Reference Energy System Analysis of A Generic Ship

Egemen Sulukan, Doğuş Özkan, and Alperen Sari

Abstract—**With the ever increase of population and technology development, energy consumption and demand have increased in diminishing sources worldwide. Therefore, energy system analysis has been an important topic to control energy consumption against limited sources in the last decade. In the light of climate change, the governments and organizations have been released new environmental regulations on energy consumption and emissions in maritime sector to reduce the effects of climate change. In this study, energy consumption characteristics and energy demand segments of a generic ship were evaluated by energy system analysis approach and simplified energy network, namely Reference Energy System (RES) is developed. On this basis, data-driven and technology-rich RES will be available to help prospective analyses on a base scenario. Furthermore, the respective energy model of a generic ship will be ready to be developed and analyzed, taking into account technical, economic and ecological constraints.**

Index Terms—**Reference energy system, ship energy system analysis, energy modelling, energy efficiency.**

I. Introduction

A ship is a complex energy system in the sea and fossil fuels are currently the most used fuel in ships. The broad discussion on whether ship-source greenhouse gas (GHG) emissions are classified as marine pollution has put off the international regulation and subsequent implementation to restrain the carbon emissions from the shipping sector [1]. International standards have been approved for increasing prices of fossil fuels, increasing environmental pollution caused by GHG and for increasing the energy efficiency of ships in the world [2]. Low freight rates, fluctuating fuel prices, stricter environmental regulations, and expectations to reduce GHG emissions make the current situation especially challenging for the shipping industry [3].

Marine Environment Protection Committee (MEPC) has been established by the International Maritime Organization (IMO) in order to protect the interest of the marine environment and ecosystem. The first climate change treaty after the Kyoto Protocol was made in July 2011, for all ships at MEPC 62 in order to reduce the impacts of climate change.

Important guidelines are produced by IMO aiming to support the implementation of the mandatory measures to increase energy efficiency and reduce GHG emissions from international shipping, encompassing the regulation on the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) to be applied by Administration and industry [4].

The projected increase in world trade points prospective challenges to meet a future target for emissions required to achieve stabilization in global temperatures. IMO has initiated the possible options for further technical and operational measures to improve the energy efficiency of ships [5].

II. The Significance of Ship Energy System Analysis

Ships are one of the most important transportation and trade vehicles in our world. Ship-sourced GHG emissions could increase by up to 250% by 2050 from 2012 levels, owing to increasing global freight volumes [6]. Unchecked, such emissions levels are projected to constitute 17% of the global CO_2 emissions by 2050 from the current figure of approximately 2% [7]. Efforts are being made on energy efficiency in ship design and ship lifecycle to reduce the environmental impacts of pollutant emissions for ships.

Increasing the energy efficiency of a ship mainly allows reducing fuel consumption and carbon dioxide emissions. In recent years, research and development efforts recorded to improve ship energy efficiency, from the improvement of existing components to the development of state of art technology solutions [2].

There have been significant studies analyzing the lifecycle analyses of ships, focusing the maritime transportation from the shipbuilding to dismantling phases; including the operation and maintenance issues [8]. In particular, Baldi et. al. focused on a ship's energy system in the case of a chemical tanker, in terms of energy analysis methodology to is applied to evaluate the different energy flows [9].

Fossil fuels are the most important primary energy source and the relevant price fluctuates drastically according to sociopolitical dynamics [10]. A high dependency on energy commodity imports addresses a total increase in the total cost and the risks of the supply security [11]. In this respect, the energy system of a ship should be carefully analyzed, with a holistic approach; taking into account the technology, economy and environmental issues under the same spot.

III. Reference Energy System Concept

A structure called Reference Energy System (RES) is a set of parameters that describe the characteristics of technologies and resources used to achieve energy balance, basically including fixed and variable costs, technology availability, performance and pollutant emissions. The RES

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is a network representation of all of the technology activities required to supply various forms of energy to end-use activities [12].

