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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

REFERENCE ENERGY SYSTEM ANALYSIS OF A WARSHIP*

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ABSTRACT

Considering the growing maritime sector in today's conditions, it is of great importance to use the energy used in ship systems in the most efficient and cost-effective manner. The greenhouse gas emissions caused by this energy network emerge as a big problem that needs to be solved. The International Maritime Organization (IMO) has been working since 1958 to control the ship's CO2 emission problem. In this study, a warship was examined as an example in the first stage and the current situation was revealed with Reference Energy System Analysis, taking into account the existing technologies. As a second step, the study in question has handled various scenarios with the Long-range Energy Alternatives Planning System (LEAP) software, which transforms the energy sector into a mathematical model, and within the framework of the results, analysis work has been completed for the improvement of a warship in the field of energy. The results have shown us that improvements can be achieved in the field of energy on a warship, and greenhouse gas emissions can be reduced as a result of these improvements.

Keywords: *Ship Energy System Analysis, Ship Energy System Modeling, Reference Energy System, Warship.*

BİR SAVAŞ GEMİSİNİN REFERANS ENERJİ SİSTEM ANALİZİ

ÖZ

Günümüz koşullarında büyüyen denizcilik sektörü göz önüne alındığında gemi sistemlerinde kullanılan enerjinin en verimli, en az maliyetle kullanılması büyük önem arz etmektedir. Bu enerji ağının ortaya çıkardığı sera gaz emisyonları çözülmesi gereken büyük bir sorun olarak karşımıza çıkmaktadır. Uluslararası Denizcilik Örgütü (IMO) Gemi CO_2 emisyon sorununu kontrol etmek maksadı ile 1958 yılından günümüze kadar çalışmalarını sürdürmektedir. Bu çalışmada birinci aşamada bir savaş gemisi örnek olarak incelenmiş ve mevcut teknolojiler göz önünde bulundurularak Referans Enerji Sistem Analizi ile mevcut durum ortaya koyulmuştur. İkinci aşama olarak bahse konu çalışma, enerji sektörünü matematiksel bir modele dönüştüren Long-range Energy Alternatives Planning System (LEAP) yazılımı ile çeşitli senaryolar ele alınmış ve ortaya çıkan sonuçlar çerçevesinde bir harp gemisinin enerji alanında iyileştirilmesi için analiz çalışması tamamlanmıştır. Ortaya çıkartılan sonuçlar bize bir harp gemisinde de enerji alanında iyileştirme sağlanabileğini ve bu iyileştirmeler sonucunda sera gaz emisyonlarının azaltılabileceğini göstermiştir.

Anahtar Kelimeler: *Gemi Enerji Sistemi Analizi, Gemi Enerji Sistemi Modelleme, Referans Enerji Sistemi, Savaş Gemisi.*

1. INTRODUCTION

Energy has been the cornerstone of life for the human being to survive until this time. Historically, in the journey of energy to the present, the decrease in the world energy resources has made it necessary for human beings to find new methods of energy. The world's energy resources are divided into two groups as renewable (solar, wind, geothermal energy, biomass energy, etc.) and non-renewable energy sources, fossil fuels (coal, oil, natural gas, etc.) and currently continue to meet the global energy needs.

Considering that 80% of energy is obtained from fossil fuels, the excess energy need caused by rapid population growth with the industrial revolution will further reduce fuels such as coal, oil and natural gas as a resource and will make it mandatory for people to use renewable energy. The supply-demand balance that occurs due to the decreasing resources and the increasing population will create an inverse proportional increase in prices, and cost increases will bring more burden to the economies of the country to meet the energy demand.

Although fossil fuels generate high-calorie energy, the environmental damage caused by emission gases is substantial. These effects cause irreversible damage to nature and living things day by day with global warming. All fossil fuels (coal, petroleum, natural gas, etc.) generate energy as a result of combustion and generate greenhouse gases (GHG). The resulting carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) greenhouse gases increase the temperature in the atmosphere and cause global warming and thus climate change with the greenhouse gas effect. In order to reduce environmental impacts, fossil fuels and the systems they use should be examined in every field and measures should be taken to reduce these impacts.

Although the use of fossil fuels in the maritime sector seems more efficient as in many other sectors, it is one of the sectors that should be emphasized in terms of environmental and economic effects. Transition to a cost-effective, efficient and environmentally friendly structure in the field of maritime, from the smallest ship to the largest ship, necessitates the establishment of a common control mechanism that will take into account all kinds of situations.

2. LITERATURE REVIEW

It is a fact that the demand for the maritime sector is increasing day by day in our world where approximately 71% is covered with water and this demand will increase even more. This is the scope and analysis of marine vehicles, which are important building blocks of the sector, in terms of energy and effects, has come to the fore compared to the past and many studies have been carried out on this subject.

In the "Ship Systems Energy Analysis" study, the average seasonal temperature values of a gas turbine ship in various conditions (port, anchor, maneuver, and cruise) and the energy use depending on the ship speed were modeled and analyzed. In the energy analysis, the main propulsion system using fuel, electrical systems and the ship's air conditioning system (HVAC), which draws the highest load on the electrical load, were examined and the annual average energy modeling was performed with Matlab / Simulink software. As a result of the study, it was concluded that the conditions under which the systems and devices in the ship will be used will save fuel and it has been revealed that the CO_2 emission will decrease as a result of the fuel saving (Öztürk, 2017).

In the "Reference Energy System Analysis of a Chemical Tanker Ship" study, an energy diagram was created with the reference energy system approach of all systems in the ship. In the study, the energy data resulting from the use of systems and devices within a specified scenario were modeled with LAEP (Long - range Energy Alternatives Planning System) software. As a result of the data obtained in the modeling, it was concluded that in which area energy improvements can be made in the Chemical Tanker Ship system and greenhouse gas emissions can be reduced, accordingly (Sarı, 2019).

"Exergy and Thermodynamic Analysis in Gas Turbine Ships", specifically General Electric LM 2500 gas turbine was examined technologically in the main propulsion system and calculations were made according to the turbine operating cycles. Total exergy and exergy loss and thermodynamic analysis of the calculations were made. As a result of the analysis, it has been concluded that the use of the General Electric LM 2500 gas turbine used in the ship main propulsion system at high speed will provide more benefits in terms of efficiency (Çubuğuzun, 2006).

In the "Energy and Exergy Analysis of a Passenger Ship" study, the efficiency of the main propulsion system, electrical power, heating and cooling (HVAC) systems in which the majority of the energy demand is met on a cruise ship in the Baltic Sea, was analyzed and energy models were created. In the study, four operational modes were determined: high speed (15 Nm), low speed (between 4-15 Nm), maneuvering speed (between 2-4 Nm) and port state (drift).

In the "Experimental and Theoretical Investigation of Exhaust Emissions from a Ferry" study, the greenhouse gas measurements emitted from a ferry were calculated by experimental methods and the results were compared with international studies in line with the criteria determined by IMO (Durmaz, 2015).

3. METHODOLOGY

3.1. Reference Energy System Concept

MARKAL (Market Allocation) is a model structure that means market allocation. The main purpose of the model is to evaluate the comprehensive and integrated energy technologies. With various technologies that produce or consume with energy carriers, it starts from the extraction, conversion or process in each relevant sector and continues until the end use. These energy technologies create a RES (Reference Energy System) with a single energy input and output in the energy system.

RES is a diagram that models the energy system structure. It defines the flow of energy from sources to end use. It shows all energy flows from primary energy source, large and small scale energy cycles, different distribution forms and end use of energy in different sectors. RES often contains useful information about energy demand and even energy services; it enables to see how energy conversion technologies affect fuel-technology connections in an energy system. This network is defined with parameters and numerical inputs and the energy balance for the year, which is generally defined, is called a "base scenario". This study actually forms the basis of an on-board sustainable energy action plan mentioned above (Sulukan, 2010).

