DDS 200-2

DESIGN DATA SHEET

CALCULATION OF SURFACE SHIP ANNUAL ENERGY USAGE, ANNUAL ENERGY COST, AND FULLY BURDENED COST OF ENERGY

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC 20376-5124

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1. APPLICABLE DOCUMENTS

1.1 General. The documents listed in this section are specified in the main body of this document. This section does not include documents cited in the Appendices.

1.2 Government documents.

1.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-5624	-	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-DTL-16884	-	Fuel, Naval Distillate

DEPARTMENT OF DEFENSE STANDARDS

DOD-STD-1399-301	-	Interface Standard for Shipboard Systems, Section 301, Ship Motion and Attitude

(Copies of these documents are available online at https://assist.dla.mil or http://assistdocs.com.)

1.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DESIGN DATA SHEETS (DDS)

DDS 051-1	-	Prediction of Smooth-Water Powering Performance for Surface-Displacement Ships
DDS 200-1	-	Calculation of Surface Ship Endurance Fuel Requirements
DDS 310-1	-	Electric Power Load Analysis for Surface Ships

(Copies of these documents are available from Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160, or by email at commandstandards@navy.mil with the subject line “DDS request”.)

OPNAV INSTRUCTIONS

OPNAVINST 3500.38	-	Universal Naval Task List (UNTL)
OPNAVINST 3501	-	Required Operational Capabilities/Projected Operational Environments (ROC/POE)

(Copies of these documents are available from the Department of the Navy Issuances, SECNAV/OPNAV Directives Control Office (DNS-5), Washington Navy Yard, Bldg. 36, 720 Kennon Street, SE Rm. 203, Washington Navy Yard, DC 20374-5074 or online at http://doni.daps.dla.mil/default.aspx.)

1.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS (SNAME)

T&R Bulletin 3-28 - Marine Gas Turbine Power Plant Performance Practices

T&R Bulletin 3-49 - Marine Diesel Power Plant Practices

(Copies of these documents are available from the Society of Naval Architects and Marine Engineers, 601 Pavonia Avenue, Jersey City, NY 07306 or online at www.sname.org.)

1.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2. INTRODUCTION

A major consideration in the design of any naval ship or craft is its total ownership cost. One important input to total ownership cost estimation is the annual energy consumption. The Navy generally uses NATO F76 for ship propulsion and power generation and JP5 for aircraft. JP5 is also used occasionally for ship propulsion and power generation. While inport, naval ships typically will use electricity (shore power) for their energy needs.

The lifecycle cost of energy is a function of three important factors, all of which include varying amounts of uncertainty: the operational profile of the ship, the future Fully Burdened Cost of Energy (FBCE), and the physical characteristics of the ship and its equipment. This Design Data Sheet (DDS) outlines the procedure to estimate the annual energy consumption and annual energy cost of non-nuclear surface ships. As shown in Figure 2-1, this procedure is decomposed into four distinct tasks that individually estimate the three important factors and then combine them into an actual estimate.

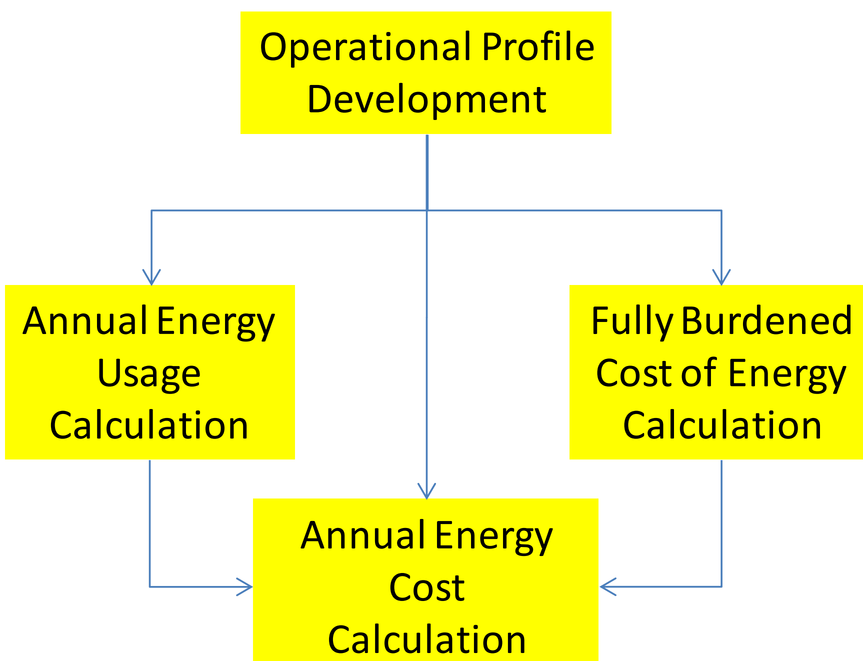


Figure 2-1. Annual Energy Cost Tasks.

This document is organized in a task oriented approach. The General Requirements section, intended primarily for use by study planners, details the input and outputs of the Annual Energy Usage and Annual Energy Cost Calculation Process. These inputs and outputs are defined in the Definition section. The Specific Requirements section provides details on the method to calculate the process outputs based on the inputs for the individuals tasked with completing the work. Appendix A provides details on calculating the burden to apply to fuel as part of the FBCE Calculation task. Appendix B and C provide data to support the development of Operational Profiles. Appendix D provides a worked example.

3. DEFINITIONS

3.1 Baseline Security Posture (BSP). Baseline Security Posture describes the steady-state military capability requirements needed to address the day-to-day activities supporting long-term security commitments.

3.2 Major Combat Operations (MCO) scenario. A Major Combat Operations scenario is a planning concept for large-scale operations conducted against a nation state(s) that possesses significant regional military capability, with global reach in selected capabilities, and the will to employ that capability in opposition to or in a manner threatening to U.S. national security. An MCO scenario generally incorporates several Tactical Situations.

3.3 Tactical Situations (TACSITs). A Tactical Situation is a planning concept for tactical employment of both friendly and enemy forces. A TACSIT includes a description of all forces involved (including their capabilities), a notional timeline, and behavior rules for each force element.

3.4 Future naval force architecture. The future naval force architecture provides the Office of the Chief of Naval Operations (OPNAV) projection of the number and types of ships comprising the battle force for each year over an extended period of time, typically 30 years. If the OPNAV projection is incomplete or does not extend to the end of the design service life of the ship, then the assumptions for extending the OPNAV projection should be described in the study guide.

3.5 Ship mission and mobility capabilities list. For each of the warfare areas, the ship mission and mobility capabilities list provides levels of capability. For the ship missions, the levels correspond to specific mission systems equipment and associated watchstanders needed to perform the mission to an associated level of performance. The mobility capability is generally specified in the range of speeds (typically from bare steerageway to sustained speed) that the propulsion plant is capable of achieving. Taxonomies for the ship mission and mobility capabilities list can be derived from OPNAVINST 3501 from related ships, or from the Universal Naval Task List (UNTL) detailed in OPNAVINST 3500.38.

3.6 Ship state. A ship state assigns a level of capability to each element of the ship mission and mobility capabilities list. The mobility capability level consists of a speed vs. percent time profile (commonly referred to as a "speed-time profile").

3.7 Operational modes. Operational modes typically include operational deployments, training cycles, in port periods, and maintenance and modernization availabilities over the life of the ship. It may prove beneficial to have more than one operational mode to discriminate among different types of operational deployments. For example, an anti-piracy deployment may be very different from a Theater Ballistic Missile Defense (TBMD) deployment. Operational modes are associated with one or more ship states through the ship state participation table.

3.8 Ship deployment and employment profile. A ship deployment and employment profile provides the number of hours in each year for each of the ship's operational modes over the ship's design service life. These profiles are generally used to model different operational tempos (OPTEMPOs) for the ship. A low OPTEMPO profile would model essentially constant peacetime operations, while a high OPTEMPO profile would model multiple MCOs over the ship's design service life.

3.9 Ship state participation table. A ship state participation table consists of participation factors (fraction of time) of each ship state for each operational mode.

3.10 Ambient condition profile. The ambient condition profile consists of a number of temperature/relative humidity ambient conditions and an associated percentage of time spent operating in the particular ambient condition.

3.11 Electric Power Load Analysis (EPLA). Electric Power Load Analysis is used to calculate the ship service loads in the specified operational condition over the ambient condition profile. The EPLA includes margins. DDS 310-1 describes how to prepare an EPLA.

3.12 Electrical generation, conversion, and distribution efficiencies. Electrical generation, conversion, and distribution efficiencies are used to convert the ship service load (and propulsion load for electric propulsion) into load sustained by the prime movers. The efficiencies should account for all losses associated with the electrical generation, conversion, and distribution. The efficiencies are typically a function of power. If the Specific Fuel Consumption (SFC) curve for an electrical generator set includes the generator efficiency, then the generator efficiency is not required to be known independently.

3.13 Electric and propulsion plant Concept of Operations (CONOPS). The electric and propulsion plant Concept of Operations is used to determine which prime movers are online, how propulsion power is shared among the propulsors, and for determining how power is shared among the prime movers for given operational conditions and loads. In early stages of design, the electric and propulsion plant CONOPS is included as part of the study guide. In later stages of design, it typically is a stand-alone document.

3.14 Propulsion motor module efficiency (electric drive). Propulsion motor module efficiency is used to convert the propulsion power (kW) measured at the output of the motor to electrical power at the input of the motor drive (including transformer, if applicable). The efficiency should account for all losses associated with the propulsion motor module including those losses associated with thrust bearings if incorporated into the motor design. The efficiency is typically a function of power.

3.15 Reduction gear efficiency (mechanical drive). Reduction gear efficiency is used to convert the propulsion power (kW) measured at output of the reduction gear to the power (kW) at the output of the attached engine. The efficiency should account for all losses associated with the reduction gear including thrust bearings and couplings. The efficiency is typically a function of power. For early stages of design, T&R Bulletin 3-49 and T&R Bulletin 3-28 may be used to estimate reduction gear efficiency.

3.16 Prime mover Specific Fuel Consumption (SFC) curves. Prime mover Specific Fuel Consumption (kg/kW-h) curves are used to calculate the amount of fuel burned per hour (kg/h) for each prime mover for a given load (kW). The prime mover SFC curves may require correction factors to account for conditions such as higher than normal exhaust backpressure, higher temperatures, and attached pumps. For electrical generator sets, the SFC curve may include the generator efficiency. In later stages of design, or earlier if known, the SFC curves should reflect the impact of the ambient condition profile.

Where available, use manufacturer guidance to interpolate between constant SFC lines on fuel consumption contour plots. If such guidance is not provided, use the SFC value of the closest contour line; if equally distant to two contour lines, use the higher SFC value. Where the difference between the SFC values of the two bounding contour lines is greater than 5 percent of the higher SFC value, interpolating between the contour lines is also permissible.

3.17 Plant deterioration allowance. The plant deterioration allowance accounts for increased fuel consumption as the equipment ages.

3.18 Sea state and fouling factor. Sea state and fouling factor accounts for additional drag to the ship's hull due to average fouling and sea state. The impact of sea state is determined for a specified operating area, in head seas, at the high end of sea state 4 as defined in the latest revision of DOD-STD-1399-301 using the propeller coating, bottom coating, and cleaning methods intended for the ship. The sea state and fouling factor may be a function of speed.

3.19 Annual energy usage table. The annual energy usage table provides the fuel(s) consumed in kg and the shore power used in kW-h for each operational mode for each year in the ship deployment and employment profiles. The fuel consumed accounts for fuel used by the ship itself and the fuel consumed for embarked vehicles (aircraft, boats, and unmanned vehicles).

3.20 Standard price for fuel. The standard price for fuel is the anticipated cost to the Government for providing a barrel (42 gallons) of fuel to Department of Defense customers by the Defense Logistics Agency Energy (DLA Energy).

3.21 Commodity price for electricity. The commodity price for electricity is the anticipated cost to the Government for providing a kW-h of electrical energy to Department of Defense customers. Because the price for electricity is very dependent on geographical location, it may be advantageous to express the commodity price for electricity as a random variable.

3.22 Table of fully burdened cost of fuel. The table of fully burdened cost of fuel (dollars per kg) provides the fully burdened cost of fuel for each operational mode for each year in the ship deployment and employment profiles. Each cost element of the table is typically expressed as a random variable (probability density function) to account for the uncertainty in the underlying estimation method.

3.23 Annual cost of energy table. The annual cost of energy table provides the estimated energy cost for each year of the ship's service life for each ship deployment and employment profile. Each cost element of the table is typically expressed as a random variable (probability density function). For energy provided as fuel, the table entries have units of $/kg. For energy provided as electricity to the ship (shore power), the table entries have units of $/kW-h.

3.24 Lifecycle cost of energy. The lifecycle cost of energy is the total estimated cost of energy over the service life of the ship for each ship deployment and employment profile. It is typically expressed as a random variable (probability density function).

3.25 Average annual energy cost. The average annual energy cost is obtained by dividing the lifecycle cost of energy by the design service life of the ship. It is typically expressed as a random variable (probability density function).

