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Evaluation of Electric Ships' Markets, and Considered New Design Marine Cabin Combined with Solar Power

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Abstract

In this study, firstly, literature reviews were made, and the obtained data with an integrated transfer explaining the importance of the subject with respect to the demands for energy saving and emission reduction in the maritime. The recent electric ship markets have been examined in these respects. Furthermore, this study has aimed presentation of considered new design Electric Battery Sea Cab which is aware of the requirements in practical applications such as a public transportation or barge ship. The cab is 14.95 meters long and 4 meters wide. Considering the average resistance value for 16 knots speed, it has been examined that the motor to be used should provide approximately 200 HP power. Furthermore, this study's reviewed reports and studies are stated that there is progress towards the global green ship finance market, and 28 important ports offer port-based financial incentives to green ships. Consequently, the results of this study have serviced that alternative in green ship technology information on the use of battery systems is provided. In addition, the new considered cab which represents showing that battery electrical ship can be achieved shall be interesting to the future focuses of the representatives of the maritime sector.

1. Introduction

The motivation of this study comes from the climate change and technological requirements of today's life which are mentioned below. In this context, motivational elements will be briefly explained in this section, primarily in the environmental context. In this study, there are two main approaches to reviewing the study, quantitative and qualitative methods. Quantitative reviews in the study examine the relationships between variables such as market and global requirements for electric and green ships, the primary purpose of which is to review. Qualitative methods were chosen because the aim of the study was to examine the phenomena by presenting a sample design. In the following sections, it will be discussed in the context of electric ship technology. In addition to particulate matter, sulfur oxides (SOx), nitrogen oxides (NOx) and carbon dioxide emissions from ship engines, primarily greenhouse gases (GHG), are investigated. In BAU (Business as usual) scenarios, it is specified for CO2 as 1,000 Mt. On the other hand, it is expected to be the projection subject of the future for the marine bunker industry. Because, in 2020, we must remember an important formation, that is associated with Low Sulfur Fuel Oil (LSFO). While options for traditional fuels such as liquefied natural gas (LNG) are on the rise with technology, formations such as electric propulsion are other contributors to making the shipping industry environmentally friendly. Although some high costs seem to be a constraint in 2021, the rapid expansion also presents sanctions as stronger than cost calculations due to the dominance of environmental effects. However, by 2030, high-emission ships are expected to be nearly as costly to operate as a zero-waste ship (Serra and Fancello, 2020; Olmer, 2015; Sims et al, 2014; Milousi et al, 2019; Faber and et all, 2021).

On the other hand, according to the 2018 report of the OECD International Transport Forum, it is stated that 28 important ports offer port-based financial incentives such as different fees specific to green ships (International Transport Forum, 2018, 7-14). Green port fees are:

- Environmental Ship Index, which expresses the environmental performance of a single ship,
- Green Award,
- Clean Shipping Index,

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- GG Emission ratings

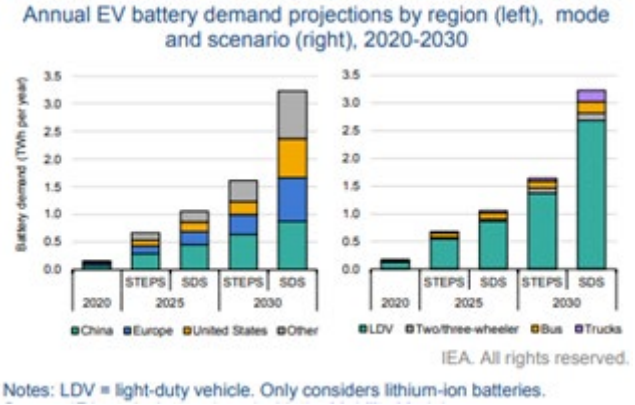
based on indices (Wartsilal, 2021).
According to Bank of KfW IPEX, it is stated that there is progress towards the global green ship finance market, where a large demand is expected (Hand, 2021; Sisson et al., 2019).
In light of all above information, the importance of this study is directly related to the necessity of reducing global warming and reducing CO2 emissions, for which sanctions decisions that will be very effective throughout the world have been taken recently. In addition, this study will set an example for shortcut transportation in green energy vessels and battery service for green ships, and it is expected that it will be important for those who are interested in the subject. The aim of this project is to provide a projection for the future of green marine vehicles by obtaining electrical energy from renewable (wind, solar energy) energy and using the storage of this energy in the newly considered cab, as well as providing service to those who need it.
Globally, a rising middle class in China and India is driving the demand for fossil fuel consumption, driven by increased demand for passenger cars and, with it, population growth and technology use. It is stated that there may be as many as 1,5 billion cars on the roads in 2050, compared to 750 million in 2010. It is also stated that such a demand presents both a challenge and an opportunity to take advantage of new vehicle technologies, and significant economic development will be achieved in the process (Todd and Thorstensen, 2013). The unit cost of batteries for electric vehicles is stated in the IEA document, which has dropped 85% since 2010, with industry studies recording a sales weighted average cost of US$156/kWh as of 2019 (EPO and IEA,2020). By considering these requirements of technology and the outputs of environmental studies together, some new formations on the basis of countries appear. For example, in 2011, the US Department of Transportation (DOT) and the Environmental Protection Agency (EPA) are known to propose common pollution standards for new vehicles. These proposed standards are stated to reach the equivalent of 54,5 miles per gallon (mpg) and 163 grams of CO2 per mile for the average new vehicle by 2025 (BlueGreen Alliance,,2012; Tatar and Ozer, 2018; Serra and Fancello, 2020; Deloitte's Global Automotive Team, 2020; Jansen et al., 2011; Fuels Institute, 2021; BRE and RECC, 2016; Smith et al., 2014). The most important operating cost for vehicles is the consumer's expenditure on fuel, which is determined by the vehicle's fuel efficiency, daily mileage and fuel price (Curtin et al 2019, 27-32).
Taking into account the technological developments related to the climate, in this study, it is aimed to use this newly designed a battery electric sea cab (BESC) as a barge support for green ships or to offer cab services as its name suggests. The new design vessel to be realized with this study is aimed at reducing CO2emissions, which is supporting by the G20 decisions and by the climate pact decisions at the COP26 conference of parties in Glasgow in 2021. The international climate agreement appears as an issue that changes the order of priorities in CO2 emissions are placed in studies in many countries. It is clearly observed that it will shape the sharing of national sanctions in the world with sub-discussions in which sustainable cities are discussed at the highest level. In this context, what has been done on the basis of green energy marine vehicles in the past and today is mentioned in this study.