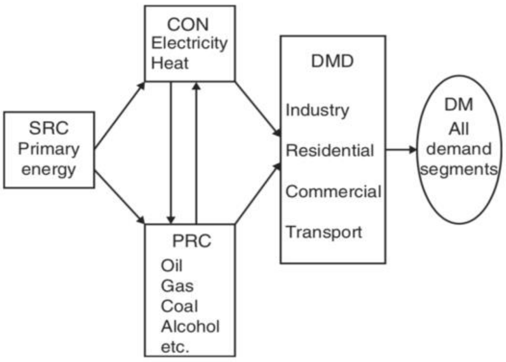

Fig. 1. Simplified representation of a typical RES [13].

Fig. 1 gives a simplified representation of a typical RES showing the five main components usually recognized in each model structure: primary energy sources (SRC), energy conversion technologies (CON), other energy processing (PRC) and energy end uses (DMD), and the demands (DM) for energy services and energy products [13]. The RES is a flowchart showing all possible routes from each source of primary energy through various transformation steps to each end-use demand sector. The flowchart can be extended to show emissions when energy is transported or converted to another [14]. The RES is defined for a specific time snapshot of interest (i.e.1985 or 2000) and serves as the framework for assessment by replacing an existing technology or energy requirement with the one under observation [14].

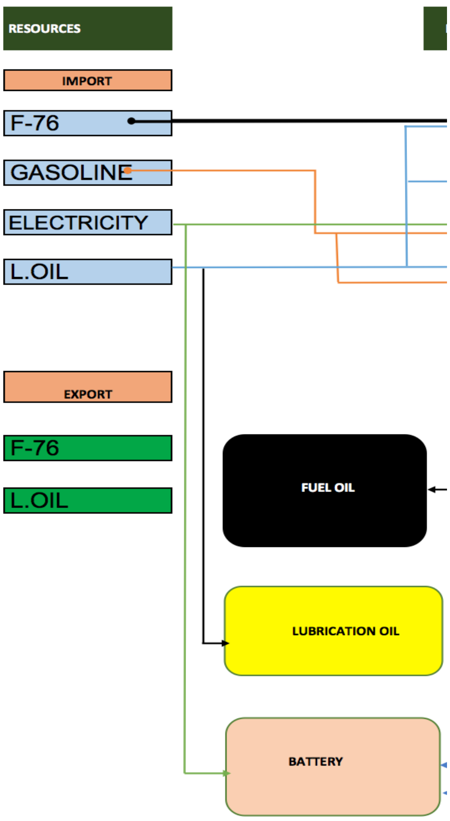

Fig. 2. Resource technologies of a generic ship.

IV. Implementation of RES Concept on Board

Reference Energy System of a ship represents the general structure of the energy flows from resource to demands throughout every step within the conversion process, and end-use technologies [13]. A generalized RES of a generic ship is shown in Fig. 4. Proposed RES consists of six main columns.

A. *Resource Technologies (Import-Export)*

A ship has different kinds of resources classified in the RES as imports and exports are shown in Fig. 2. Fuel is the main energy resource for a ship. In this ship; F-76, lubricating oil, and gasoline are used as fuel types. Electricity taken from shore-grid is another supply resource for a ship, as one of the significant inputs.

B. *Primary Energy Carriers*

Energy resources enter the Ship Energy System with primary energy carriers of F-76, gasoline, electricity and lubricating oil is shown in Fig. 3.