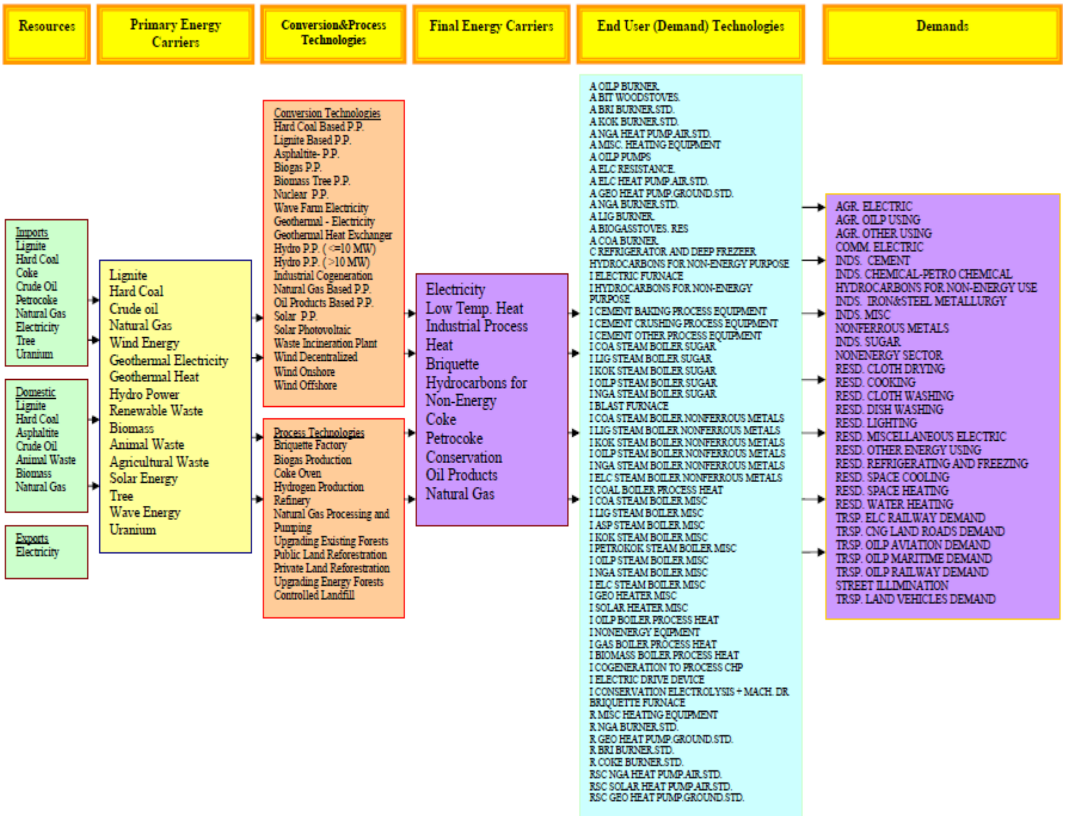

Figure 1. General outline of the RES concept (Sulukan, 2010).

Figure 1 expresses a simplified representation of a typical MARKAL RES, which is generally accepted in each model structure and shows the basic components. Primary Energy Carriers, which are created with existing resources, are transformed into electricity or heat (final energy carriers) together with Conversion Technologies and Process Technologies, and other energy processing and demand technologies (end user technologies) and the demands for energy services and products (demands). Each can be on the scale of a country, a region, a city, a district or a ship defined as a model (Sulukan, 2010).

3.2. Energy Modeling Tools Overview

Modeling tools, also known as decision support tools, are software that help many integrated systems come together to create a simulation. Although each of the softwares differs in interface and function, its main purpose is to give us some results in order to perform the system analysis with the simulation created. Each result that emerges will help to improve a problem, if any, on the system.

In order to create the simulation, each of the softwares needs parameters and data related to the system to be created. Simulations (building, ship, city, country, etc.) can be done in micro and macro scales. Today, as in many fields, modeling tools are available in the field of energy.
Various modeling tools have been developed to date in order to make accurate analysis in the field of ship energy. The modeling tool (LEAP) chosen for this study is introduced below.

3.2.1. Energy Modeling Tool LEAP Overview

The LEAP modeling tool is windows-based software used below for energy policy analysis and climate change at the Stockholm Environment Institute. Currently, 190 countries and hundreds of countries are developing resource planning, greenhouse gas emission restrictions and low emission, emission strategies in cities, regions, regions or many different regions globally.

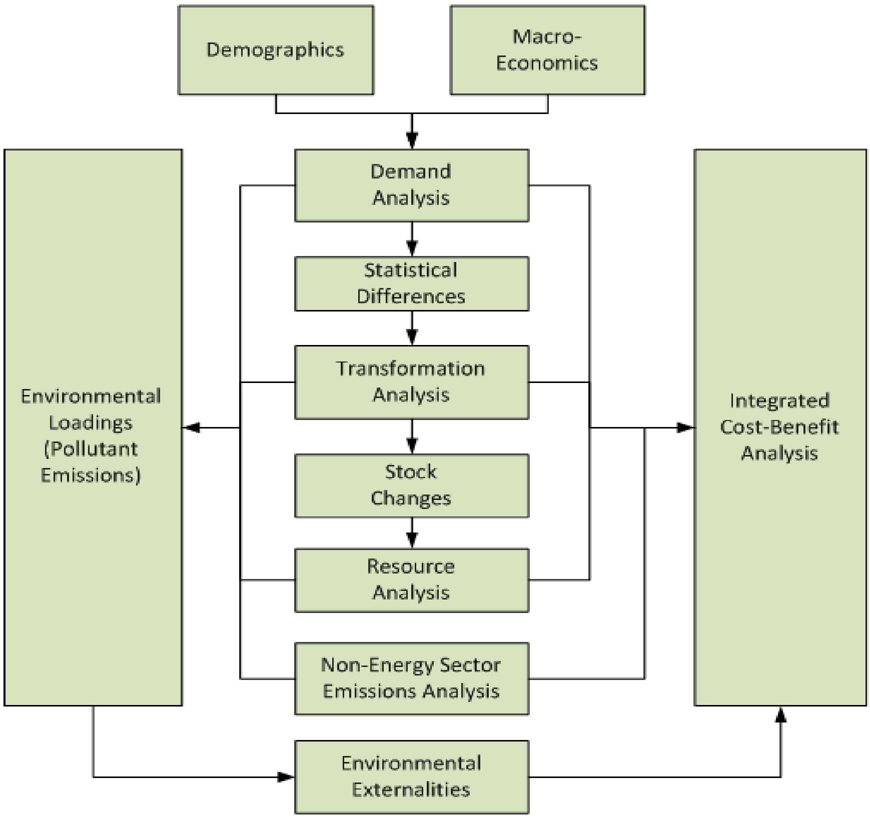

Figure 2. LEAP calculation structure (Low Emissions Analysis Platform, 2021).

LEAP puts all demands in front of us with an integrated structure, thanks to the calculation structure shown in Figure 2, along with the demographic and macroeconomic data, as well as all the demands, technology and expenditures, environmental pollutant emissions. In addition, thanks to its flexible interface, it provides many conveniences for the users who want to work in various fields and levels.