3.26 Study guide. A study guide is a planning document intended to align customer expectations with work accomplished in a technical study. Among many other items, study guides include the general approach for conducting the study and a list of key assumptions.

3.27 Design service life. The design service life is the number of years the customer intends for a ship to be operationally relevant. Ship system design, maintenance strategies, and modernization strategies are all impacted by the design service life.

4. SYMBOLS

$/kg	Dollars per Kilogram
$/kW-h	Dollars per Kilowatt-Hour
AAW	Anti-air Warfare
AEO	Annual Energy Outlook
AoA	Analysis of Alternatives
ASN(RD&A)	Assistant Secretary of the Navy for Research, Development and Acquisition
ASuW	Anti-surface Warfare
ASW	Anti-submarine Warfare
bbl	Barrel (42 U.S. gallons)
BCA	Business Case Analysis
BSP	Baseline Security Posture
CONOPS	Concept of Operations

CP	Conventionally Propelled
DESC	Defense Energy Support Center
DFM	Diesel Fuel Marine
DLA	Defense Logistics Agency
DoD	Department of Defense
DRM	Design Reference Mission
DWCF	Defense Working Capital Fund
EIA	Energy Information Administration
EPLA	Electric Plant Load Analysis
FBCE	Fully Burdened Cost of Energy
FISC	Fleet Industrial Supply Centers
IAC	Initial Acquisition Cost
kg	Kilogram
kg/h	Kilograms per Hour
kg/kW-h	Kilograms per Kilowatt-Hour
kg/L	Kilogram per Liter
kW	Kilowatt
kW-h	Kilowatt-Hour
MCO	Major Combat Operations
MSC	Military Sealift Command
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NEURS	Navy Energy Utilization Reporting System
NOLSC	Navy Operational Logistics Support Center
O&S	Operating and Support
OMB	Office of Management and Budget
OPNAV	Office of the Chief of Naval Operations
OPTEMPO	Operational Tempo
OSD	Office of the Secretary of Defense
OSD(PA&E)	Office of the Security of Defense for Program Analysis and Evaluation
POE	Projected Operational Environment
ROC	Required Operational Capability
SFC	Specific Fuel Consumption

SV	Salvage Value
SYSCOM	Systems Command
TACSIT	Tactical Situation
TBMD	Theater Ballistic Missile Defense
TLR	Top Level Requirements
UL	Useful Life
UNREP	Underway Replenishment
UNTL	Universal Naval Task List
VAMOSC	Visibility and Management of Operating and Support Costs

5. GENERAL REQUIREMENTS

5.1 Operational profile.

5.1.1 Introduction. The operational profile describes the number of hours a ship operates for each year within the ship's design service life in each of its operational modes and with a corresponding speed-percent time profile. In early stages of design, the operational profile is often assumed identical for every year based on average expected OPTEMPOs. As the design evolves, the operational profile is typically refined to reflect periods of peace, limited conflicts, major conflicts, and the maintenance and modernization strategy.

5.1.2 Operational profile inputs.

1. BSP
2. MCO scenarios and associated TACSITs
3. Future naval force architecture
4. Ship mission and mobility capabilities list

5.1.3 Operational profile outputs.

1. Table of "ship states"
2. Operational modes list
3. One or more ship deployment and employment profiles
4. Ship state participation table

5.2 Annual energy usage.

5.2.1 Introduction. Annual energy usage calculations use the operational profile outputs and the characteristics of the ship design to calculate the amount of fuel and/or electricity (shore power) consumed in each year of the ship's design service life for each of the operational modes.

Some studies may not require the calculation of fuel used by embarked vehicles, or the amount of electrical power consumed from shore power, to address the goals of the study. The rationale for eliminating these calculations should be documented in the study guide.

5.2.2 Annual fuel consumption inputs.

1. Ship characteristics (required for DDS 200-1 calculations)
    a. Electric and propulsion plant CONOPS
    b. Electrical generation, conversion, and distribution efficiencies
    c. Propulsion motor module efficiency (electric drive) or reduction gear efficiency (mechanical drive)
    d. Propulsion speed power curve

   e. Electric power load analysis including margins – see DDS 310-1
   f. Electric power service life allowance
   g. Prime mover SFC curves
   h. Plant deterioration allowance – see DDS 200-1 for default values
   i. Sea state and fouling factor – see DDS 200-1 for default values
   j. Ambient condition profile – see DDS 200-1 for default values
2. Operational profile outputs
   a. Table of “ship states”
   b. Operational modes list
   c. Ship deployment and employment profiles
   d. Ship state participation table
3. Embarked vehicle energy usage

5.2.3 Annual fuel consumption outputs.

1. Annual energy usage tables

5.3 Fully Burdened Cost of Energy (FBCE).

5.3.1 Introduction. The FBCE incorporates the following costs for each operational mode of the ship for each year of the ship’s service life:

1. Standard commodity cost.
2. The cost, including personnel costs, of operating service-owned fuel delivery assets that are required for resupply of the platform or weapon systems.
3. The costs associated with force protection/convoy escorts that are required for fuel delivery to the platform or weapon system.
4. The depreciation costs of the associated fuel delivery and force protection/convoy assets.

5.3.2 FBCE cost inputs.

1. Energy Information Administration (EIA) Annual Energy Outlook (AEO)
2. DLA Energy standard price buildup

5.3.3 FBCE outputs.

1. Table of FBCE

5.4 Annual energy cost.

5.4.1 Introduction. Annual energy cost calculations use the annual energy consumption and FBCE to calculate the annual fuel cost for each ship deployment and employment profile.

5.4.2 Annual energy cost inputs.

1. Annual energy usage tables
2. Table of fully burdened cost of fuel
3. Ship deployment and employment profiles

5.4.3 Annual energy cost outputs.

1. Annual cost of energy table
2. Lifecycle cost of energy for each ship deployment and employment profile
3. Average annual energy cost for each ship deployment and employment profile

6. SPECIFIC REQUIREMENTS

While this document provides data for specific years in the past, it also provides sources for obtaining more recent data. The user of this document is encouraged to use more recent data when such data is available. Specific sources of data should be detailed in the study guide.

6.1 Operational profile.

6.1.1 Introduction. Developing a useful and representative operational profile is perhaps the most challenging activity in performing annual fuel calculations. In many cases, the simplest manner to construct the operational profile products is to modify the operational profile used in a previous study. Care must be taken to ensure the assumptions of the original study are consistent with the current study. In some cases, it will be necessary to develop an operational profile from scratch.

The methods in this section are derived from those developed for the study conducted to produce the Report to Congress on Alternative Propulsion Methods for Surface Combatants and Amphibious Warfare Ships of January 2007.

6.1.2 Operational mode development. The operational modes describe the capability sets that a ship must support for a given period of time (generally at least a month in duration). Examples of operational modes include:

1. Presence and training at home
2. Presence overseas
3. TBMD operations
4. Lesser contingencies
5. MCO
6. Maintenance and modernization

The goal is to be able to capture the entire range of ship activities over its service life in a relatively few number of categories.

6.1.3 Ship state development. The ship states reflects a level of capability for each element of the ship mission and mobility capabilities list. The ship states should reflect the categories used in the EPLA. Examples of ship states include:

1. Inport – shore
2. Inport – anchor
3. Underway – peacetime cruising
4. Underway – wartime cruising
5. Underway – Anti-Submarine Warfare (ASW) operations (mission)
6. Underway – Anti-Air Warfare (AAW) operations (mission)
7. Underway – Anti-Surface Warfare (AsuW) operations (mission)
8. Underway – Surveillance operations (mission)
9. Underway – TBMD station (mission)

In early stages of design, it will likely be advantageous to combine some of these categories to result in fewer states than used in later stages of design. It is important to remember that it must be possible to estimate the electrical loads and assign a speed-percent time profile for each state. In establishing the speed-time profile, at least three techniques are available:

1. Construct a Design Reference Mission (DRM) based on the BSP and MCO TACSITs to gain the requisite insight to develop the speed-percent time profile and annual operating hours.

2. Use measured data from ships with a similar mission to develop representative speed-percent time profiles and annual operating hours. The Navy Energy Utilization Reporting System (NEURS) is a good source of information for annual operating hours and total energy consumption (useful for validating speed-time profiles).
3. Use data from Appendix B and Appendix C for ships with a similar mission. Document any adjustments made and the rationale.

6.1.4 Ship state participation table development. The ship state participation table is produced by examining the BSP, MCO scenarios, and the associated TACSITs to estimate the fraction of time (participation factor) spent in each state for each operational mode.

6.1.5 Ship deployment and employment profile development. Generally three ship deployment and employment profiles should be sufficient for many studies. These three profiles correspond to:

1. Low: peacetime operation with no MCOs and a limited number of lesser contingencies.
2. Medium: adds a single MCO to the Low profile.
3. High: adds two MCOs to the Low profile.

For each year in the projected service life of the ship, the number of hours the ship spends in each operational mode is estimated and recorded in the ship deployment and employment profile. In determining the number and length of deployments, the projected number of ships in the future naval force architecture in any one year must be considered in determining the operational needs for both the BSP and the MCOs.

6.2 Annual energy usage.

6.2.1 Introduction. The output of the annual energy usage process consist of an annual energy usage table for each ship deployment and employment profile. The annual energy usage table provides the fuel(s) consumed in kg and, unless otherwise specified in the study guide, the shore power used in kW-h for each operational mode for each year in the ship deployment and employment profiles. Unless otherwise specified in the study guide, the fuel consumed accounts for fuel used by the ship itself and the fuel consumed for embarked vehicles (aircraft, boats, and unmanned vehicles). For many studies, point estimates for annual energy usage provide sufficient insight. In some cases, stochastic modeling and simulation techniques may be needed to understand the anticipated variance of the annual energy usage. DDS 310-1 provides guidance for stochastic load analysis in estimating the electrical load. In the following discussion, variables can be considered either point estimates or random variables depending on the needs of the study as documented in the study guide.

The annual energy usage table elements are comprised of three sub-elements:

a. Fuel (kg) consumed by the ship
b. Shore power (kW-h) used by the ship
c. Fuel (kg) consumed by embarked vehicles

6.2.2 Fuel consumed by the ship. The EPLA provides the 24-hour average ship service power profiles for each ship state. For each year in the ship's operating life, this value should be adjusted to reflect consumption of service life allowance in one of the following ways:

a. Apply 50 percent of the service life allowance to all years.
b. Incrementally apply the service life allowance in equal amounts for each year in the ship's life.
c. Apply the service life allowance in a manner defined in the study guide.

This electric load (corresponding to the 24-hour average mission ship service electric load profile) and the speed-time profile for the ship state are used to compute a calculated operational presence fuel rate (kg/h) using the method detailed in DDS 200-1 for the operational presence burnable fuel load. For each ship state, the calculated ship state fuel rate (kg/h) is equal to the corresponding calculated operational presence fuel rate (kg/h) multiplied by the plant deterioration allowance.

For each operational mode, the calculated operational mode fuel rate (kg/h) is calculated by summing the product of each calculated ship state fuel rate (kg/h) with its corresponding participation factor from the ship state participation table.

The ship contribution to the fuel consumption elements of the annual energy usage table (kg) is constructed by multiplying the appropriate calculated operational mode fuel rate (kg/h) by the number of hours for that operational mode as provided in the corresponding ship deployment and employment profile.

6.2.3 Shore power used by the ship. The EPLA provides the 24-hour average ship service power profiles for "shore power" ship state. The ambient condition profile is applied to the 24-hour average ship service power profile for "shore power" to calculate the 24-hour average shore power load.

For each operational mode, the calculated operational mode shore power (kW) is calculated by summing the product of the 24-hour average shore power load with its corresponding participation factor from the ship state participation table.

The ship contribution to the shore power elements of the annual energy usage table (kW-h) is constructed by multiplying the appropriate calculated operational mode shore power (kW) by the number of hours for that operational mode as provided in the corresponding ship deployment and employment profile.

6.2.4 Fuel consumed by embarked vehicles. The fuel consumed by embarked vehicles is determined by modeling the embarked vehicles and their CONOPS to determine an embarked vehicle fuel rate (kg/h) for each ship state. The method for modeling the embarked vehicles and the CONOPS should be documented in the study guide.

For each operational mode, the calculated embarked vehicle operational mode fuel rate (kg/h) is calculated by summing the product of each embarked vehicle fuel rate (kg/h) for each ship state with its corresponding participation factor from the ship state participation table.

The embarked vehicle contribution to the fuel consumption elements of the annual energy usage table (kg) is constructed by multiplying the appropriate calculated embarked vehicle operational mode fuel rate (kg/h) by the number of hours for that operational mode as provided in the corresponding ship deployment and employment profile.

6.3 Fully Burdened Cost of Energy (FBCE).

6.3.1 Introduction. The output of the FBCE process is a table of fully burdened cost of fuel ($/kg) and fully burdened cost of electricity ($/kW-h) for each operational mode for each year in the ship deployment and employment profiles. Typically expressed as a random variable (probability density function) to account for the uncertainty in the underlying estimation method.