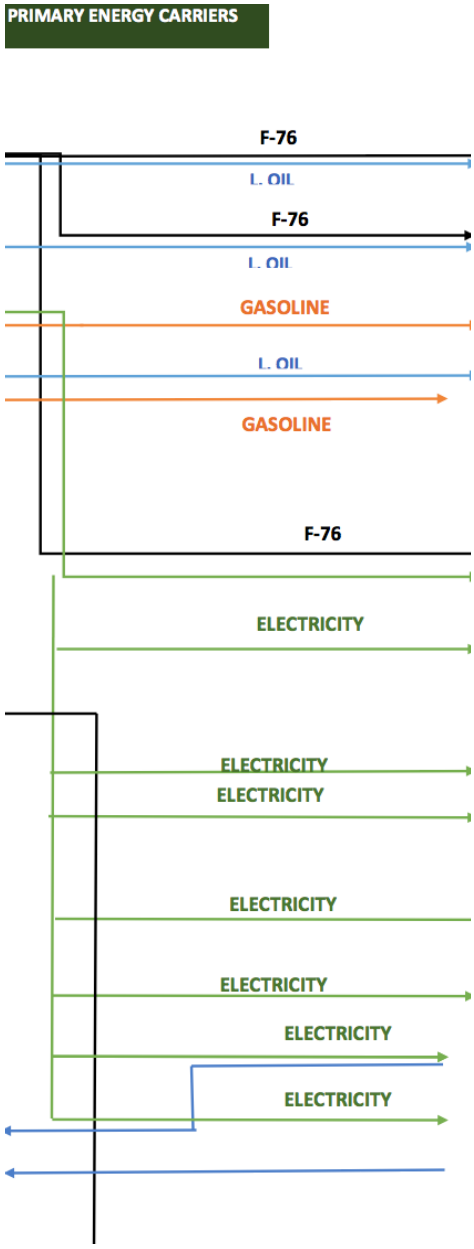

Fig. 3. Primary energy carriers of a generic ship.