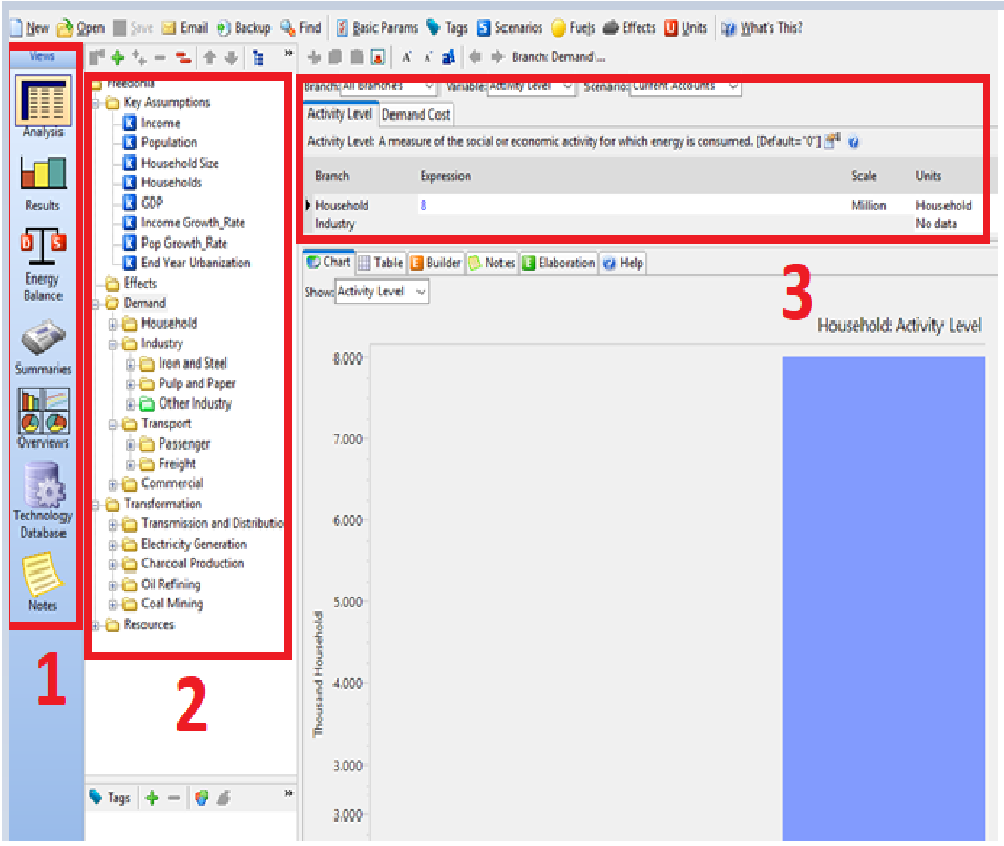

Figure 3. LEAP program interface.

Users can easily name and enter all components of the energy system they will model into the technology tree shown in box 2 in Figure 3, and create sub-categories. Thanks to this structure, the connection and relationship between all components of energy systems can be introduced to the program.

Figure 3 shows the interface encountered when the LEAP application is opened for the first time. Here, the demands of the system, the technologies that meet these demands and the energy carriers and the technologies that transform these carriers into the necessary final energy carriers are defined and the relationship is established in the above-mentioned technology tree. In section 3, the required data of the technologies are defined as well as the desired unit and scale. Then, in the light of the data and parameters entered in the Result section, calculations are made and results are drawn. In the Energy Balance tab, the distribution of the energy entering the system, spent in the system or given out from the system can be seen. In addition, thanks to the Technology Database available in the program, information about the technologies to be introduced to the system and the relevant parameters of these technologies can be obtained.

Another feature of the program is that it allows forward-looking medium or long-term models in different scales. After choosing a specific year to create the base scenario, the user can model the system up to 2050 annually or five years. Alternative scenarios to be created thanks to the defined ready functions can be easily compared with the base scenario.

In the LEAP Modeling tool, system-based energy consumption of many sectors can be seen. At the same time, with the program, emission analyzes of local and regional air pollutants can be made and as a result of the analysis, it provides benefits by giving an idea to the users about the prevention of local air pollution (Low Emissions Analysis Platform, 2020).

4. APPLICATION OF THE RES SYSTEM CONCEPT TO A WARSHIP

In this study, an AX Class warship, one of the floating elements of the Turkish Naval Forces, was selected and all systems of this ship were examined and energy analysis was made. In analyzes made, 10 knots ship speed was accepted as constant. The main characteristics of the ship are shown in Table 1.

Figure 4. AX class warship overview.

Table 1. Warship main characteristics (Turkish Naval Forces, 2021).

AX Class Warship Main Characteristics	
Length – Width - Draft	98,2 x 11,8 x 4,4 MT
Displacement Tonnage	Full Load 2940 t
Main Drive	6 Maybach Diesel/14400/2 Propellers
Speed	20,5 KTS

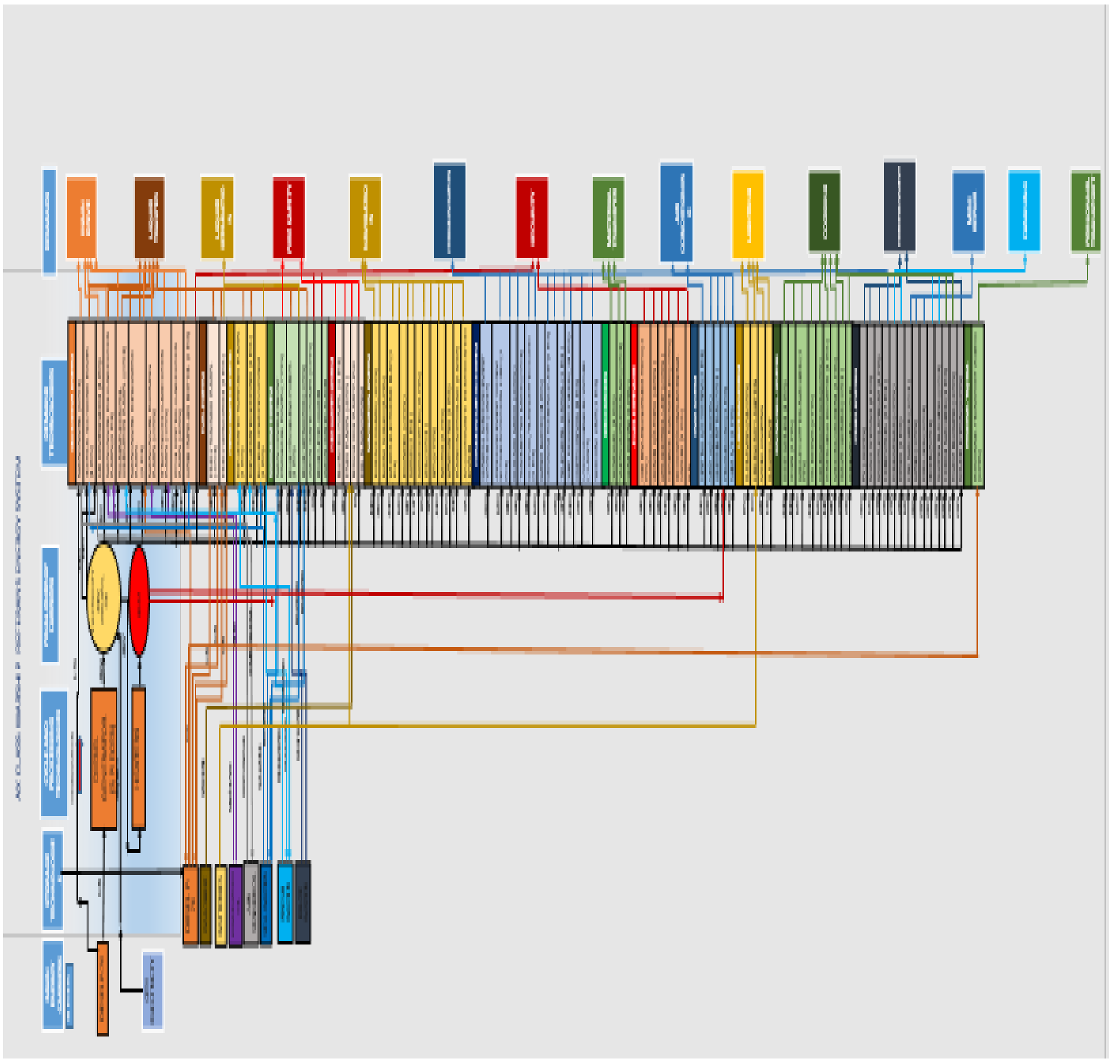

Figure 5. A Warship RES general overview.