6.3.2 Fully burdened cost of fuel. The fully burdened cost of fuel consists of two elements: the DLA Energy standard price for fuel and the fuel burden. Appendix A provides the method for calculating the fuel burden for F76. This method should be adapted to calculate the burden for JP5.

The DLA Energy standard price of fuel is not a marketplace price, but rather reflects the anticipated cost to the Government for providing the commodity to DoD customers. Table 6-1 shows the buildup of the DLA Energy standard price for FY 2011. Note that DLA Energy only provides the breakout for the composite standard price, which represents the average for all types.

Table 6-1. FY 2011 DLA Energy Standard Price Buildup.

	FY11 Fuel Prices - COMPOSITE		Distillate/F76
	Oct-10 - May-11	Jun-11 - Sep-11	OSD and ASN (FM&C) Guidance as of 7/25/2011 Represents Weighted Average for all FY11
Crude Oil	$85.02	$105.00	
Refined Product	$25.51	$31.50	
Adjustments	$2.01	$14.80	
Storage, Transport & Management	$14.72	$14.60	
Standard Price	**$127.26**	**$165.90**	**$139.72**

(FY11 Weighted average $140.14)

In estimating the range of crude oil prices, the EIA publishes an AEO which includes world crude oil price projections. The AEO includes a reference case, a low price case, and a high price case for roughly 5, 15, and 25 years in the future to bound the uncertainty of future crude oil prices. These estimates can be interpolated or extrapolated to develop estimates for other years. Based on data from AEO 1998 through AEO 2009, the high price case has proven a more accurate predictor of price than the low price case. Historically, AEOs have underestimated crude oil prices in the long-term.

If better information is not available, the product refinement cost can be estimated as 30 percent of the crude oil price.

The cost recovery from prior years should normally be estimated as negligible.

The cost to store, transport, and manage DLA Energy bulk petroleum products should be escalated using standard escalation indices from the last year data is available.

In most studies, a single fuel burden can be applied to all the fuel consumed by a ship without significant impact on design decisions. Some studies; however, may require different burdens be calculated for fuel delivered inport and fuel delivered at sea. In this case, the methods described in Appendix A would require some modification.

The great volatility of crude oil prices (AEO 2011 shows a 4 to 1 ratio of the long-term high oil price to low oil price projections) suggests that a simple projection of fuel price in the future will not be sufficient to gain the insight needed for many decisions. If better insight is needed, the impact of the variability of crude oil prices can be accounted for in several ways including:

a. Use the current DLA Energy price as a baseline, then show the impact of varying this amount both upwards and downwards to reflect the anticipated volatility.

b. Use the AEO to predict future DLA Energy prices for the baseline, high price and low price to reflect the volatility.

c. Use the AEO to develop a stochastic model of the DLA Energy price as a function of year.

Note that the fully burdened cost of fuel is generally expressed per barrel (1 bbl = 42 U.S. gallons) while fuel consumption is expressed in kg. The specific gravity (kg/L) of JP5 is between 0.788 and 0.845 (per MIL-DTL-5624) depending on temperature and the crude oil the fuel is derived from. An average value of 0.81 is representative. For F76, a representative value is 0.84 (Note the maximum value per MIL-DTL-16884 is 0.876).

Hence, the mass per barrel of JP5 is: 0.81 kg/L x 3.785 L/gal x 42 gal/bbl = 129 kg/bbl

The mass per barrel of F76 is: 0.84 kg/L x 3.785 L/gal x 42 gal/bbl = 134 kg/bbl

6.3.3 Fully burdened cost of shore power. The fully burdened cost of shore power is very dependent on the particular port from which a ship operates. For example, the price of electricity charged to ships on the west coast can be double that charged on the east coast.

The major element of the fully burdened cost of shore power is the commodity price for electricity. The Naval Facilities Engineering Command (NAVFAC) tracks the usage and cost of electricity by naval facilities. Rate information is provided in the Defense Utility Energy Reporting System (DUERS) Energy Audit Reports (EAR16) available from https://navyenergy.navfac.navy.mil/.

The AEO includes projections for the commodity price for electricity. The 2011 edition predicts average electricity prices to be essentially constant through 2035 with a price of roughly $0.09 (±$0.003) per kW-h in FY09 dollars. The price for electrical power in west coast ports is typically higher than this average while the price in east coast ports is typically lower.

While not explicitly known, the additional burden to cover Navy owned electrical system infrastructure is expected to be low. Hence, using the AEO average price of $0.09 (±$0.003) per kW-h in FY09 dollars is likely conservative in cases where the homeport is not known or will vary greatly. If the homeport is known, then DUERS data for the ship's homeport may be used.

6.4 Annual energy cost.

6.4.1 Annual cost of energy table. The annual cost of energy table is constructed by summing the product of the sub-elements of each element of the annual energy usage table with the corresponding fully burdened cost of fuel/electricity. The resulting table provides the cost of energy for each year over the ship's design service life. As documented in the study guide, some studies may require energy usage and energy cost data for different categories of energy use (i.e., propulsion). Some studies may also require a roll-up of annual energy costs of all the ships in a class where the commissioning and decommissioning schedule of ships in the class are detailed in the study guide.

6.4.2 Lifecycle cost of energy. The lifecycle cost of energy for each ship deployment and employment profile is the sum of the annual cost of energy over the design service life.

6.4.3 Average annual energy cost. The average annual energy cost is the lifecycle cost of energy for each ship deployment and employment profile by the design service life.

APPENDIX A. FULLY BURDENED COST OF ENERGY (FBCE) FOR F76

A.1 Introduction/Background.

DoD Instruction 5000.02 requires that the fully burdened cost of delivered energy (fuel) be used in trade-off analyses for all DoD tactical systems with end items that create a demand for energy.

ASN (RD&A) memo "Energy Evaluation Factors in the Acquisition Process" dated 20 June 2011 states, "System Commands (SYSCOMS) will develop a uniform method for calculating FBCE to support their respective acquisition programs." Per the memo, all FBCE methodologies should, at a minimum, contemplate (i) a standard commodity cost; (ii) the cost, including personnel costs, of operating service-owned fuel delivery assets that are required for resupply of the platform or weapon system; (iii) the cost associated with force protection/convoy escorts that are required for fuel delivery to the platform or weapon system; and (iv) the depreciation costs of the associated fuel delivery and force protection/convoy assets. The memo also states that all cost projections must be tied to planning scenarios in the AoA Guidance, and scenarios must represent both steady-state and surge OPTEMPO.

For Analyses of Alternatives (AoAs), Business Case Analyses (BCAs), or other analyses comparing alternatives with different fuel/energy demands, analysts should use the FBCE to capture the additional indirect/burdened cost for each alternative. Different energy/fuel demands may include not only nuclear vs. conventional propulsion, but also conventional propulsion systems that have different fuel consumptions or efficiencies. Operating and Support (O&S) cost estimates to support budget planning for a specific system should not include the additional indirect/burdened cost of energy in their estimates. The FBCE does not represent a direct budget charge to a program.

For naval ship applications, the FBCE includes the acquisition cost of a barrel of ship propulsion fuel burdened with the additional indirect costs associated with delivering it to the warfighter. The acquisition cost of bulk petroleum products is established by OSD and reported by the DLA Energy, previously known as the Defense Energy Support Center (DESC). The DoD standard price includes storage, handling, management, and transportation of the fuel to DoD fuel supply points worldwide. DLA Energy/OSD issues a standard price of fuel for all bulk petroleum products including naval distillate fuel (NATO Symbol F76 formerly known as Diesel Fuel Marine (DFM)) and jet propulsion (JP5) fuel. F76 is the primary propulsion and electrical power generation fuel for naval vessels in shipboard boilers, gas turbines, and diesel engines. JP5 is typically used to power aircraft, but can be used for ship propulsion and electrical power generation under certain operational scenarios.

For sea systems, the majority of the additional indirect costs are associated with the Underway Replenishment (UNREP) of naval vessels by fuel delivery ships. The burdened costs also include Navy fuel barge maintenance costs and potential environmental liability costs. The NAVSEA 05C FBCE methodology calculates the additional burdened cost associated with ship propulsion fuel (F76).

The total cost of naval fuel is made up of four major components: acquisition cost, storage and handling cost, delivery cost, and other. The elements of the cost structure are shown in Table A-1. This cost structure was defined in the OSD Program Analysis and Evaluation (PA&E) memo dated 16 July 2007 entitled, "Fully Burdened Cost of Fuel Methodology."

Table A-1. Cost Structure of Navy Fuel.

	Category	Element	Description
	Acquisition	Commodity Cost of Fuel	DLA Energy DoD standard price for the appropriate type or types of fuel.
BURDENED ELEMENTS	Storage & Handling	Direct Fuel Infrastructure O&S and Recapitalization Cost	Cost of fuel infrastructure that is not operated by DLA Energy and directly tied to energy delivery.
		Indirect Fuel Infrastructure O&S Cost	Cost of base infrastructure that is shared proportionally among all base tenants.
	Delivery	Depreciation Cost of Primary Fuel Delivery Assets	Measures the decline in value of fuel delivery assets with finite service lives using straight-line depreciation over total service life.
		Primary Fuel Delivery Asset O&S Cost	Cost of operating service-owned fuel delivery assets including the cost of military and civilian personnel dedicated to the fuel delivery mission.
	Other	Environmental Cost	Cost representing carbon trading credit prices, hazardous waste control, and related subjects.
		Other Service & Platform Delivery Specific Costs	Includes potential costs associated with delivering fuel such as convoy escort, force protection, regulatory compliance, contracting, and other costs as appropriate.

The cost structure can also be illustrated by Figure A-1.

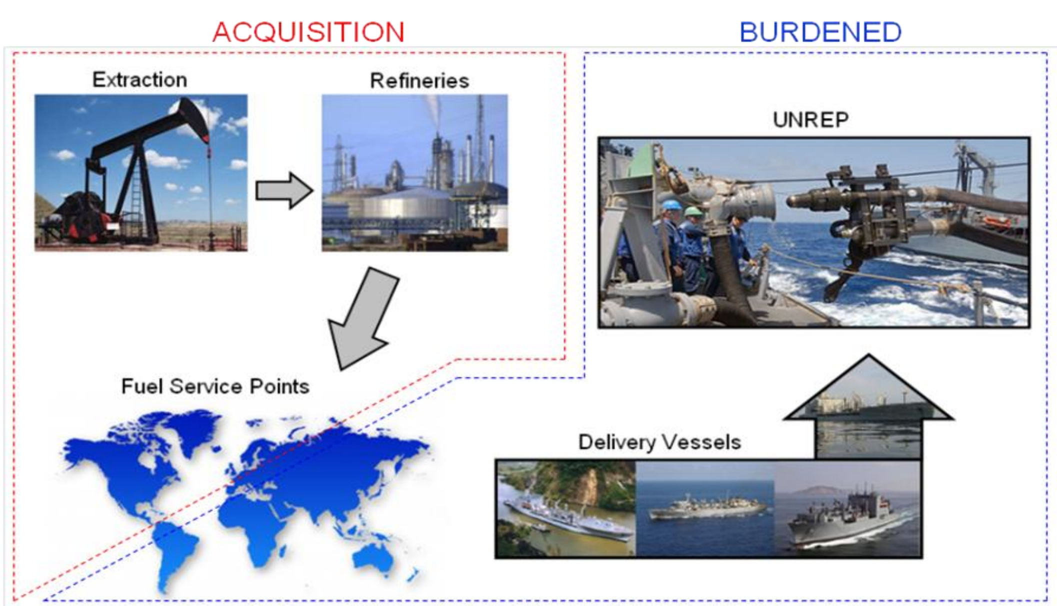


Figure A-1. Breakdown of Fully Burdened Cost of F76.

In this appendix, Sections 2 through 5, each cost component, its derivation, and the data sources will be discussed in greater detail. Section 6 summarizes the results of the most recent fuel study analysis and Section 7 provides future considerations for determination of the FBCE.

A.2 Acquisition cost.

Fuel for all DoD components is centrally managed and supplied by the DLA Energy. DLA Energy contracts, distributes, and controls DoD fuel. DLA Energy charges all DoD customers the same standard price for specific types/grades of fuel. Standard prices were created by DoD fiscal managers to insulate the military services from the normal ups and downs of the fuel marketplace. It provides the military services and OSD with budget stability despite the commodity market swings, with gains and losses being absorbed by a revolving fund known as Defense Working Capital Fund (DWCF). In years where the market price of the fuel is higher than the estimated price, the DWCF loses money and vice versa. The gains and losses are made up by adjusting future standard prices.

The standard price includes the following:

1. Estimate of a barrel of crude oil for a given year (typically estimated 18 months in advance of application)
2. Product refinement costs
3. Cost recovery (profits/losses) from prior years through a DWCF
4. Costs to store, transport, and manage DLA Energy bulk petroleum products at DoD fuel supply points worldwide

The standard price of fuel is not a marketplace price because of the substantial lead time in the estimation of crude oil prices and the buying power of DoD. It is not intended that the standard price of fuel be comparable to similar fuels in the commercial marketplace.

Standard prices are updated at least annually. Mid-year price changes have occurred since 2005 due to large fluctuations in the price of crude oil.