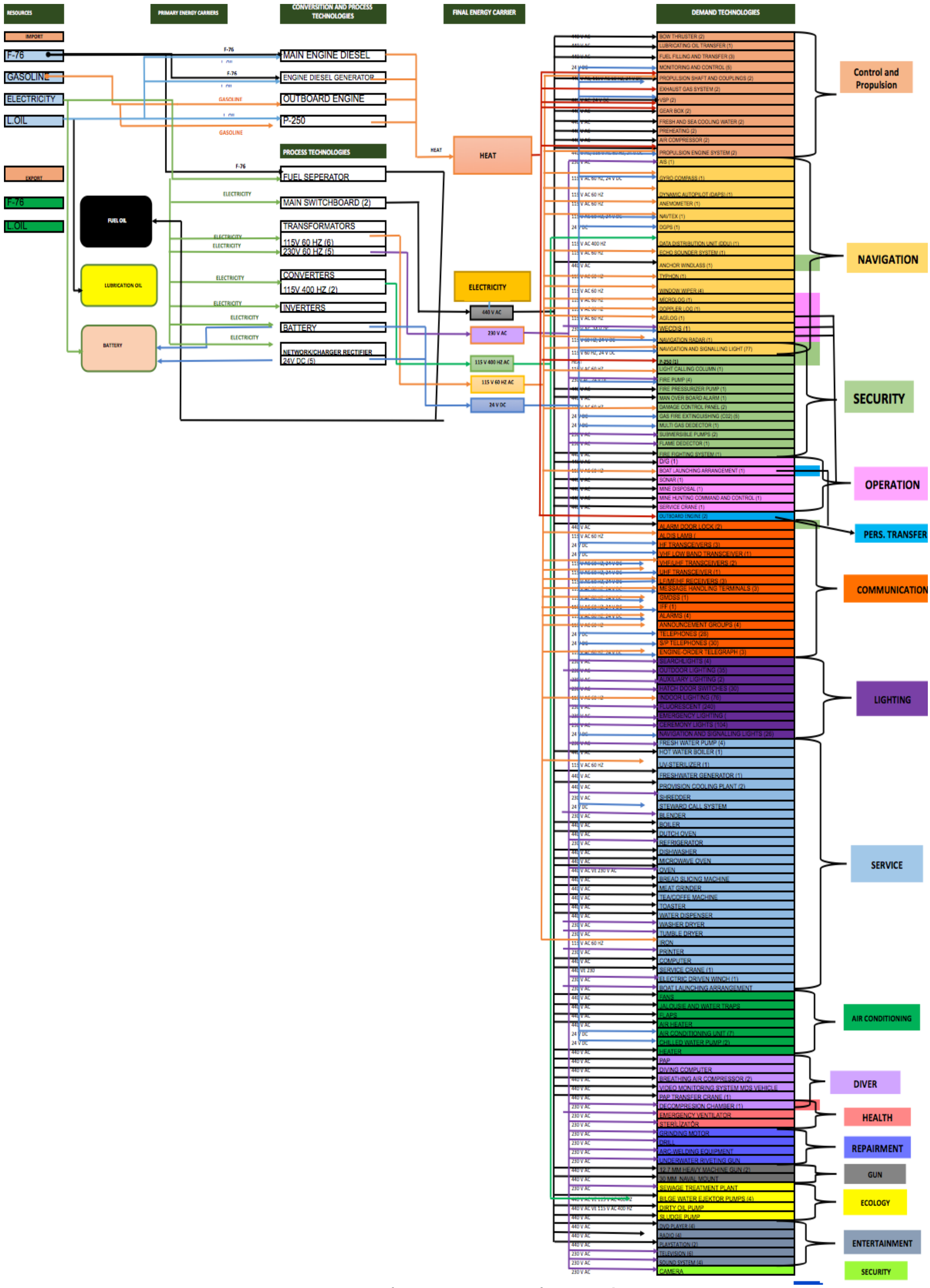

Fig. 4. Reference energy system of a generic ship.

C. Conversion Technologies

Some of the primary energy carriers converted to final energy carriers partially by conversion or process technologies. Conversion technologies are utilized for converting primary energy carriers to final energy carriers as electricity or heat [14]. Conversion technologies are shown in Fig. 5, Main engine diesel, Diesel and generator group, outboard engine and portable fire pump (P-250) are specified as the conversion technologies on a ship.

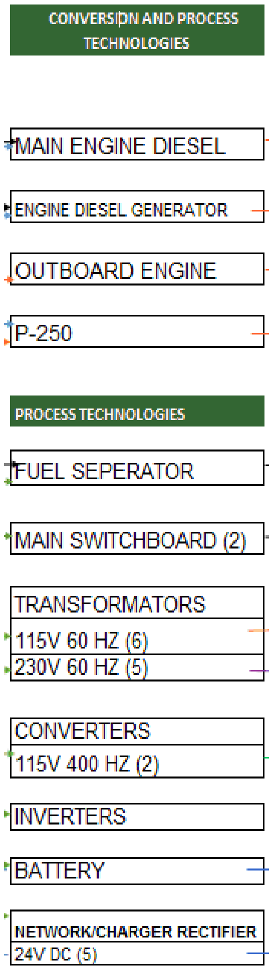

Fig. 5. Conversion and process technologies of a generic ship.

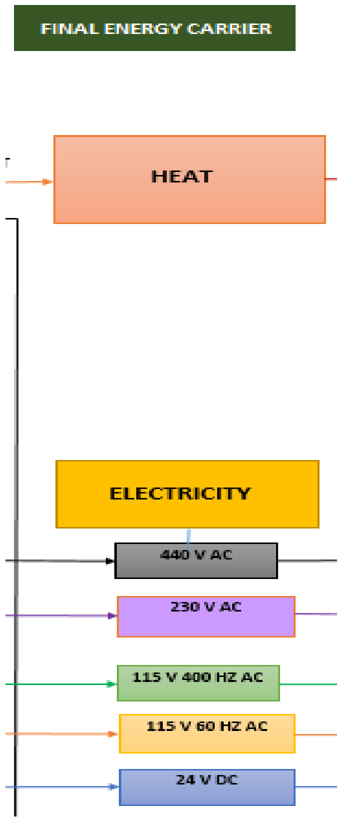

Fig. 6. Final energy technologies of a generic ship.

D. Process Technologies

Process technologies are those that change the form, characteristics or location of energy. Process technologies are utilized for mainly obtaining final energy carriers from primary forms [15]. Process technologies identified and shown in Fig. 5 are as follows: Fuel separator, transformers, converters, inverters, and rectifiers.

E. Storage Technologies

Ships have to store some energy resources required while sailing. So, ships have storage tanks for fuel, gasoline and different lubricating oil types. Ships also need electricity stored in batteries in case of emergency use.

F. Final Energy Carriers

Final energy carriers are specified as electricity and heat in a ship as shown in Fig. 6.

G. Demand Technologies

Demand technologies are those devices that are used to satisfy end-user service demands directly, including vehicles, pumps and electrical devices [14]. Demand technologies in a generic ship are shown in Table I.