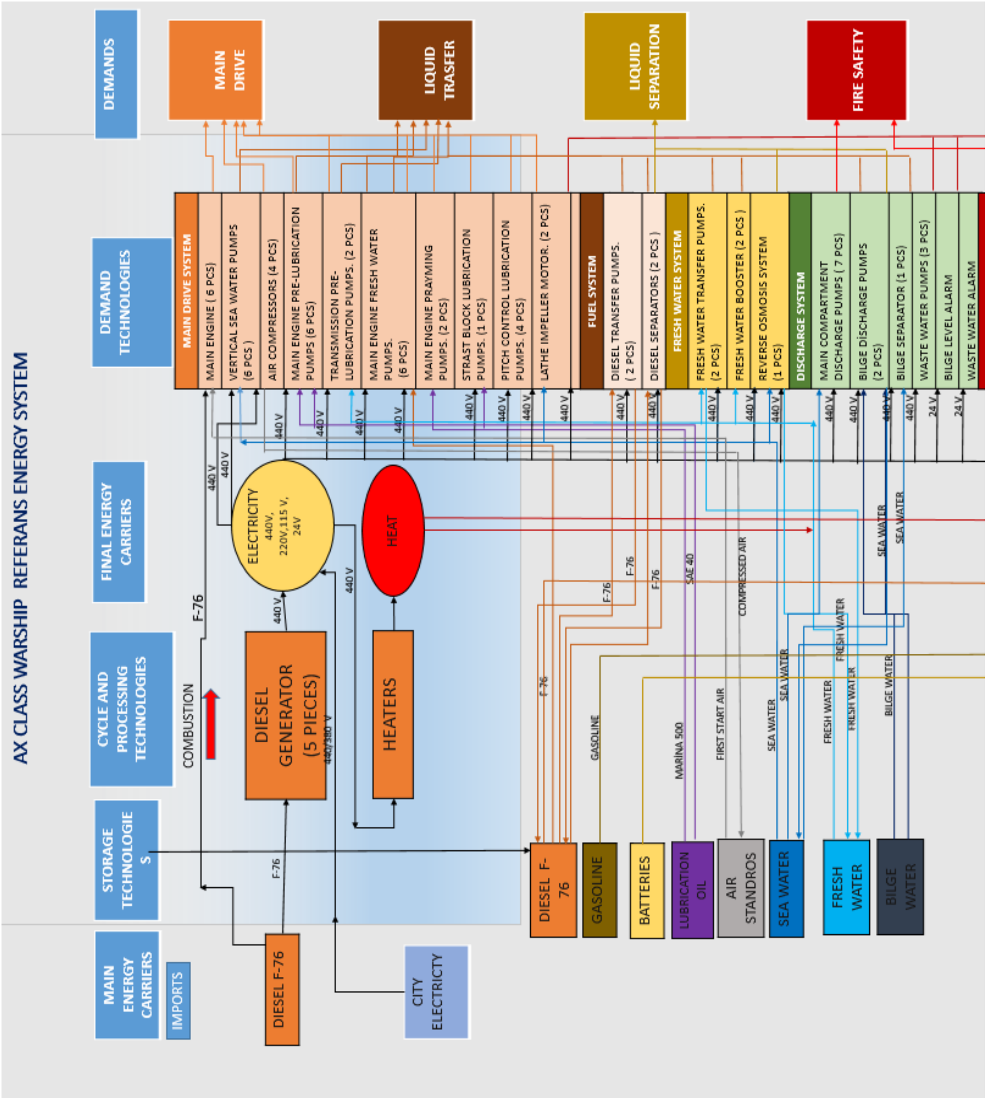

Figure 6. A Warship RES enlarged overview.

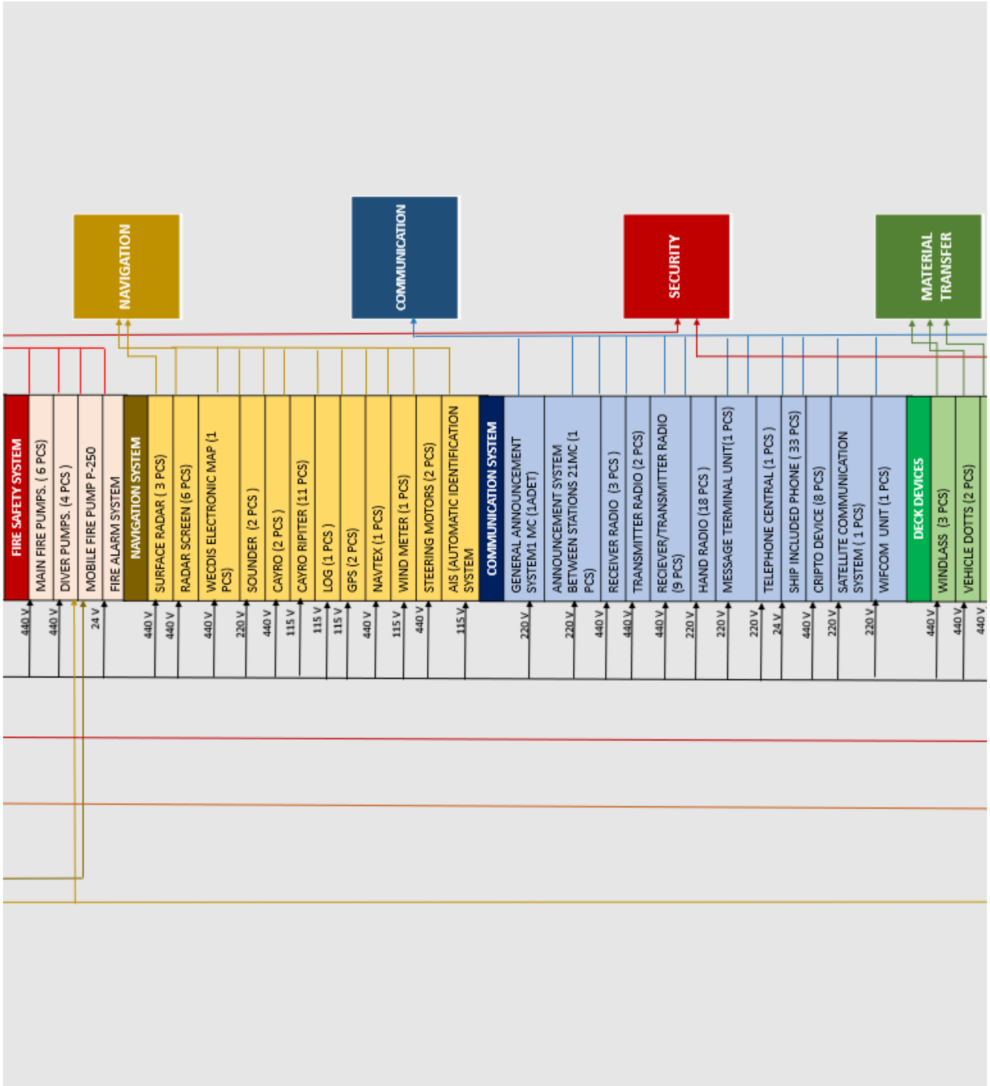

Figure 7. A Warship RES enlarged overview (continued).