DoD standard prices can be accessed from the website http://www.energy.dla.mil under “Home > Customer > Standard Prices of Fuel”.

F76, also known as Naval Distillate, is the primary fuel used for Navy ship propulsion and electrical power generation. JP5 is primarily used for powering aircraft.

The FY 2011 DoD composite standard price of distillate (including F76) fuels as of 1 June 2011 is $165.48 per barrel, up from the 1 October 2010 price of $126.84. This price includes an amount for cost recovery. The FY 2011 average price specifically for F76 through 30 September 2011 is $139.72. The breakdown of the DoD standard price per barrel into individual line items is shown in Table 6-1.

A.3 Burdened cost: storage and handling cost derivation.

Storage and handling is the first element of the additional burdened costs. The majority of naval fuel is provided by Fleet Industrial Supply Centers (FISCs) throughout the world. As of 2003, the Navy transferred ownership and operation of the Navy FISC bulk fuel terminals to DLA Energy. The depreciation and operating costs associated with these fuel terminals are now included as part of the DoD standard price as described in Section 2. Non-DLA Energy storage and handling costs include the storage and handling of the fuel after DLA Energy delivers the fuel to DoD fuel service points. The fuel stored at fuel service points is delivered either to the delivery vessels transporting fuel to battle-force ships or directly to the docked end user. The additional storage and handling costs primarily reflect the overhaul and maintenance costs of Navy fuel barges that transport fuel between fuel supply points and delivery vessels.

The cost to deliver fuel to the docked end user has not been assessed and is anticipated to be insignificant, as only minimal logistics are required to fuel the docked end user.

The O&S costs for Navy-owned fuel barges are funded by DLA Energy with the rest of the FISC fuel terminal operating costs, and are included in the DLA Energy "storage, transport, and management" cost element of the acquisition costs described earlier. The only cost not included in the DoD standard price is the overhaul and maintenance of the fuel barges. Based on information provided by the Navy Operational Logistics Support Center (NOLSC) Petroleum, each fuel barge is overhauled once every 6 years and the average cost of an overhaul is $600,000 (FY06). This equates to an average annual cost of $100K per barge per year. For the 14 Navy-owned fuel barges, the total average annual cost is $1.4M.

$$14 \text{ barges} \times [(\$0.6\text{M per overhaul})/(6 \text{ years})] = \$1.4\text{M/year}$$

Fuel barges deliver various types of fuel, so it is difficult to apportion overhaul costs to specific fuel types. The annual amount of $1.4M divided over 29.1M bbls of all fuel consumed by the fleet in FY 2006 resulted in an estimated additional cost of $0.05 per barrel of fuel for barge overhauls.

A.4 Delivery cost derivation.

A.4.1 Overview.

The delivery cost of fuel consists of the acquisition/depreciation and O&S costs for fuel replenishment/delivery ships. Different cost components are associated with different types of fuel delivery ships, based on the ownership and the operation of the ships. In general, there are two different types of ships:

Type (1) - Navy-owned and Navy-operated ships

(Depreciation and O&S Costs)

Type (2) - Navy-owned and Military Sealift Command (MSC)-operated ships

(Depreciation and MSC per diem charges for O&S)

Currently, all fuel delivery ships are Navy-owned and MSC-operated.

A.4.2 Acquisition/Depreciation cost of fuel delivery ships.

There are several classes of Navy-owned ships capable of delivering fuel, including T-AO, T-AOE, T-AKE, T-AE, and T-AFS. Delivery ships' acquisition costs are depreciated over the period of their respective service lives. Although OMB Circular A-76 guidance states that the expected Useful Life (UL) of cargo and tanker vessels is 30 years, with a disposal/Salvage Value (SV) at the end of the UL of 8.54 percent of the Initial Acquisition Cost (IAC), MSC assumes the expected service life of cargo and tanker ships to be 40 years. Delivery vessel inventory is phased based on a first-in, first-out methodology. The future acquisition strategy and inventory counts over time are based on the President's budget battleforce tables provided by OPNAV. This information includes the dates (years) when fuel delivery ships are projected to enter into and retire from service.

The IAC for each hull currently in operation is obtained from the NAVSEA 05C Cost Information Management System historical ship cost database. Costs for future ships are based on NAVSEA 05C estimates or class average costs for similar ship types. The NAVSEA 05C SCN Shipbuilding Composite Inflation Index is used to update the acquisition cost from the acquisition year dollars to FY dollars for which the FBCE is being calculated.

Annual depreciation for a given hull for each year over its projected service life is calculated by applying the straight line depreciation method. As mentioned earlier, the SV for each hull is assumed to be 8.54 percent of the IAC at the end of 30 years of UL according to OMB guidance. The standard straight line depreciation formula for each year is as follows:

$$\text{Depreciation (\$/year)} = (IAC - SV)/UL$$

Where: IAC = Initial Acquisition Cost ($)

SV = Salvage Value ($)

UL = Useful Life (years)

Substituting SV = IAC * 0.0854, the equation becomes

Depreciation = (IAC – (IAC * 0.0854))/30 ($/year)

= IAC * (1 - 0.0854)/30 ($/year)

= IAC * (0.03049) ($/year)

Although UL is 30 years, the actual or expected service life of a fuel delivery ship could be longer than 30 years. If the service life is longer than 30 years, the assumed SV at the end of 30 years needs to be depreciated until the asset value reaches zero or the ship is salvaged, whichever occurs first. Once the asset is fully depreciated, the depreciation amount for any remaining years of service life is set to zero.

Using straight line depreciation, the formula for the asset value in year n is as follows:

Asset Value_n = IAC – n*(Depreciation_n) ($)

= IAC – n*(IAC * (0.03049)) ($)

To determine the point (year n) at which the asset value is zero, set Asset Value_n to zero and solve the equation for n:

n = 1.0/(0.03049) = 32.8 years

The asset value will be completely depreciated by 33 years of service life. The annual depreciation amount for each hull is expressed as follows:

Years 1 through 32:

Depreciation amount = IAC * (0.03049) ($/year)

Year 33:

Depreciation amount = IAC * [1 - (0.03049*32)] ($/year)

Accounts for residual depreciation needed after year 32 so that:

Total depreciation amount = IAC ($)

Years 34 and beyond:

Depreciation amount = 0 ($/year)

The annual depreciation for each ship (hull) in service for that class for that year is summed to calculate the total depreciation value for each class in any given year.

$$\text{Annual Depreciation for a Class} = \sum_{\substack{\text{All}\\ \text{hulls}\\ \text{in the}\\ \text{class}}} (\text{Annual Depreciation})_{\text{hull}}$$

Depreciation cost for each class is the average annual depreciation cost for the period of 35 years, assuming average service life of the delivery ships to be 35 years as shown below (mid-point of OMB guidance of 30 years of UL and MSC assumption of 40 years of service life).

$$\text{Depreciation \$ for a class} = \frac{\sum_{\substack{n=1 \\ \text{to } 35}} \left[\begin{array}{c}\text{Annual Depreciation} \\ \text{for a class}\end{array}\right]_n}{35}$$

Because FBCE is calculated as $/barrel to be applied over the entire life of Navy programs, the above formula allows for factoring in the effect of the long range shipbuilding plan on the number of fuel delivery ships, as well as any changes in costs for reasons other than inflation. Other factors influencing future acquisition costs may include changes in specifications, environmental or legislative requirements, such as the Federal law passed after the Exxon Valdez spill requiring all oil tankers to be double-hulled by 2015.

A.4.3 Apportioning depreciation cost to ship propulsion fuel.

As mentioned previously, there are several classes of delivery ships, including T-AO, T-AOE, T-AKE, T-AE, and T-AFS. These ships also deliver other items in addition to fuel, including ammunition, food, stores, and other supplies. Hence, only a portion of the depreciation costs are applied to fuel delivery. The depreciation costs for these ships are apportioned based on the portion of the ship's mission operations dedicated to fuel replenishment/delivery. The information on mission percentages dedicated to fuel operations is provided by the cognizant ship program managers. The following percentages represent the current baseline case assuming peacetime operations: T-AO 100%, T-AOE 90%, T-AKE 10%, T-AE 0%, and T-AFS 0%. The percentages for T-AOE and T-AKE may be modified as needed to represent specific scenarios.

Navy ships primarily use F76 propulsion fuel and Navy aircraft use JP5 propulsion fuel. Because the delivery ships carry F76 and JP5, as well as other types of fuels, acquisition costs are further apportioned based on the ship propulsion F76 fuel portion of total fuel replenishment operations, as measured by the quantities of types of fuel delivered. Out of the total JP5 delivered to the ships, only a small portion is used for ship propulsion. The majority of the JP5 delivered is consumed for the use by aircraft aboard ships. Hence, for the sea systems ship propulsion FBCE, costs are not further apportioned based on the small amount of JP5 consumed for ship propulsion.

NOLSC Petroleum provides the amount of fuel (in bbls) delivered annually to the Navy fleet by each fuel delivery ship, broken out by fuel type (F76, JP5, other). F76 delivered as a percentage of total fuel delivered (average by fuel delivery ship class) is calculated based on this information. These percentages are used to apportion the depreciation cost for each fuel delivery ship. Historically, T-AOs deliver approximately 75% F76 as a percentage of total fuel delivered, T-AOEs 65%, and T-AKEs 90%.

The apportioned depreciation cost is divided by the total barrels of F76 ship propulsion fuel consumed by the fleet in a given year to calculate a cost per barrel.

The following references are used to project fuel consumption:

1. Navy Visibility and Management of Operating & Support Costs (VAMOSC) provides the consumption of propulsion fuels for the Navy and MSC fleets.
2. President's Budget Battleforce Tables (produced by OPNAV) governs the shipbuilding outlook for the next 30 years.

The following variables are extracted from the above references:

1. Number of Conventionally Propelled (CP) ships, non-nuclear, in a given year
2. bbls F76 consumed per CP ship (average)

Table A-2 is an example of the fleet fuel consumption profile assumed in estimating the FBCE for future years. The assumption made in calculating this profile is that the fuel consumption per ship remains relatively constant over years.

Table A-2. Prediction of Fleet Fuel Consumption.

	Number non-nuclear ships in Battle Force	Consumed F76 K bbls
2011	202	15,450
2012	204	15,603
2013	204	15,603
2014	202	15,450
2015	202	15,450
2016	212	16,215
2017	218	16,674
2018	226	17,286
2019	231	17,668
2020	226	17,286
2021	239	18,280
2022	240	18,356
2023	242	18,509
2024	245	18,739
2025	242	18,509
2026	241	18,433
2027	239	18,280
2028	239	18,280
2029	224	17,133
2030	228	17,439
2031	225	17,209
2032	224	17,133
2033	223	17,056
2034	224	17,133
2035	222	16,980
2036	226	17,286
2037	228	17,439
2038	230	17,591
2039	233	17,821

As mentioned earlier, annual apportioned depreciation costs are divided by the annual average barrels of naval fuel (F76) consumed aboard Navy ships for ship propulsion to determine the depreciation cost per barrel. The depreciation cost per barrel formula is shown below.

$$\text{Depreciation Cost/Barrel} = \frac{\sum_{\substack{\text{Oiler}\\ \text{Classes}}} \left[(\text{Depreciation \$}) \times (\text{\% Fuel Ops}) \times (\text{\% F76}) \right]_{\text{class}}}{(\text{Total Navy Fleet F76 Propulsion Fuel Consumption})}$$

A.4.4 O&S cost for fuel delivery ships.

Currently, all Navy fuel delivery ships are operated by the MSC (Type (2)). MSC charges the Navy specified per diem rates for each class of ships, which covers all costs associated with operations and maintenance of the Navy-owned ships. MSC provides actual and projected per diem rates billed to the Navy for the MSC operated ships. For future years where MSC rates are not available, costs are inflated to the FY$ for which the FBCE is being calculated using O&M,N composite inflation rates. If the Navy in the future owns Type (1) ships, O&S costs will have to be directly estimated.

Annual O&S costs for each hull are calculated based on MSC charter/per diem rates. MSC operations assume 365 days of full operating status per year for each fuel delivery ship, unless a ship is in a reduced operating status or maintenance cycle. Therefore, the annual cost is 365 days times the applicable per diem rate. The O&S cost for a given year for each class is the sum of the annual O&S for each ship (hull) in service for that class for that year.

$$\text{Annual O\&S Cost} = \sum_{\substack{\text{All}\\\text{hulls}\\\text{in the}\\\text{class}}} (\text{Annual O\&S Cost})_{\text{hull}}$$

O&S cost for each class is the average annual O&S cost for the period of 35 years assuming average service life of the delivery ships to be 35 years as shown below (mid-point of OMB guidance of 30 years of UL and MSC assumption of 40 years of service life).

$$\text{O\&S \$ for a class} = \frac{\displaystyle\sum_{\substack{n=1\\\text{to } 35}} (\text{Annual O\&S Cost})_n}{35}$$

The above formula allows for factoring in the effect of the long range shipbuilding plan on the number of fuel delivery ships, as well as any changes in costs for reasons other than inflation.