TABLE I: DEMAND TECHNOLOGIES OF A GENERIC SHIP

Demand Technologies	**Demands**
Bow Thruster	CONTROL AND PROPULSION
Lubricating Oil Transfer	
Fuel Filling and Transfer	
Monitoring and Control	
Propulsion Shaft and Couplings	
Exhaust Gas System	
VSP	
Gear Box	
Fresh and Sea Cooling Water	
Preheating System	
Air Compressor	
Propulsion Engine System	
AIS	NAVIGATION
Gyro Compass	
Dynamic Autopilot (DAPS)	
Anemometer	
NAVTEX	
DGPS	
Echo Sounder System	
Anchor	
Typhon	
Microlog	
Demand Technologies	**Demands**
Window Wiper	NAVIGATION
Doppler Log	
Agilog	
Navigation and Signaling Lights	
Navigation Radar	
Portable Control Desk	
P-250	SAFETY
Light Calling Column	
Fire Pump	
Fire Pressurizer Pump	
Man Over Board Alarm	
Damage Control Panel	
Gas Fire Extinguishing (CO2)	
Multi Gas Detector	
Submersible Pumps	
Outboard Engine	
D.A.D. Alarm	
Fire Fighting System	
D/G	OPERATION
Boat Launching Arrangement	

Sonar	
Service Crane	
Outboard Engine	PERS. TRANSFER
Alarm Door Lock	COMMUNICATION
Aldis Lamb	
HF Transceivers	
VHF Low Band Transceivers	
UHF Transceivers	
LF/MF/HF Receivers	
Message Handling Terminals	
GMDSS	
Alarms	
Announcement Groups	
Telephones	
S/P Telephones	
Engine-Order Telegraph	
Searchlights	LIGHTING
Outdoor Lighting	
Auxiliary Lighting	
Hatch Door Switches	
Indoor Lighting	
Fluorescent	
Emergency Lighting	
Ceremony Lights	
Navigation and Signaling Lights	
Fresh Water Pump	SERVICE
Hot Water Boiler	
UV-Sterilizer	
Freshwater Generator	
Provision Cooling Plant	
Shredder	
Steward Call System	
Blender	
Boiler	
Dutch Oven	
Refrigerator	
Dishwasher	
Microwave Oven	
Oven	
Bread Slicing Machine	
Meat Grinder	
Tea/Coffee Machine	
Toaster	
Water Dispenser	
Washer Dryer	
Tumble Dryer	
Iron	

Demand Technologies	**Demands**
Printer	SERVICE
Computer	
Service Crane	
Electric Driven Winch	
Boat Launching Equipment	
Fans	AIR CONDITIONING
Jalousie and Water Traps	
Flaps	
Air Heater	
Air Conditioning Unit	
Chilled Water Pump	
Heater	
PAP	DIVING SYSTEMS
Diving Computer	
Breathing Air Compressor	
Video Monitoring System	
PAP Transfer Crane	
Decompression Chamber	
Emergency Ventilator	MEDICAL
Sterilizator	
Grinding Motor	REPAIRMENT
Drill	
Arc-Welding Equipment	
Underwater Riveting Gun	
Sewage Treatment Plant	ENVIRONMENTAL PROTECTION
Bilge Water Ejector Pumps	
Dirty Oil Pump	
Sludge Pump	
DVD Player	ENTERTAINMENT
Radio	
Entertainment Console	
Television	
Sound System	
Camera	SECURITY

H. Demands

While developing the RES of a generic ship, demands are determined in time by analyzing the rest of the RES in detail [12]. A generic ship's demands are determined and given in Table I.

V. Results

In this paper, a complete energy system analysis is made for a generalized ship profile. A ship energy-system analysis model, including the whole energy inputs, satisfied demands, and relevant technologies have been determined and classified in terms of energy system analysis basis, from reference energy system point of view.

VI. Conclusion

In this study, the interaction and interrelations within a generalized ship energy system are analyzed from reference energy system perspective. Energy carriers are specified for a ship RES; namely primary and final energy carriers. Energy technologies are involved stepwise as conversion, process and end-use technologies in terms of their role on-board. The whole energy system is illustrated as a specified network; characterizing the energy input/output processes in relevant supply/demand phases.

As the future work, the proposed RES will be specified with actual data and the appropriate parameters will be assigned in the next step. Then, the current situation of the energy system will be analyzed as the base case. Following this phase; technical, economic and environmental constraints will be applied and run against the base scenario in order to foresee the lifecycle of the analyzed ship energy system including financial and environmental aspects.

Disclaimer*—The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied of Turkish Armed Forces, National Defense University, and any affiliated organization or government.*

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