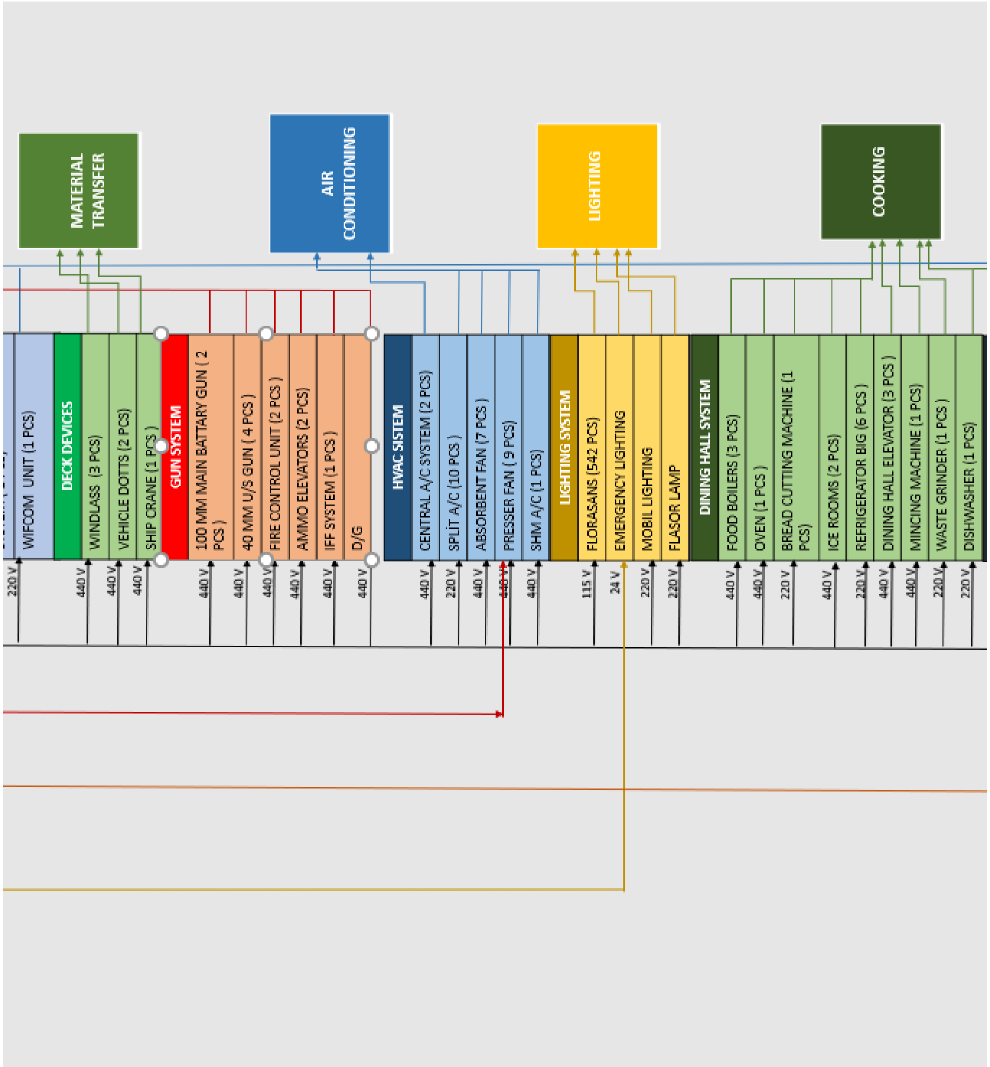

Figure 8. A Warship RES enlarged overview (continued).

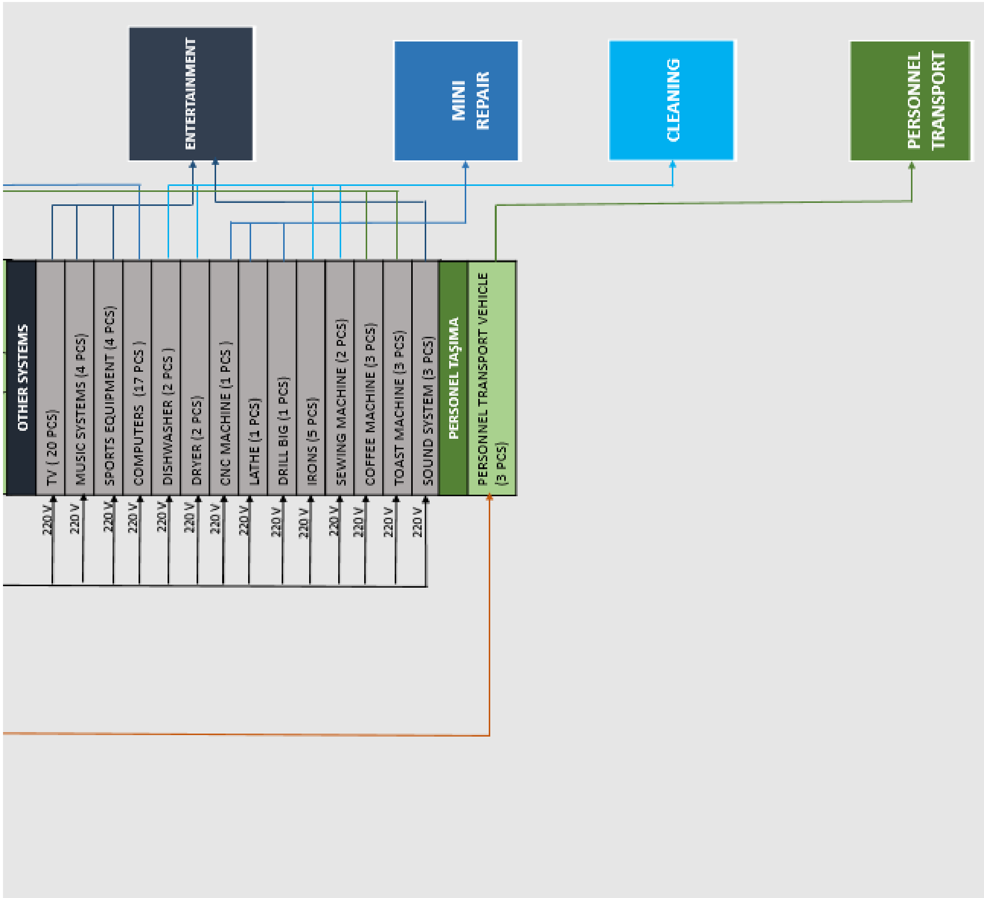

Figure 9. A Warship RES enlarged overview (continued).

4.1. Ship Energy System Resources (Main Energy Carriers)

Described as RES in the MARKAL model refers to the different types and forms of energy produced and consumed at different levels in the energy system. Energy carriers (Energy System Resources) include fossil fuels such as hard coal, lignite, crude oil and petroleum products, electricity and renewable energy (e.g. wind, biomass, solar, geothermal and hydro).
Energy carriers provide connections between various technologies in the MARKAL model by transferring them from one or more technologies to others. The Main Energy Carriers (Import) in the first column of the RES created are Diesel (F-76) and Coastal Electricity (in the case of the port-state).

4.2. Storage Technologies

In order to understand the RES better, the storage technologies in the second column of the RES are specified in Figure 6 and all the elements currently stored in the system are shown. Diesel F-76, Gasoline, Batteries, Lube Oil, Air Stands, Sea Water, Fresh Water and Bilge Water are stored in the system. The stored items are used in Conversion and Process Technologies, Final Energy Carriers, Demand Technologies and Demands. In order to ensure the stability of the ship, the storage is generally carried out under the waterline in the existing storage areas such as cisterns and tanks.

4.3. Conversion and Process Technologies

Some of the main energy carriers have been converted into final energy carriers through conversion or process technologies. Conversion technologies are used to convert primary energy carriers into final energy carriers as electricity or heat. Process technologies, on the other hand, are technologies that change the shape, property or location of energy (Sulukan et al., 2017). 5 diesel generators in the third column of the RES formed in Figure 6 were transformed into electricity, which is the final energy carrier, and the generated electricity into low-voltage electricity and heat with cycle and process technologies such as heater, transformer, and transferred to demand technologies in order to meet all demands on the system.

4.4. Final Energy Carriers

The energy needed by end-use technologies and transformed into primary energy carriers by conversion and process technologies is called final energy carriers. Electricity and heat shown in the fourth column of RES in Figure 6; has emerged as the Ultimate Energy Carrier transformed by conversion and process technologies. Ship electricity is produced in 440 Volt by means of Diesel Generators and distributed to Ship Demand Technologies as 220V, 115V, 24V through Transformers.

4.5. End Use (Demand) Technologies

Demand technologies are devices used to directly meet end-use service requests, including vehicles, pumps and electrical devices (Sulukan, 2017). Technologies are characterized using parameters that define technology costs, fuel consumption and efficiency and availability.
The demand technologies shown in the fifth column are grouped on a system basis and the operating voltages and storage technologies, if any, are specified for each technology.

4.6. Demands

Energy service demands define the quantities required for specific end-use energies services to be distributed to relevant subsectors in an energy system. The demands required by the ship system are defined in the last column. Demands determined on WPP are mixed through demand technologies. In RES analysis, one or more demand technologies can meet one or more demands.