The O&S costs are apportioned in the same manner as the depreciation costs, based on the portion of the delivery ship's mission operations dedicated to fuel replenishment and percentage of type of fuel delivered. The formula to calculate O&S costs per barrel is as follows:

$$\text{Operating and Support Cost/Barrel} = \frac{\displaystyle\sum_{\substack{\text{Oiler}\\\text{Classes}}} \Big[(\text{O\&S \$}) \times (\text{\% Fuel Ops}) \times (\text{\% F76}) \Big]_{\text{class}}}{(\text{Total Navy Fleet F76 Propulsion Fuel Consumption})}$$

A.5 <u>Other costs</u>.

A.5.1 <u>Environmental costs</u>.

For environmental costs, the OSD (PA&E) guidance of $0.10 per gallon is used. This information was provided in the OSD (PA&E) memo dated 16 July 2007 entitled, "Fully Burdened Cost of Fuel Methodology". Based on 42 gallons per barrel, this cost is estimated to be $4.20 per barrel.

A.5.2 <u>Platform delivery specific costs</u>.

Depending on the platforms and scenarios under consideration, additional factors may need to be considered. For example, an AoA for nuclear vs. conventionally fueled aircraft carriers must also determine if additional fuel delivery ships would be required to support the conventional propulsion option, beyond those reflected in the long range shipbuilding plan. The associated depreciation and O&S costs for those additional ships would need to be included in the platform-specific FBCE. Other platform-specific design or operational characteristics may also require adjustments to the delivery component of the burdened cost.

The current NAVSEA process for determining the baseline FBCE does not include the potential costs associated with force protection or convoy escorts. Based on information from the MSC, fuel delivery ships (Naval Fleet Auxiliary Force ships) are not specifically provided escorts, so no additional burdened costs are calculated to reflect depreciation or other costs associated with force protection or convoy escort ships. In the future, costs associated with force protection may be included should the operating practice of the fleet change to provide delivery ships with dedicated force protection.

A.6 Summary.

The NAVSEA process for calculating the baseline FBCE captures the elements specified in the memo from ASN (RD&A).

Considering all the factors of burdened elements, the preliminary FY 2011 additional burdened cost is estimated to be $46.26 per barrel of ship propulsion fuel. The total FBCE is estimated to be $185.98 per barrel F76. Table A-3 shows burdened elements broken out into individual line items.

Table A-3. Breakdown of Fully Burdened Cost of F76 in FY 2011.

Per Barrel of F76	FY 2011
Acquisition	**$139.72**
DLA Energy Price	$139.72
Storage & Handling	**$0.05**
Direct Fuel Infrastructure - Facilities Cost	$0.00
Indirect Fuel Infrastructure - Barge Overhauls	$0.05
Delivery	**$42.01**
Fuel Delivery Ship Acquisition/Depreciation	$11.67
T-AO	*$8.80*
T-AOE	*$2.80*
T-AKE	*$0.07*
T-AE	*$0.00*
T-AFS	*$0.00*
Fuel Delivery Ship Operating & Support	$30.34
T-AO	*$22.80*
T-AOE	*$7.25*
T-AKE	*$0.30*
T-AE	*$0.00*
T-AFS	*$0.00*
Other	**$4.20**
Environmental	$4.20
Service/Platform Specific	$0.00
Burdened Cost	**$46.26**
Fully Burdened Cost	**$185.98**

A.7 Future considerations.

Options could be explored to incorporate risk analysis into the calculation of the FBCE. As the price of fuel/energy can be highly volatile, risk analysis would provide Navy decision makers with better insight into the costs and likelihood of various outcomes for the platform or system alternatives under consideration.

A.8 References.

1. DoD Instruction 5000.02, "Operation of the Defense Acquisition System", 2 December 2008
2. ASN (RD&A) memo, "Energy Evaluation Factors in the Acquisition Process", 20 June 2011
3. OSD Program Analysis and Evaluation (PA&E) memo, "Fully Burdened Cost of Fuel Methodology", 16 July 2007
4. DoD standard prices from Defense Logistics Agency Energy (DLA Energy), http://www.energy.dla.mil, "Home > Customer > Standard Prices of Fuel"
5. Office of Management and Budget Circular A-76 March 1996 Revised Supplemental Handbook, "Useful Life and Disposal Value"
6. President's Budget Battleforce Tables, OPNAV N8F
7. NAVSEA 05C Cost Information Management System historical ship cost database
8. NOLSC Petroleum data on fuel delivery
9. Navy Visibility and Management of Operating & Support Costs (VAMOSC) data for consumption of propulsion fuels by the Navy and MSC fleets
10. Naval Center for Cost Analysis Joint Inflation Calculator, https://www.ncca.navy.mil/tools/inflation.cfm, O&M,N composite inflation rates

APPENDIX B. SPEED VS. PERCENT-TIME PROFILE REFERENCE DATA

This appendix contains speed vs. percent-time profiles for surface ships of the U.S. Navy based on the sources listed in Table B-1 and modified using data from the NEURS over the period FY 1998-2002.

Table B-1. Speed-Time Profile Sources.

Ship Class	Original Sources for Speed-Time Profiles
AOE 6	Based on a previous AOE 1 Class Speed-Time Report 1985
CG 47	Derived from actual engine operating profile data (Westinghouse MTD report)
DD 963	Derived from actual engine operating profile data (Westinghouse MTD report)
DDG 51	Based on the CG 47 Speed-Time Profile derived from actual engine profile data
FFG 7	Derived from actual engine operating profile data (Westinghouse MTD report)
LHA 1	The calculations are based on the LHDX Speed-Time Profile (based on TLR)
LHD 1	The calculations are based on the LHDX Speed-Time Profile (based on TLR)
LSD 41/49	The calculations are based on the TLR for LSD 41 Class
MCM	The calculations are based on actual engine operation data (MCM 3)
MHC 51	The calculations are based on actual engine operation data (MCM 51)

Table B-2. AOE 6 Class (Gas Turbine).

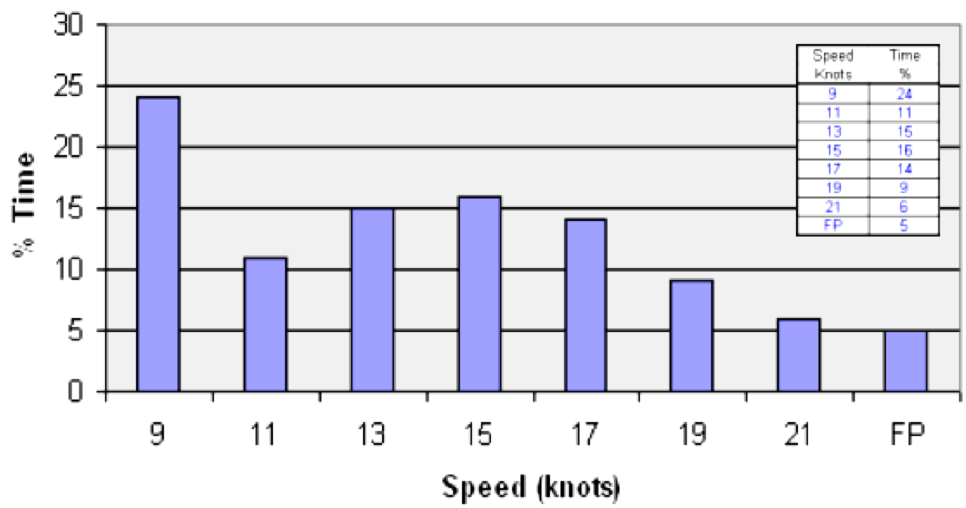


Table B-3. <u>CG 47 Class</u>.

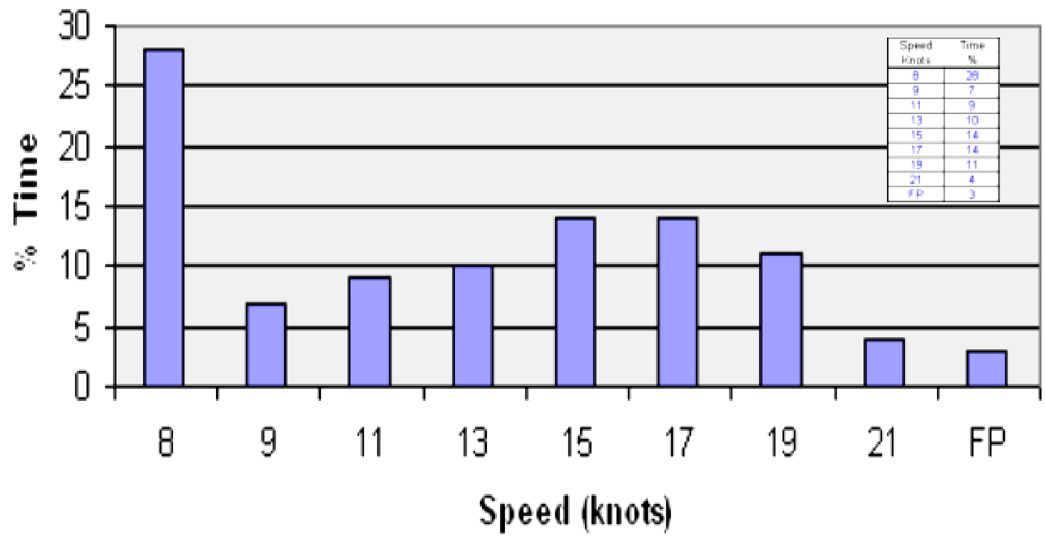


Table B-4. <u>DD 963 Class</u>.

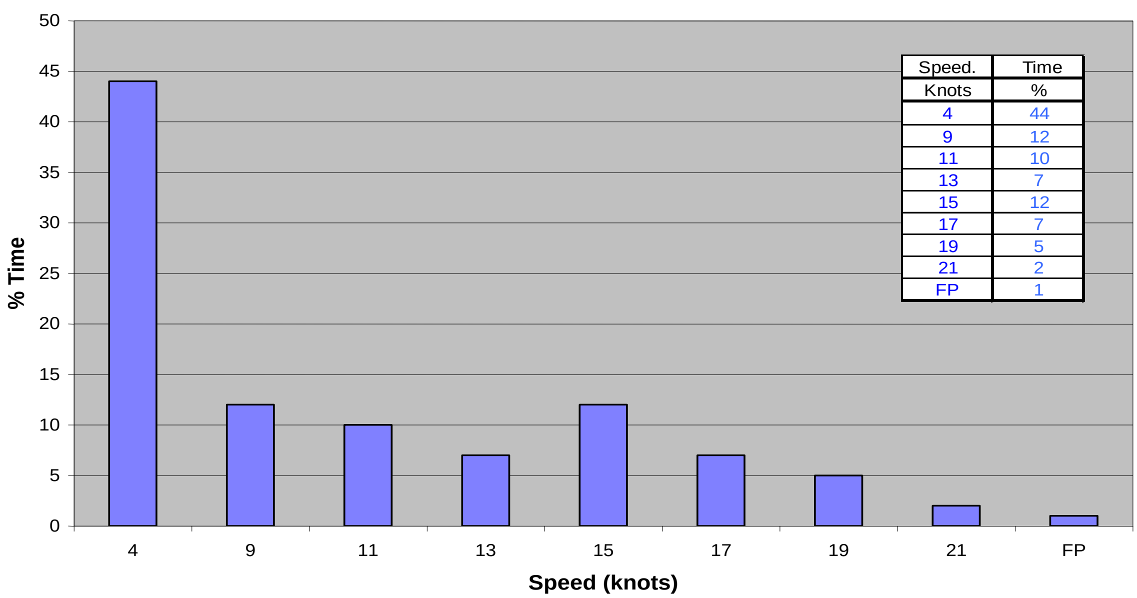


Table B-5. DDG 51 Class.

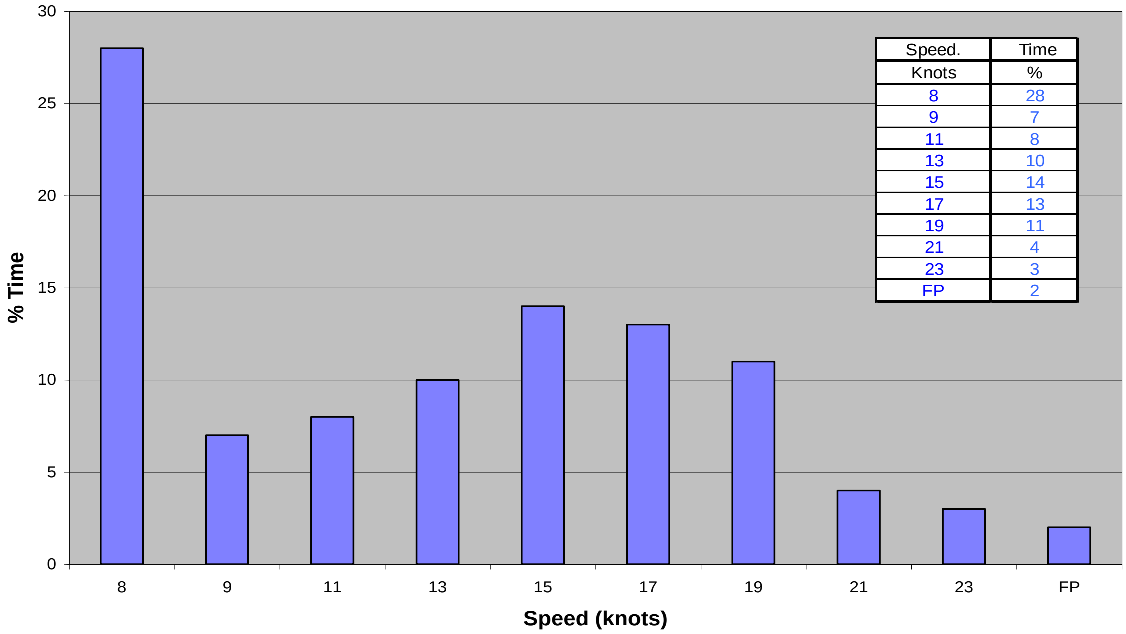


Table B-6. FFG 7 Class.

