance by the industry.

The results of the analysis and the conclusions and recommendations are presented below.

6. RESULTS OF THE ANALYSIS

The results of the analysis described above, are presented in Table IV-3. Two general conclusions can be drawn from these results.

(1) All Program Areas Identified Show a Net Economic Benefit Based on 1974 Costs

As shown in columns three and four of Table IV-3, the introduction of each of the program areas into the current U.S. flag fleet resulted in a reduction of the required freight rate (RFR) for all applications.

The percentage reduction varied due to applications on different vessels and trade routes. The assumption upon which the economic analysis were based are considered conservative:

TABLE IV-3
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	1.7	8.6	5.5	12.7	FY-78	2	0.500	–	–
LOW	PT	0.3	2.1	1.4	0.0	FY-78	–	0.000	–	–
LOW	VR	0.0	0.0	0.0	0.0	FY-78	–	0.000	–	–
MEDIUM	OBC	6.7	10.2	3.6	11.2	FY-78	2	UNKNOWN	3.000	–
MEDIUM	HMS	0.4	5.5	3.1	6.2	FY-78	1	"	0.250	–
MEDIUM	GTCC	0.3	9.7	1.2	2.9	FY-78	2-3	"	4.000	–
MEDIUM	TS	0.2	2.3	0.6	0.9	FY-78	1	"	0.300	–
MEDIUM	CR	1.8	3.4	0.5	3.1	FY-78	2-3	"	4.000	–
MEDIUM	HPTRS	4.5	9.3	0.4	2.8	FY-78	10	"	3.000	–
MEDIUM	PIN	0.9	0.9	0.0	0.3	FY-78	2-3	"	1.000	–
MEDIUM	CH	0.1	0.1	0.0	1.4	FY-78	1	"	0.300	–
HIGH	AD	7.5	18.3	10.2	6.7	FY-80	5	"	UNKNOWN	2.000
HIGH	NAHBE	5.6	6.7	5.4	2.9	FY-79	3	"	"	1.000
HIGH	CCGT	6.4	11.4	1.4	2.7	FY-80	6-7	"	"	50.000
HIGH	SAC	1.9	1.9	0.0	0.7	FY-78	1	"	"	0.400

Source: Booz Allen & Hamilton.

- Residual and diesel fuel priced during 1974 at $13.02/bbl
- 20-year lifetime
- Straight line depreciation
- 5 percent escalation in fuel costs per year.

Of the 15 program areas considered, three programs:

- Diesel bottoming cycles
- Adiabatic diesels
- Closed cycle gas turbines

showed the greatest percentage reduction in RFR.

(2) Five Program Areas Have Energy Reduction Potential Greater Than 5 Percent in Either 1974 or 2000

Columns five and six of Table IV-3 show the potential for energy reduction in the event the programs are applied to the U.S. flag vessel types in accordance with Tables IV-1 and IV-2.

Five program areas had energy reduction potentials greater than 5 percent in either 1974 or 2000:

- Slow speed diesels (SSD)
- Diesel bottoming cycles (DBC)
- Hull maintenance and smoothing (HMS)
- Adiabatic diesels (AD)
- Naval Academy heat balance engine (NAHBE).

The energy conservation potential is defined as the difference between the energy required to transport the base year cargo movements, either 1974 or 2000, with the generic fleet defined for that year and the energy required to transport the same cargo movements with a modified fleet reflecting the introduction of the applicable R&D programs.

7. THREE PROGRAM AREAS ARE RECOMMENDED FOR FUNDING IN FY78

Three program areas are recommended for funding in FY78. Based on the energy savings potential identified in Table IV-3, the program areas in:

- Slow speed diesels (SSD)
- Diesel bottoming cycles (DBC)
- Hull maintenance and smoothing (HMS)

offer the greatest potential for future energy savings. All three programs are complementary and potential applications exist in all seven industry sectors, as shown in Table IV-4.

TABLE IV-4
Applications of Recommended Program Areas

Program Areas	Industry Sector: Foreign Trade	Great Lakes	Inland Rivers	Coastal	Offshore	Pleasure	Fishing & Misc.
Slow Speed Diesels	•	•		•			
Diesel Bottoming Cycles	•	•	•	•	•	•	•
Hull Maintenance and Smoothing	•	•	•	•	•		•

The elements of each of these program areas are discussed below.

(1) Recommended Program Elements in the Slow Speed Diesel Program Area

Two topics in the slow speed diesel program area require further investigation.

The first is an investigation into the interrelationship of fuel quality, engine reliability, maintenance programs and fuel additives. The second is an evaluation of the potential for and methods to prevent cold end corrosion in the exhaust waste heat recovery units due to operation of slow speed diesels on heavy residual fuels. Costs associated with studies of this type should not exceed $250,000 each.

(2) 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. We 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 $40 to $50 thousand.

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

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

It is expected that this demonstration project would span approximately two years and cost approximately $2.5 to $3.1 million.

(3) Recommended Program Elements in the Hull Maintenance and Smoothing Program Area

The Society of Naval Architects and Marine Engineers has recommended that additional research be undertaken to:

- Develop standard measurement techniques and equipment to describe hull surface profiles. These should be able to be used underwater.

- Correlate in-service speed losses with surface roughness, time and operating and dry dock costs.

- Develop advanced hull and propeller maintenance procedures to reduce drag more effectively than currently available surface preparation, maintenance and cleaning methods.

Based on the recommendations of the Society of Naval Architects and Marine Engineers, an initial assessment of current maintenance procedures, their costs and effectiveness is needed prior to funding additional work in this area. A study to:

- Correlate in-service speed losses, increased fuel consumption, lost time and operating, dry dock and cleaning costs
- Identify and evaluate currently available hull maintenance programs and equipment
- Identify, evaluate and develop recommendations for areas of further work

is estimated at $250,000 with one year's duration.

8. THREE HIGH RISK PROGRAM AREAS SHOULD BE RECONSIDERED IN THE FUTURE

Basic research is currently being conducted in three program areas that offer a potential for significant energy savings should projected potentials be realized. These program areas are:

- Adiabatic diesel (AD)
- Naval Academy heat balance engine (NAHBE)
- Closed cycle gas turbines (CCGT).

Program addressing the adiabatic diesel and NAHBE are included based on their potential for energy conservation using existing marine fuels. The closed cycle gas turbine is included based on its multifuel capability. Each of these program areas is presently being supported either by ERDA, the U.S. Navy, or the U.S. Army. Specific dates for the reevaluation of each of these program areas have been recommended and shown in Table IV-3.