5. MODELING A WARSHIP WITH LEAP AND ANALYSIS RESULTS

5.1. Creating a Reference Scenario

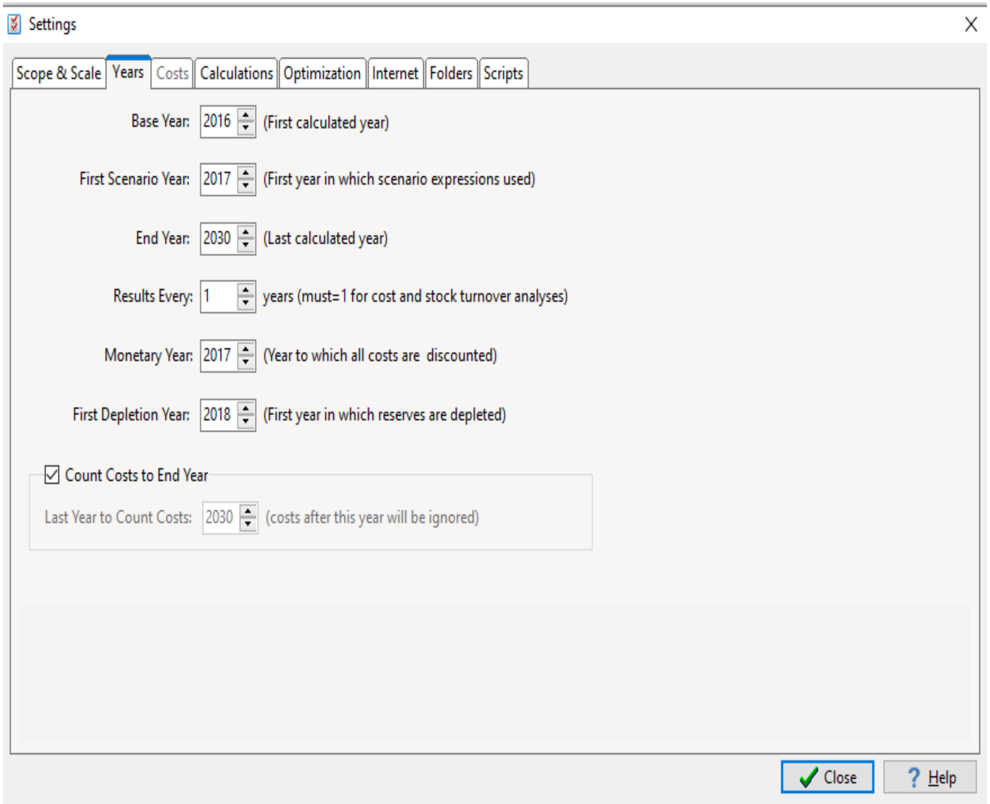

Figure 10. LEAP scenario screen.

The reference energy system analysis made in the previous stage was taken as the basis for the LEAP modeling of AX Class warship. Before starting the modeling, it is aimed to establish the annual energy balance of the warship in question in the modeling. In the study to achieve the target, the cruise and port states of the ship for 2016 were determined from official records, and the systems used by the ship during the port and cruise were calculated separately. The parameters and technical data used in the energy model are taken from the technical documents, journal records and system registration cards of each technology available in the ship system.

5.2. Creating LEAP Modelling Data

AX SINIFI SAVAŞ GEMİSİ MODELLEME İÇİN GEREKLİ PARAMETRELER VE SİSTEMLERİN TEKNİK BİLGİLERİ							
SİSTEM ADI	MEVCUT SISTEM	ÇALIŞMA VOLTAJI (V)	ÇEKTİĞİ AKIM (A)	1 SAATLİK HARCAMA VE ÇEKİLEN YÜK (kWh)	BAZ ALINAN YIL İÇİNDE KULLANIM SÜRESİ SAAT	TOPLAM KULLANILAN MİKTAR (kW)	TOPLAM KULLANILAN MİKTAR GİGA JOULE
ANA MAKİNE	6	600 KG	0	0	580	348000 KG	42.4
D.DZ.TUL.	6	440	480	292	580	169360	0.1
HAVA KOMPRESOR	4	440	200	121	115	13915	0.1
ANA MK ON Y.Y.TUL	6	440	120	73	30	2190	0.1
SANZUMAN ON Y.Y.TUL.	2	440	100	60	5	300	0.1
ANA MK.TATLI SUTUL.	6	440	96	58	580	33640	0.1
ANA MK MOT.PRIMING TUL.	6	440	120	73	70	5110	0.1
STRAST BLOK Y.Y.TUL..	1	440	10	6.	90	540	0.1
PITCH KONTROLY.Y.TUL.	4	440	128	76	580	44080	0.1
TORNA ÇARK MOT.	2	440	40	24	12	288	0.1
STERN TUP DZ.TUL.	2	440	40	24	580	13920	0.1
MOT.TRANS.TUL.	2	440	20	12	175	2100	0.05
TATLI SU TRANS.TUL.	2	440	20	12	390	4680	0.05
TATLI SU HİDRAFOR TUL.	2	440	32	19	2250	42750	0.1
SINTINE TAHLİYE TUL.	2	440	20	12	1180	14160	0.05
PIS SU TUL	3	440	96	58	120	6960	.0.5
MOTORIN PRUFAYER	2	440	100	60	115	6900	0
TERS OZMOZ	1	440	20	12	0	0	0
SINTINE SEPERATOR	1	440	10	6.	0	0	0
ANA BOLME TAH.TUL.	7	440	140	85	5	425	0.1
ANA YANGIN TUL	6	440	480	292	310	90520	0.2
DALGIC TUL	4	440	128	78	3	234	0
SEYYAR YANGIN TUL.	2	1 KG	0	0	13	13 KG	0
ANA YANGIN ALARMI	1	24	10	0,3	8766	2630	0
SU USTU SEY. RAD.	3	440	30	18	610	10980	39,528
RADAR MONITOR	6	220	6	1,8	610	1098	3,9528
WECDIS ELN. HARITA	1	440	6	3	610	1830	6,588
ELN ISKANDIL	2	220	6	1,8	610	1830	6,588
CAYRO RİPİTER	11	115	24	3,8	610	1098	3,9528
CAYRO	2	440	20	12	750	9000	32,4
PARAKETE	1	115	6	0,9	610	549	1,9794

Figure 11. Warship LEAP parameters for the year of 2016.

Each demand technology determined in the warship energy system analysis created in the first stage has been transferred to excel format. In Figure 10, the number of each demand technology, the current (A), the operating voltage (V) and the corresponding operating (kWh) values are calculated. The calculated values are shown as the energy (GJ) used by each demand technology during the total working period, taking into account the cruise and port times in the specified year.

5.3. Introducing Technology and Demands to LEAP

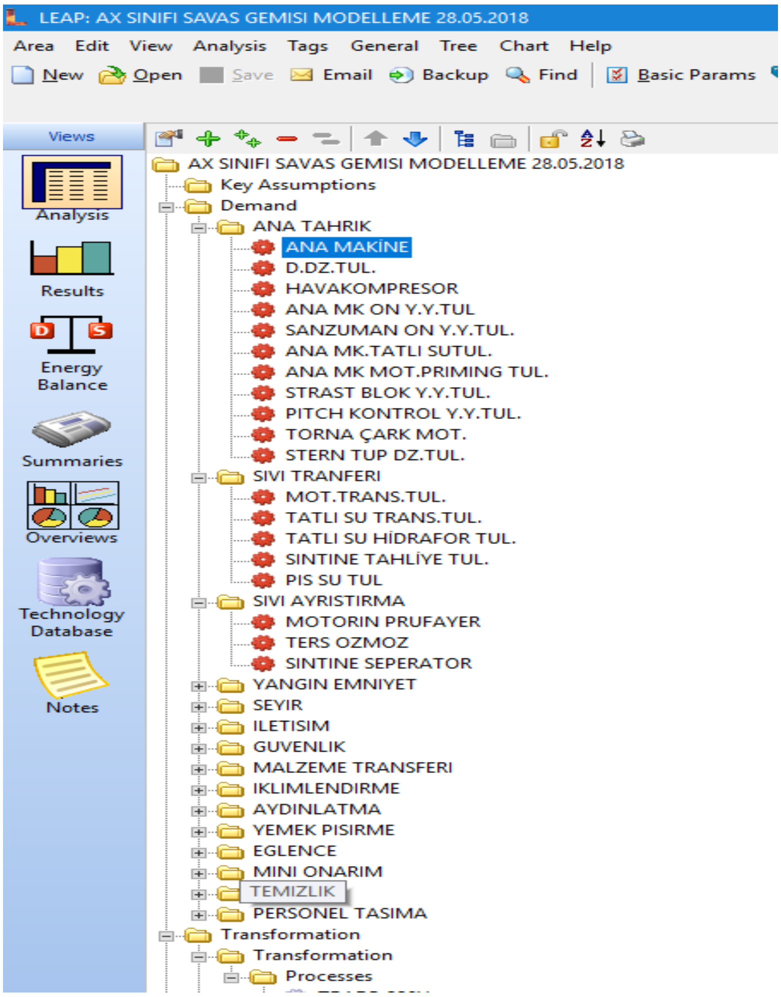

Figure 12. LEAP modelling technology and demands.