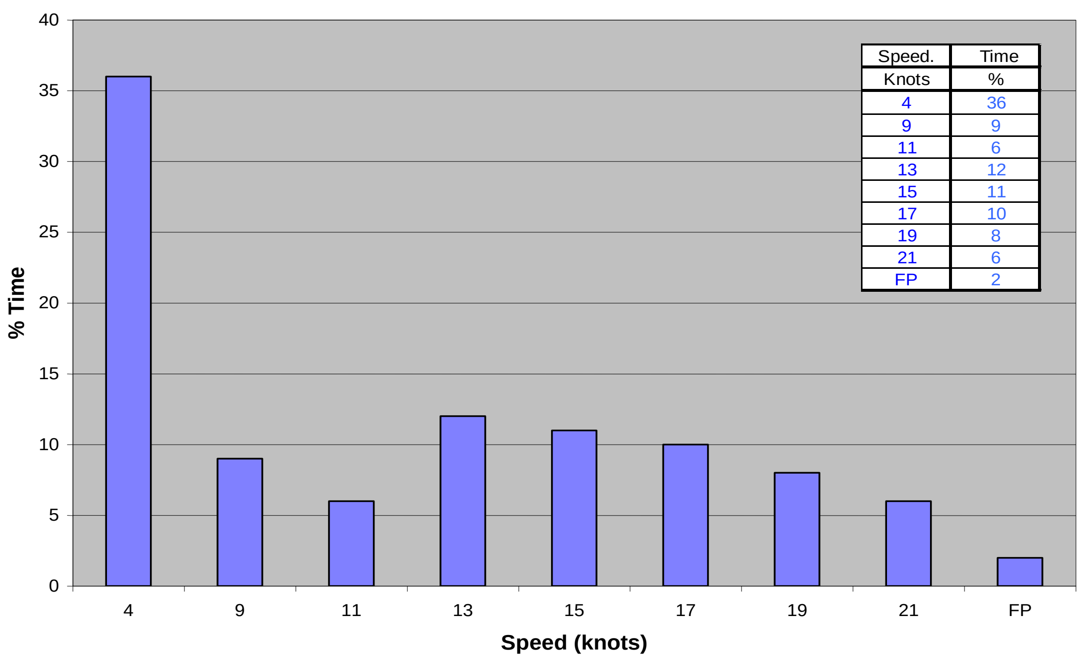


Table B-7. LHA 1 Class.

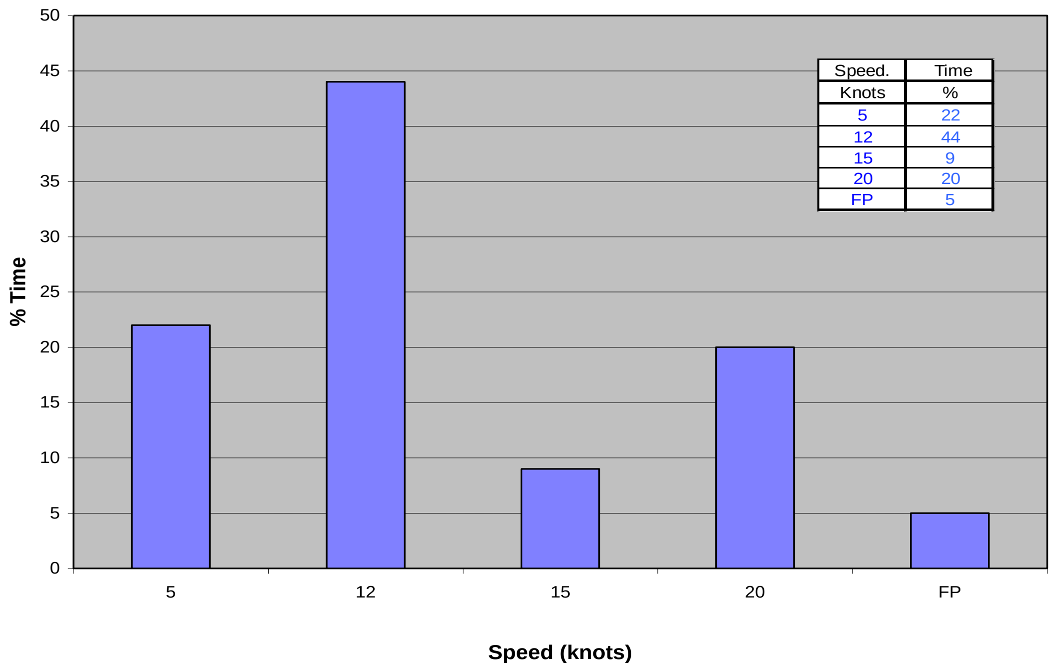


Table B-8. LHD 1 Class.

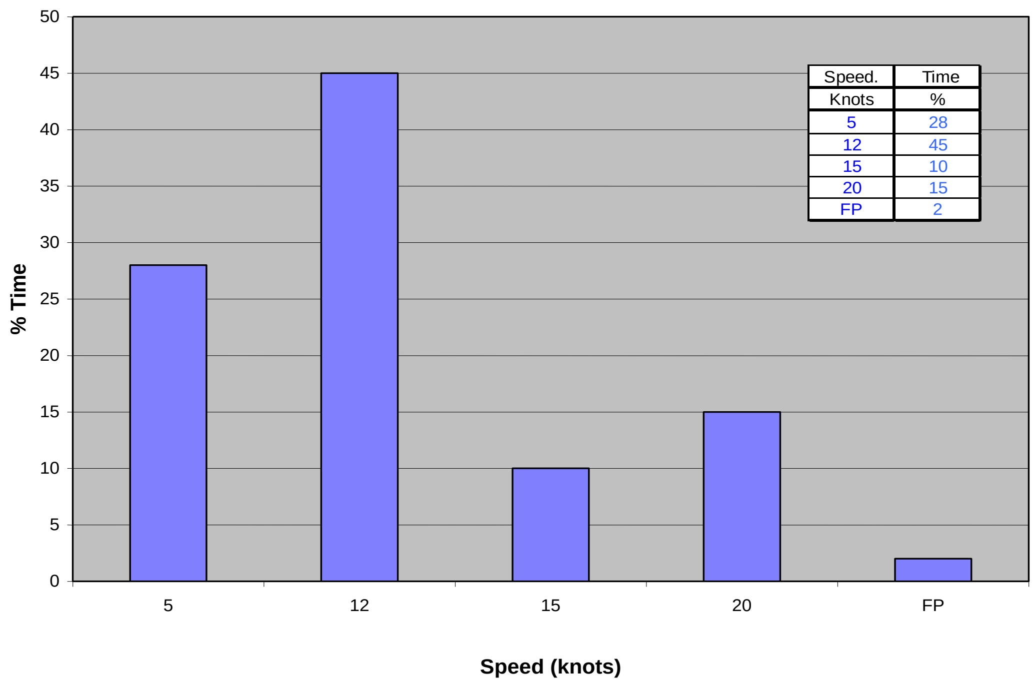


Table B-9. LSD 41 Class (Diesel).

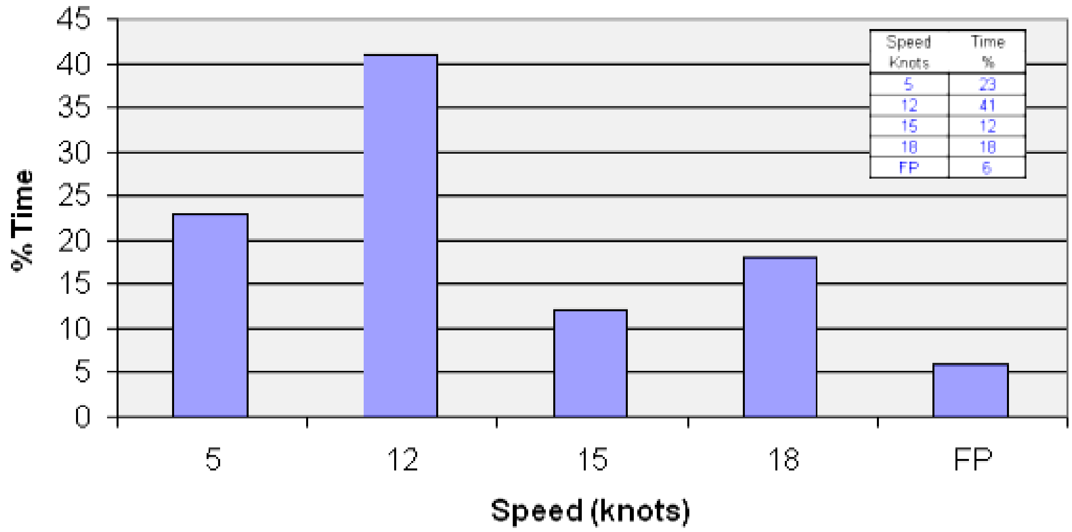


Table B-10. MCM 1 Class.

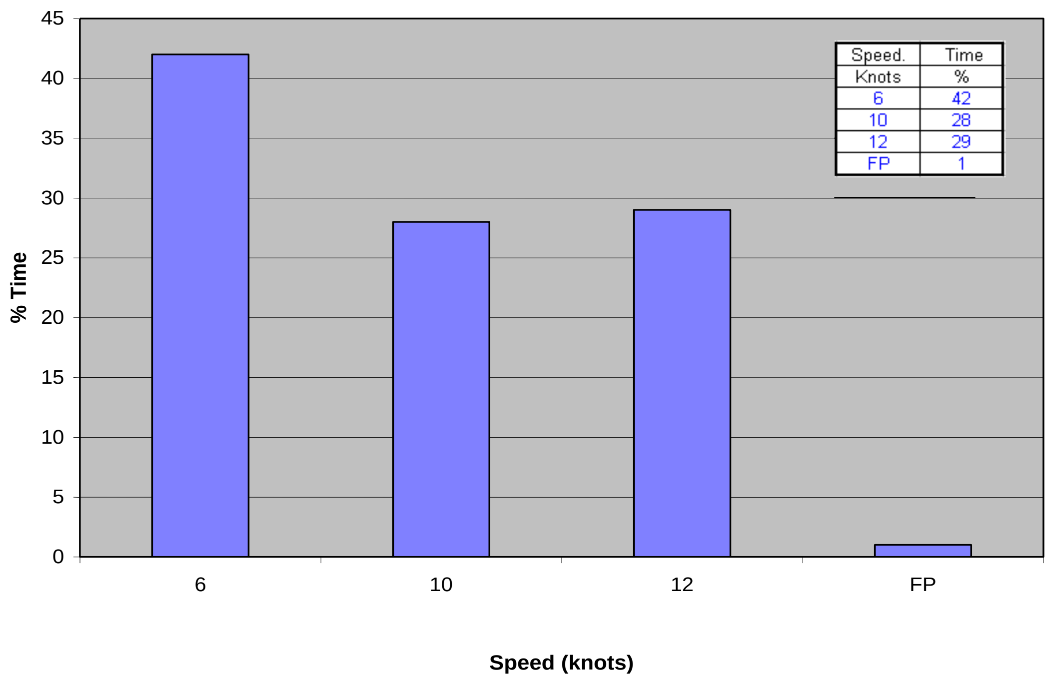
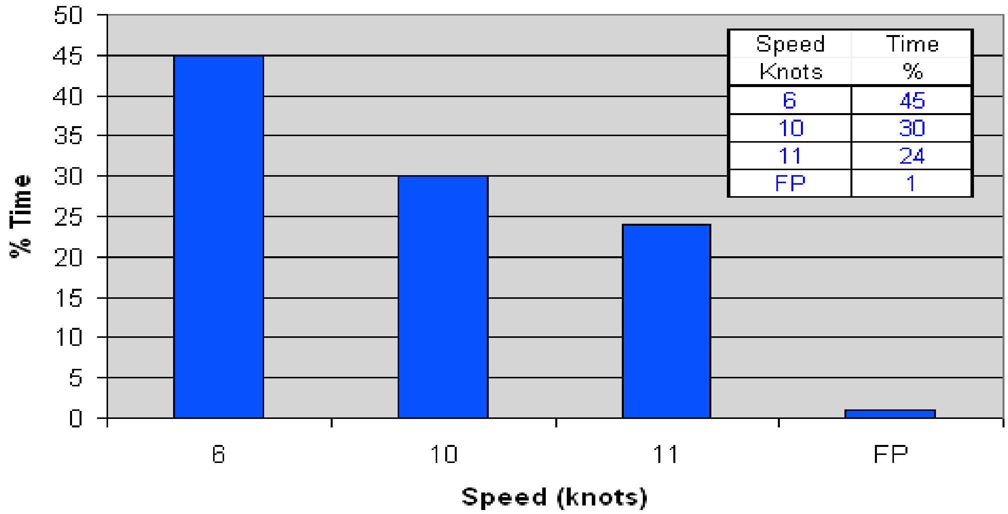


Table B-11. MHC 51 Class.