A total of fifteen different energy demands are shown in Figure 11 and a total of 93 demand technologies that meet these demands are defined in the Demands section of LEAP as a demand technology that meets each demand.

5.4. LEAP Demand Technology Data Entry

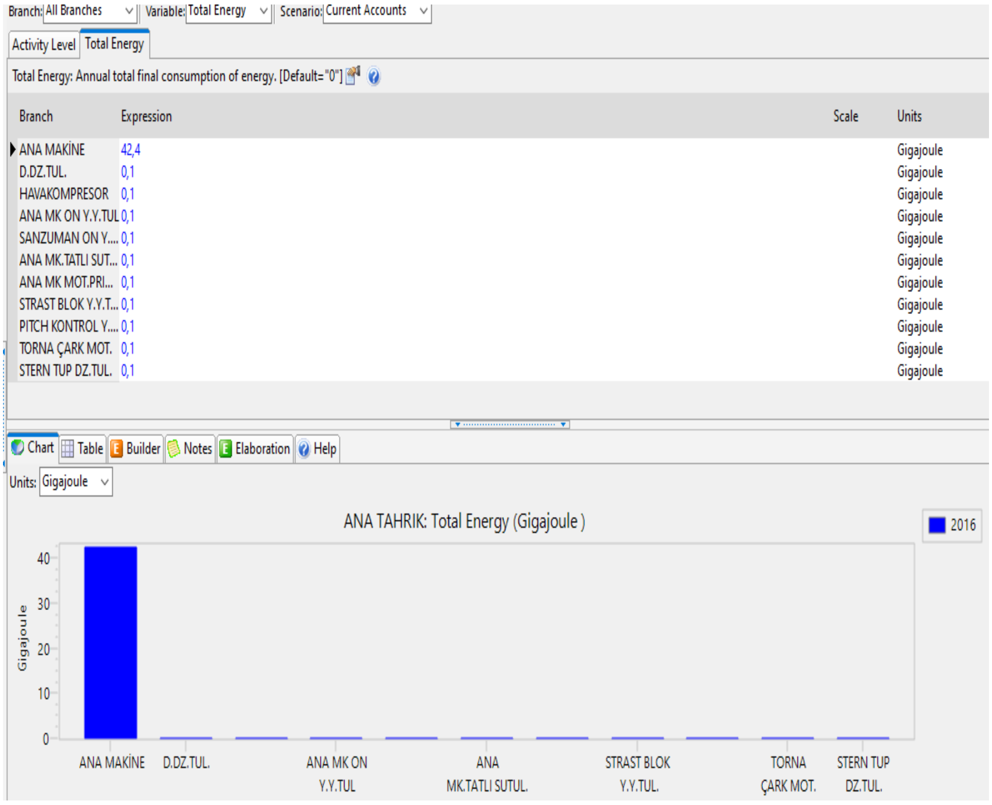

Figure 13. LEAP modelling demand technology data entry.

In Figure 12, the total energy consumption of each demand technology calculated in the following excel table is entered in the Demand technologies section of the LEAP interface as annual expenditure gigajoule (GJ).

5.5. Introduction of Conversion and Process Technologies to LEAP

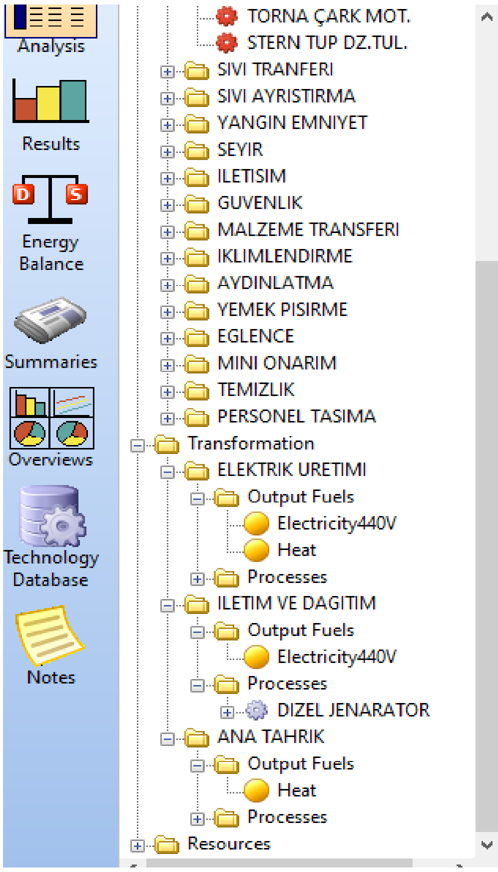

Figure 14. LEAP modelling conversion and process technologies.

In this section under the Transformation section of the LEAP interface, cycle and process technologies are defined. As seen in Figure 13, this section defined in the energy tree under 3 main headings consists of Transformers, Heater and Diesel Generator definitions sequentially. Identification sequences are also important for establishing the energy balance. In the Transformers section, 2 types of transformers used on the ship are defined and the losses in these transformers during distribution are specified. Fan hits that provide warm air for the warming of the ship in winter are defined under the heading Heater. Finally, Diesel Generators that provide electricity to all systems except the main engines on the ship are defined under the title of Diesel Generator.

5.6. Introducing the Main and Final Energy Carriers to LEAP

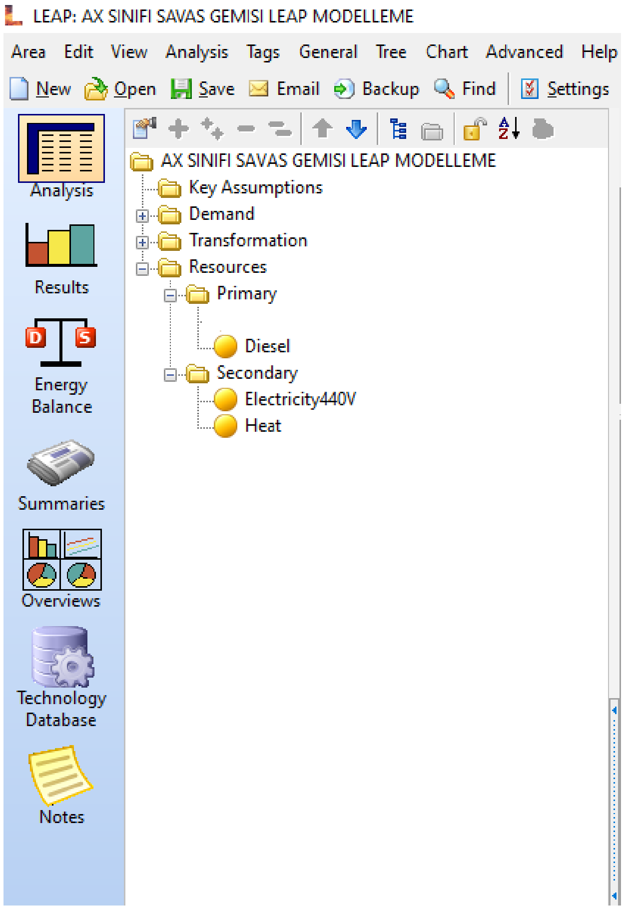

Figure 15. LEAP modelling the main and final energy carriers.

As indicated in Figure 14, the main energy carriers used in the ship's energy system are Diesel under the Primary title under Resources, and the final energy carriers created by Conversion and Process technologies as Electricity 440V and Heat under the title of Secondary.

5.7. One – Year Energy Balance and Analysis

Table 2. LEAP modelling the main and final energy carriers.

Energy Balance for Area "AX SINIFI SAVAS GEMISI LEAP MODELLEME"				
Scenario: Current Accounts, Year: 2016, Units: Gigajoule				
	Electricity440V	Diesel	Heat	Total
Imports	76,3	37,2	52,7	166,2
Exports	-	-	-	-
Total Primary Supply	76,3	37,2	52,7	166,2
İLETİM VE DAGITIM	-47,4	-19,7	-	-67,1
ELEKTRIK URETIMI	-	-	-	-
Total Transformation	-47,4	-19,7	-	-67,1
ANA TAHRIK	1,0	11,2	31,2	43,4
ELEKTRIK URETIMI	19,7	6,3	21,5	47,5
SIVI TRANFERI	0,3	-	-	0,3
SIVI AYRISTIRMA	0,0	-	-	0,0
YANGIN EMNIYET	0,3	-	-	0,3
SEYIR	0,1	-	-	0,1
ILETISIM	0,1	-	-	0,1
GUVENLIK	0,1	-	-	0,1
MALZEME TRANSFERI	0,1	-	-	0,1
IKLIMLENDIRME	4,1	-	-	4,1
AYDINLATMA	2,5	-	-	2,5
YEMEK PISIRME	0,3	-	-	0,3
EGLENCE	0,0	-	-	0,0
MINI ONARIM	0,0	-	-	0,0
TEMIZLIK	0,0	-	-	0,0
PERSONEL TASIMA	0,2	-	-	0,2
Total Demand	28,9	17,5	52,7	99,1
Unmet Requirements	-	-	-	-

After all the data entered and all the definitions, the annual energy requirement of an AX Class warship set forth by LEAP is calculated in Gigajoule and shown in Table 2. The energy need required is seen on the basis of demand and the amount of energy consumed by the system appears as the total demand.

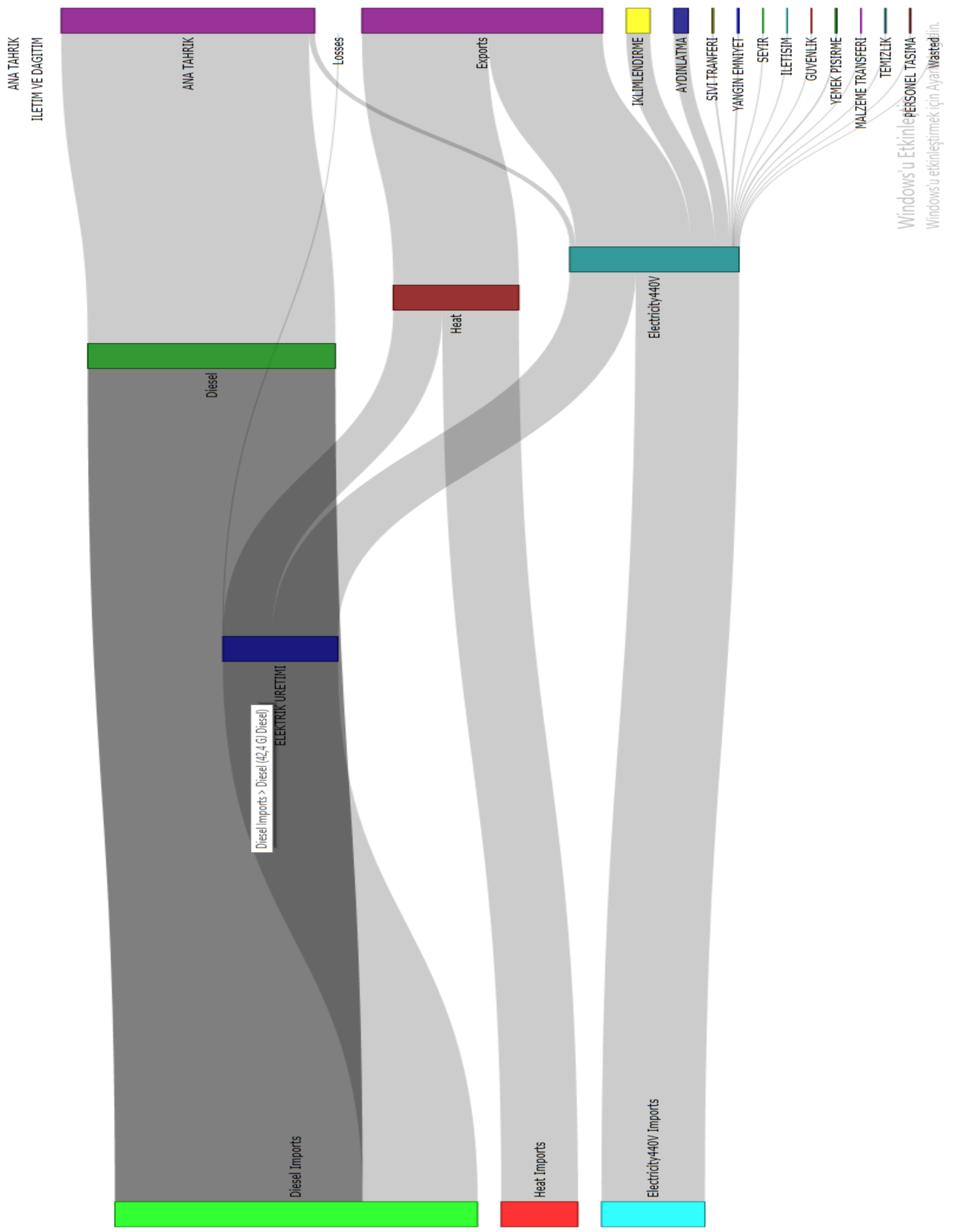

Figure 16. LEAP modelling one-year Energy Sankey Diagram.

In the Sankey Diagram expressed in Figure 15, the energy transformations and energy flows of all technologies, from primary energy carriers to demands, can be seen visually.

6. CONCLUSION

In this study, which is a continuation of the ship reference energy system analysis, taking into account the MARKAL model RES concept, the Reference Energy System analysis of an AX Class warship was integrated into the LEAP modeling program. In the integration, all elements of the system were introduced to the program together with their parameters and the amount of energy required by the system annually was determined.

In this study, it is seen that the total annual energy production of the warship shown in Figure 15 is 166.2 Gigajoules and the part of this demand, which is 99.1 Gigajoules, is the energy produced from the ship fossil fuel used in the Main Engine and Diesel Generators. This constitutes 59.6% of the total energy demand of ships. The remaining 67.1 Gigajoules of ship energy demand represents the energy losses in the cycle, heat, transmission and distribution of the ship energy system.

While the main propulsion requirement of the ship should be 43.4 Gigajoules, 12.2 Gigajoules of energy can be obtained due to heat and transmission losses. This has shown that the existing main engines on the ship operate at an efficiency of 28% and there is a need for technology improvement in the efficiency of the main engines in the main propulsion system.

Ship electricity constitutes all the demand of the ship energy cycle, excluding the main engine and diesel generators. This energy requirement is provided by 5 diesel generators on board. While the electricity requirement of the ship should be 76.3 Gigajoules, 47.4 Gigajoules of the requested energy is seen as loss due to heat and transmission losses. The remaining 28.9 Gigajoule electricity generation meets all the demands within the ship life cycle.

Table 3. IMO Greenhouse Gas Emission Data

(Turkish Chamber of Shipping, 2020).

Type of fuel	Reference	Emission factor ($t\text{-}CO_2/t\text{-}fuel$)
1 Diesel/Gas oil	ISO 8217 Grades DMX through DMB	3.206
2 Light fuel oil (LFO)	ISO 8217 Grades RMA through RMD	3.151
3 Heavy fuel oil (HFO)	ISO 8217 Grades RME through RMK	3.114
4 Liquefied petroleum gas (LPG)	Propane	3.000
	Butane	3.030
5 Liquefied natural gas (LNG)		2.750
6 Methanol		1.375
7 Ethanol		1.913

In Table 3, CO2 emissions corresponding to 1 ton of fuel burned are expressed in tons. According to IMO data, 3,206 tons of CO2 emission occurs as a result of burning 1 ton of diesel fuel. This showed that a total of 693 tons of diesel fuel (F-76) burned in the ship system (Main engine, Diesel Generator) produced 1406,688 tons of CO2 emissions into the atmosphere and was released into the atmosphere.

The first strategy determined by IMO's Marine Environment Protection Committee (MEPC) for reducing greenhouse gas emissions from ships is to determine the needs for increasing energy efficiency for each ship, to reduce CO2 emissions by at least 40% by 2030, to increase this rate to 70% until 2050 and to continue these studies.

The results of the analysis in the study conducted in line with this strategy showed that the slightest efficiency improvement to be made in ship main engines and diesel generators will reduce the annual fuel consumption as well as decrease the CO_2 emission.

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