APPENDIX C. OPERATING HOURS REFERENCE DATA

This appendix contains operating hours and fuel consumption reference data for surface ships of the U.S. Navy based on data from the NEURS over the period FY 1998-2002.

Table C-1. AOE 6 (Gas Turbine) Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2147	1726	72405	7398
1999	2847	1669	115833	7776
2000	2597	1456	102200	7270
2001	3235	1089	124901	5638
2002	2527	836	113499	4049
Average	2671	1355	105768	6426

Table C-2. ARS 50 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	1581	1860	5889	1678
1999	1570	801	5422	881
2000	2064	1522	7112	1649
2001	1573	1056	4677	957
2002	2044	955	6354	1071
Average	1766	1239	5891	1247

Table C-3. AS (AS 33 + AS 39) Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	1107	840	26602	7453
1999	960	809	23645	6993
2000	1338	1282	28875	13713
2001	1467	1474	32133	14289
2002	1201	1074	27842	11332
Average	1215	1096	27819	10756

Table C-4. CG 47 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2636	1160	81849	8144
1999	2663	1029	83115	6960
2000	2448	976	78195	7125
2001	2686	899	84149	6455
2002	3001	862	100970	5821
Average	2687	985	85656	6901

Table C-5. DD 963 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2302	1240	64147	7379
1999	2552	1133	71749	6738
2000	2550	1209	72125	6555
2001	2636	1004	72865	6025
2002	2733	792	78886	5268
Average	2555	1076	71954	6393

Table C-6. DDG 51 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2723	1358	71841	8171
1999	2436	951	65355	5392
2000	2401	1121	66481	6394
2001	2512	914	68070	5314
2002	2745	785	75167	5156
Average	2563	1026	69383	6085

Table C-7. FFG 7 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2329	1109	29001	2262
1999	2417	995	30141	1990
2000	2311	996	30224	2117
2001	2369	859	29363	1641
2002	2466	734	31288	1607
Average	2378	939	30003	1923

Table C-8. LCC 19 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	1917	1655	49617	19276
1999	2258	2597	51829	30498
2000	1490	1419	36512	17730
2001	1639	1545	41528	17396
2002	1966	1467	50493	15961
Average	1854	1737	45996	20172

Table C-9. LHD 1 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2473	1233	108820	19247
1999	2656	1192	122011	19112
2000	2536	1373	107993	23107
2001	2593	1288	113886	21686
2002	3203	883	138777	18354
Average	2692	1194	118297	20301

Table C-10. LSD 41 (Diesel) Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2264	1479	32025	6914
1999	2352	1285	29044	5582
2000	1856	1539	24086	6313
2001	2067	1041	25711	3946
2002	2899	982	38473	3986
Average	2288	1265	29868	5348

Table C-11. LSD 49 (Diesel) Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	2028	1416	25392	6423
1999	1809	1426	23103	6176
2000	2583	1508	34803	7419
2001	2686	1188	36183	5451
2002	3231	889	43663	2957
Average	2467	1285	32629	5685

Table C-12. MCM 1 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	1270	608	1609	278
1999	1867	741	2656	375
2000	1435	565	1926	332
2001	1617	457	2242	279
2002	1569	615	2111	277
Average	1552	597	2109	308

Table C-13. MHC 51 Five Year Class Average 1998-2002.

Year	Underway Hours	Not Underway Hours	Underway Barrels Used	Not Underway Barrels Used
1998	1100	331	1229	124
1999	982	457	1174	205
2000	1330	685	1550	286
2001	1014	325	928	122
2002	1257	411	1243	172
Average	1137	442	1225	182

APPENDIX D. EXAMPLE

D.1 Introduction.

This appendix provides a fictional example demonstrating the mechanics of performing the annual energy usage and annual energy cost calculations for an early stage ship concept. This example is not intended to be representative of any current or future ship in the U.S. Navy.

D.2 Operational profile development.

D.2.1 Operational mode development.

For this fictional ship, an examination of the ships requirements and employment strategy identified the following operational modes:

a. Maintenance and modernization

b. Predeployment training

c. Deployment

d. MCO

D.2.2 Ship state development.

The four operational modes can be characterized by the following ship states:

a. Inport – shore

b. Underway – economical transit

c. Underway – surge to theater

d. Underway – mission

The electric load (including margins, power system efficiencies, and 50 percent of service life allowance) associated with each operational mode are:

Temperature (°F)	**Inport - Shore (kW)**	**Underway - Economical Transit (kW)**	**Underway - Surge to Theater (kW)**	**Underway - Mission (kW)**
	Shore Power	**Generators**	**Generators**	**Generators**
10	1000	3000	3000	4800
59	500	1800	1800	3200
100	900	2400	2400	4000

The inport – shore operational mode does not have any propulsion power associated with it.

For the underway – economical transit operational mode, the design propulsion power is 7100 kW (equally split between two shafts).

For the underway – surge to theater operational mode, the design propulsion power is 46,800 kW (equally split between two shafts).

For the underway –mission operational mode, the design propulsion power is in accordance with the following:

Speed (knots)	Profile % time
5	20%
10	30%
15	25%
20	15%
25	8%
30	2%

D.2.3 Other design details.

a. This ship is not part of a larger class of ships. The deployment and employment profile does not depend on the number and type of other ships in the future naval force architecture.

b. The ship has a design service life of 15 years, with a single year-long modernization overhaul during its midlife. Year 1 is assumed to be 2015.

c. Electric and propulsion plant CONOPS: The propulsion plant consists of two shafts each with a Propulsion Motor Module (PMM) on each shaft. Propulsion power is shared equally between the two PMMs.

The electric plant consists of two 3000 kW gas turbine Auxiliary Turbine Generator (ATG) Power Generation Modules (PGM) and three 24,000 kW gas turbine Main Turbine Generators (MTG) PGMs. At least two PGMs are online at all times. Power is shared evenly (proportional to rating) among all online PGMs. (Note: Power sharing in this manner is not always optimal, but is an acceptable assumption for early stage design.)

d. Power generation configurations:

Power Low (kW)	Power High (kW)	Number MTG	Number ATG
1200	5700	0	2
5700	25650	1	1
25650	45600	2	0
45600	68400	3	0
68400	78000	3	2

e. Propulsion speed power curve:

Speed (knots)	Total Propulsion Shaft Power (kW)	Port Shaft (kW)	Starboard Shaft (kW)	PMM Efficiency
5	217	108	108	0.85
10	1733	867	867	0.89
15	5850	2925	2925	0.90
16	7100	3550	3550	0.91
20	13867	6933	6933	0.92
25	27083	13542	13542	0.94
30	46800	23400	23400	0.94
32.6	60000	30000	30000	0.94

Design propulsion power for smooth, deep water at full load displacement with margins and service life allowance. Measured at the output of PMM. Design motor power per shaft is the electrical power measured at the input to the PMM.

f. Prime mover SFC curves:

(1) MTG SFC:

Power (kW)	**SFC (kg/kW-h)**
2400	0.465
4800	0.375
9600	0.263
14400	0.233
19200	0.210
24000	0.200

Power is measured at the output of the electrical generator.

For power levels below 2400 kW, use a constant fuel rate (kg/h) calculated at 2400 kW.

(2) ATG SFC:

Power (kW)	**SFC (kg/kW-h)**
600	0.66
1200	0.42
1800	0.33
2400	0.27
3000	0.26

Power is measured at the output of the electrical generator.

For power levels below 600 kW, use a constant fuel rate (kg/h) calculated at 600 kW.

g. Plant deterioration allowance: Use default 1.05

h. Sea state and fouling factor: Use default 1.10 for every speed

i. Ambient condition profile: Use default:

Temperature (°F)	**Profile**
10	25%
59	50%
100	25%

j. No embarked vehicles other than rescue boats

D.2.4 Ship state participation table.

For this fictional ship, an examination of the ships requirements and employment strategy identified the following ship state participation table values:

	Inport – shore	**Underway – Economic al Transit**	**Underway – Surge to Theater**	**Underway – Mission**
Maintenance and Modernization	0.9	0.05	0.0	0.05
Predeployment Training	0.6	0.2	0.0	0.2
Deployment	0.1	0.2	0.0	0.7
MCO	0.05	0.15	0.05	0.75

D.2.5 Ship deployment and employment profile.

For this fictional ship, an examination of the ships requirements and employment strategy identified the following ship deployment and employment profiles. For this particular fictional study with the unusually short service life, two profiles were deemed sufficient to provide the requisite insight.

	Low OPTEMPO (fraction of time)				**High OPTEMPO (fraction of time)**			
Year	**Maintenance and Modernization**	**Predeployment Training**	**Deployment**	**MCO**	**Maintenance and Modernization**	**Predeployment Training**	**Deployment**	**MCO**
1	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
2	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
3	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
4	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
5	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
6	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
7	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
8	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
9	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
10	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
11	0.25	0.25	0.5	0.0	0.16	0.17	0.0	0.67
12	0.25	0.25	0.5	0.0	0.16	0.17	0.0	0.67
13	0.25	0.25	0.5	0.0	0.16	0.17	0.0	0.67
14	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0
15	0.25	0.25	0.5	0.0	0.25	0.25	0.5	0.0

Applying these fractions to 8766 hours per year (365.25 days):

	Low OPTEMPO (hours)				High OPTEMPO (hours)			
Year	**Maintenance and Modernization**	**Predeployment Training**	**Deployment**	**MCO**	**Maintenance and Modernization**	**Predeployment Training**	**Deployment**	**MCO**
1	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
2	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
3	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
4	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
5	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
6	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
7	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
8	8766	0.0	0.0	0.0	8766	0.0	0.0	0.0
9	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
10	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
11	2191.5	2191.5	4383	0.0	1402.56	1490.22	0.0	5873.22
12	2191.5	2191.5	4383	0.0	1402.56	1490.22	0.0	5873.22
13	2191.5	2191.5	4383	0.0	1402.56	1490.22	0.0	5873.22
14	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0
15	2191.5	2191.5	4383	0.0	2191.5	2191.5	4383	0.0

D.3 Annual energy usage.

D.3.1 Fuel consumed by ship.

The calculated ship state fuel rate (kg/h) is calculated for each ship state:

a. Inport – shore

For the inport – shore ship state, no fuel is consumed. All power is provided via shore power.

b. Underway – economical transit

See DDS 200-1, Rev 1, Appendix B, section B.3.a for the details of calculating the calculated ship state fuel rate for the underway – economical transit condition. These calculations result in a calculated underway - economical transit fuel rate of 3070 kg/h.

c. Underway – high speed transit

See DDS 200-1, Rev 1, Appendix B, section B.3.b for the details of calculating the calculated ship state fuel rate for the underway – surge to theater condition. These calculations result in a calculated underway - surge to theater fuel rate of 12,028 kg/h.

d. Underway – mission

See DDS 200-1, Rev 1, Appendix B, section B.3.c for the details of calculating the calculated ship state fuel rate for the underway – mission condition. These calculations result in a calculated underway - mission fuel rate of 3150 kg/h.

The calculated operational mode fuel rates are calculated by summing the product of the ship state participation table elements and the appropriate fuel rate:

	Inport - Shore	**Underway - Economical Transit**	**Underway - Surge to Theater**	**Underway - Mission**	**Calculated Operational Mode Fuel Rate (kg/h)**
Fuel Rate(kg/h)	0	3070	12028	3150	
Maintenance and Modernization	90%	5%	0%	5%	311
Predeployment Training	60%	20%	0%	20%	1244
Deployment	10%	20%	0%	70%	2819
MCO	5%	15%	5%	75%	3424

Applying the fuel rates for each operational mode to the ship deployment and employment profile yields the total fuel consumed each year and the total fuel consumed over the service life.

Low OPTEMPO:

Year	**Maintenance and Modernization (1000 kg)**	**Predeployment Training (1000 kg)**	**Deployment (1000 kg)**	**MCO (1000 kg)**	**Total Fuel (1000 kg)**
1	682	2,726	12,356	0	15,763
2	682	2,726	12,356	0	15,763
3	682	2,726	12,356	0	15,763
4	682	2,726	12,356	0	15,763
5	682	2,726	12,356	0	15,763
6	682	2,726	12,356	0	15,763
7	682	2,726	12,356	0	15,763
8	2,726	0	0	0	2,726
9	682	2,726	12,356	0	15,763
10	682	2,726	12,356	0	15,763
11	682	2,726	12,356	0	15,763
12	682	2,726	12,356	0	15,763
13	682	2,726	12,356	0	15,763
14	682	2,726	12,356	0	15,763
15	682	2,726	12,356	0	15,763
				Lifetime Fuel (1000 kg)	223,415

High OPTEMPO:

Year	Maintenance and Modernization (1000 kg)	Predeployment Training (1000 kg)	Deployment (1000 kg)	MCO (1000 kg)	Total Fuel (1000 kg)
1	682	2,726	12,356	0	15,763
2	682	2,726	12,356	0	15,763
3	682	2,726	12,356	0	15,763
4	682	2,726	12,356	0	15,763
5	682	2,726	12,356	0	15,763
6	682	2,726	12,356	0	15,763
7	682	2,726	12,356	0	15,763
8	2,726	0	0	0	2,726
9	682	2,726	12,356	0	15,763
10	682	2,726	12,356	0	15,763
11	682	2,726	0	20,112	22,402
12	682	2,726	0	20,112	22,402
13	682	2,726	0	20,112	22,402
14	682	2,726	12,356	0	15,763
15	682	2,726	12,356	0	15,763
				Lifetime Fuel (1000 kg)	243,331

D.3.2 Shore power used by the ship.

The average shore power used for the inport – shore ship state is obtained by applying the ambient condition profile to the electrical loads at each temperature:

Temperature (°F)	Inport - Shore (kW)	Profile	Weighted Shore Power (kW)
10	1000	0.25	250
59	500	0.5	250
100	900	0.25	225
		Average Power Inport - Shore (kW)	725

This average shore power for the inport – shore ship state is applied to the ship state participation table to obtain the average shore power for each operational mode.

	Inport - Shore	Underway - Economical Transit	Underway - Surge to Theater	Underway - Mission	Average Shore Power (kW)
Shore Power(Kw)	725	0	0	0	
Maintenance and Modernization	90%	5%	0%	5%	653
Predeployment Training	60%	20%	0%	20%	435
Deployment	10%	20%	0%	70%	73
MCO	5%	15%	5%	75%	36

Applying the average shore power for each operational mode to the ship deployment and employment profile yields the total shore power (kW-h) consumed each year and the total shore power (kW-h) consumed over the service life.

Low OPTEMPO:

Year	Maintenance and Modernization (1000 kW-h)	Predeployment Training (1000 kW-h)	Deployment (1000 kW-h)	MCO (1000 kW-h)	Total Shore Power (1000 kW-h)
1	1,430	953	318	0	2,701
2	1,430	953	318	0	2,701
3	1,430	953	318	0	2,701
4	1,430	953	318	0	2,701
5	1,430	953	318	0	2,701
6	1,430	953	318	0	2,701
7	1,430	953	318	0	2,701
8	5,720	0	0	0	5,720
9	1,430	953	318	0	2,701
10	1,430	953	318	0	2,701
11	1,430	953	318	0	2,701
12	1,430	953	318	0	2,701
13	1,430	953	318	0	2,701
14	1,430	953	318	0	2,701
15	1,430	953	318	0	2,701
				Lifetime Shore Power (1000 kW-h)	43,534

High OPTEMPO:

Year	Maintenance and Modernization (1000 kW-h)	Predeployment Training (1000 kW-h)	Deployment (1000 kW-h)	MCO (1000 kW-h)	Total Shore Power (1000 kW-h)
1	1,430	953	318	0	2,701
2	1,430	953	318	0	2,701
3	1,430	953	318	0	2,701
4	1,430	953	318	0	2,701
5	1,430	953	318	0	2,701
6	1,430	953	318	0	2,701
7	1,430	953	318	0	2,701
8	5,720	0	0	0	5,720
9	1,430	953	318	0	2,701
10	1,430	953	318	0	2,701
11	915	648	0	213	1,776
12	915	648	0	213	1,776
13	915	648	0	213	1,776
14	1,430	953	318	0	2,701
15	1,430	953	318	0	2,701
				Lifetime Shore Power (1000 kW-h)	40,760

D.3.3 Fuel consumed by embarked vehicles.

For this example, the fuel consumed by the rescue boats is considered negligible.

D.4 FBCE.

D.4.1 Fully burdened cost of fuel.

Estimated DLA Energy price:

The crude oil price used for this example is the reference case for imported low sulfur light crude oil as projected by the AEO 2011 in FY09 dollars as shown in Figure D-1. A complete analysis would repeat the calculations using the high oil price and low oil price to gain an understanding of the impact of the expected variance in fuel costs. Alternately, a study could use a stochastic model that considered the AEO projected D.4.1 high and low prices.

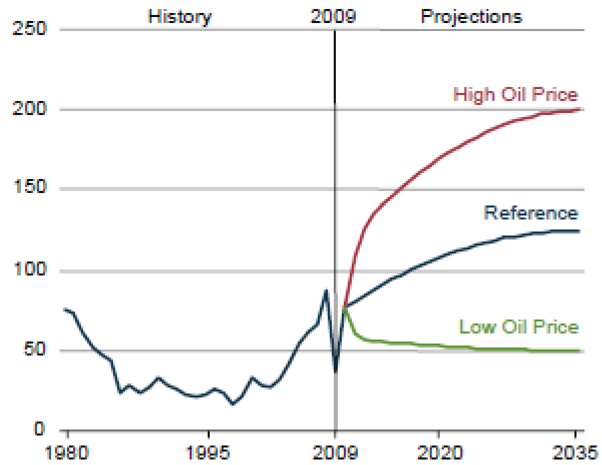


Figure D-1. AEO 2011 Projected Average Annual World Oil Prices (2009 Dollars Per Barrel).

The Refined Product element is estimated as 30 percent of the crude oil price. The storage, transport, and management is from Table 6-1 (FY11 dollars).

Year	Crude Oil Price ($/bbl)	Refined Product ($/bbl)	Adjustments ($/bbl)	Storage Transport, & Management ($/bbl)	Estimated DLA Energy Price $/bbl
2015	$94.58	$28.37	$0.00	$14.60	$137.55
2016	$97.28	$29.19	$0.00	$14.60	$141.07
2017	$99.99	$30.00	$0.00	$14.60	$144.58
2018	$102.69	$30.81	$0.00	$14.60	$148.10
2019	$105.40	$31.62	$0.00	$14.60	$151.61
2020	$108.10	$32.43	$0.00	$14.60	$155.13
2021	$109.99	$33.00	$0.00	$14.60	$157.58
2022	$111.88	$33.56	$0.00	$14.60	$160.04
2023	$113.76	$34.13	$0.00	$14.60	$162.49
2024	$115.65	$34.70	$0.00	$14.60	$164.95
2025	$117.54	$35.26	$0.00	$14.60	$167.40
2026	$118.65	$35.60	$0.00	$14.60	$168.85
2027	$119.76	$35.93	$0.00	$14.60	$170.29
2028	$120.87	$36.26	$0.00	$14.60	$171.73
2029	$121.98	$36.59	$0.00	$14.60	$173.17

Burden estimates:

Storage and Handling: $0.05 per barrel (FY11) (see Table A-3).

Fuel Delivery Ship Acquisition/Depreciation: $11.67 (FY11) (see Table A-3).

Fuel Delivery Ship O&S: $30.34 (FY11) (see Table A-3).

Environmental: $4.20 (see Table A-3).

Year	DLA Energy Estimate ($/bbl)	Storage and Handling ($/bbl)	Depreciation ($/bbl)	Fuel Delivery ($/bbl)	Environmental ($/bbl)	Other ($/bbl)	Fully Burdened Price ($/bbl)	Fully Burdened Price ($/kg)
2015	$137.55	$0.05	$11.67	$30.34	$4.20	$0.00	$183.81	$1.37
2016	$141.07	$0.05	$11.67	$30.34	$4.20	$0.00	$187.33	$1.40
2017	$144.58	$0.05	$11.67	$30.34	$4.20	$0.00	$190.84	$1.42
2018	$148.10	$0.05	$11.67	$30.34	$4.20	$0.00	$194.36	$1.45
2019	$151.61	$0.05	$11.67	$30.34	$4.20	$0.00	$197.87	$1.48
2020	$155.13	$0.05	$11.67	$30.34	$4.20	$0.00	$201.39	$1.50
2021	$157.58	$0.05	$11.67	$30.34	$4.20	$0.00	$203.84	$1.52
2022	$160.04	$0.05	$11.67	$30.34	$4.20	$0.00	$206.30	$1.54
2023	$162.49	$0.05	$11.67	$30.34	$4.20	$0.00	$208.75	$1.56
2024	$164.95	$0.05	$11.67	$30.34	$4.20	$0.00	$211.21	$1.58
2025	$167.40	$0.05	$11.67	$30.34	$4.20	$0.00	$213.66	$1.59
2026	$168.85	$0.05	$11.67	$30.34	$4.20	$0.00	$215.11	$1.61
2027	$170.29	$0.05	$11.67	$30.34	$4.20	$0.00	$216.55	$1.62
2028	$171.73	$0.05	$11.67	$30.34	$4.20	$0.00	$217.99	$1.63
2029	$173.17	$0.05	$11.67	$30.34	$4.20	$0.00	$219.43	$1.64
Note: Assume 134 kg/bbl.								

D.4.2 Fully burdened cost of shore power.

Assume a constant price for shore power of $.089 (FY09) per kW-h as projected by the AEO. Escalated to FY11, this equals $0.095 per kW-h.

D.5 Annual energy cost.

Low OPTEMPO annual cost of energy table:

Year	Price Per kg	1000 kg Fuel	Fuel Cost	Price Per kW-h	Shore Power (1000 kW-h)	Electricity Cost	Total Energy Cost
2015	$1.37	15,763	$21,623,467	$0.095	2,701	$256,597	$21,880,064
2016	$1.40	15,763	$22,036,987	$0.095	2,701	$256,597	$22,293,584
2017	$1.42	15,763	$22,450,507	$0.095	2,701	$256,597	$22,707,104
2018	$1.45	15,763	$22,864,027	$0.095	2,701	$256,597	$23,120,625
2019	$1.48	15,763	$23,277,548	$0.095	2,701	$256,597	$23,534,145
2020	$1.50	15,763	$23,691,068	$0.095	2,701	$256,597	$23,947,665
2021	$1.52	15,763	$23,979,798	$0.095	2,701	$256,597	$24,236,395
2022	$1.54	2,726	$4,197,143	$0.095	5,720	$543,382	$4,740,525
2023	$1.56	15,763	$24,557,258	$0.095	2,701	$256,597	$24,813,856
2024	$1.58	15,763	$24,845,988	$0.095	2,701	$256,597	$25,102,586
2025	$1.59	15,763	$25,134,719	$0.095	2,701	$256,597	$25,391,316
2026	$1.61	15,763	$25,304,470	$0.095	2,701	$256,597	$25,561,067
2027	$1.62	15,763	$25,474,221	$0.095	2,701	$256,597	$25,730,818
2028	$1.63	15,763	$25,643,972	$0.095	2,701	$256,597	$25,900,570
2029	$1.64	15,763	$25,813,724	$0.095	2,701	$256,597	$26,070,321
Lifetime		223,415	$340,894,897		43,534	$4,135,744	**$345,030,641**

High OPTEMPO annual cost of energy table:

Year	Price Per kg	1000 kg Fuel	Fuel Cost	Price Per kW-h	Shore Power (1000 kW-h)	Electricity Cost	Total Energy Cost
2015	$1.37	15,763	$21,623,467	$0.095	2,701	$256,597	$21,880,064
2016	$1.40	15,763	$22,036,987	$0.095	2,701	$256,597	$22,293,584
2017	$1.42	15,763	$22,450,507	$0.095	2,701	$256,597	$22,707,104
2018	$1.45	15,763	$22,864,027	$0.095	2,701	$256,597	$23,120,625
2019	$1.48	15,763	$23,277,548	$0.095	2,701	$256,597	$23,534,145
2020	$1.50	15,763	$23,691,068	$0.095	2,701	$256,597	$23,947,665
2021	$1.52	15,763	$23,979,798	$0.095	2,701	$256,597	$24,236,395
2022	$1.54	2,726	$4,197,143	$0.095	5,720	$543,382	$4,740,525
2023	$1.56	15,763	$24,557,258	$0.095	2,701	$256,597	$24,813,856
2024	$1.58	15,763	$24,845,988	$0.095	2,701	$256,597	$25,102,586
2025	$1.59	22,402	$35,720,275	$0.095	1,776	$168,750	$35,889,026
2026	$1.61	22,402	$35,961,518	$0.095	1,776	$168,750	$36,130,268
2027	$1.62	22,402	$36,202,760	$0.095	1,776	$168,750	$36,371,511
2028	$1.63	15,763	$25,643,972	$0.095	2,701	$256,597	$25,900,570
2029	$1.64	15,763	$25,813,724	$0.095	2,701	$256,597	$26,070,321
Lifetime		243,331	$372,866,041		40,760	$3,872,204	**$376,738,245**

The lifecycle cost of energy for the Low OPTEMPO case is $345M.

The lifecycle cost of energy for the High OPTEMPO case is $377M.

The average annual energy cost for the Low OPTEMPO case is $23M.

The average annual energy cost for the High OPTEMPO case is $25M.