2. Statistics and Electric Ships

2.1 Electric vehicles and ship market

An electric vehicle can be powered by electricity from a solar panel or by a battery. Electric vehicles (EVs) consist land vehicles, aircrafts, sea vehicles, and spacecrafts. EVs first appeared in the mid-19th century. However, electric power trains and smaller vehicles of all kinds also remained common. However, in the 21st century, EVs are on the rise again due to technological advances and growing growth. Electric car registrations are cited in the IEA report, where worldwide car sales due to the global pandemic have increased by 41% in 2020, despite a 16% decline (*IEA, 2021; Fuels Institute, 2021; Lan et al., 2015; Hou, 2017*).
A non-electric vehicle is constructed by internal combustion engine and related parts such as fuel tank and exhaust system. Electric vehicles, on the other hand, can operate by electricity instead of using fossil fuel. An electric vehicle may have some elements such as a set of rechargeable batteries, at least one electric motor, propulsion system. Engineers also develop special designs that run on solar energy in a variety of vehicles for many applications of renewable technology. For example, Toyota Prius uses solar cell technology to power vehicle systems. In different of a traditional vehicle, in an solar-electric vehicle, renewable energy is used to generate motion (*IEA, 2021*; *Fuels Institute, 2021*;*ABS, 2017*; *Salem and Seddiek, 2017; Travisions, 2016*). The electric vehicles battery statistics are given by the Figure1 to underline the technological formation of the future in these areas.

Figure 1. The Projections of Electric Vehicles Battery Demand



Reference: Global EV Outlook 2021, Accelerating ambitions despite the pandemic, IEA Publications International Energy Agency, Typeset in France by IEA - April 2021.

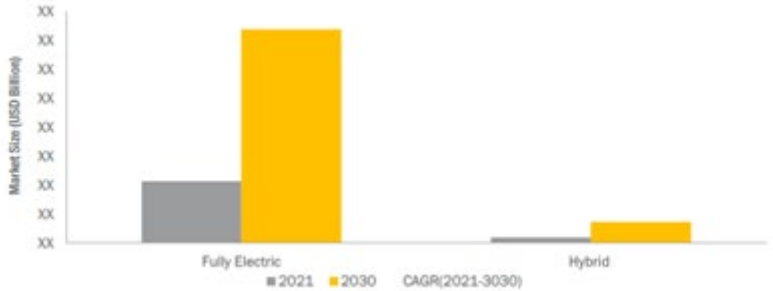
On the other hand, look at the Influencing Factors (Market Trends and Dynamics) have drivers and opportunities as shown in the Table1 (*Report Brochure, 2021*).

Table 1. Influencing Factors (Market Trends and Dynamics) for drivers and opportunities [Report Brochure, 2021, electric ships market global forecast to 2030 report brochure with sample pages report code: as 7444 received from email of sales@marketsandmarkets.com]

DRIVERS:
Implementation of sulfur 2020 rule
Hybrid and electric propulsion technology catering to the retrofit market
Increase in seaborne trade across the globe
Growing maritime tourism industry
Development of lithium-ion batteries
OPPORTUNITIES:
Potential for marine battery manufacturers to invent high powered batteries
Potential for battery charging via renewable sources of energy for onboard ship
Hybrid propulsion technology for large ships

Various factors such as grooving up maritime opportunities, the development of lithium-ion batteries for fast charging, and (hybrid and/or) electric propulsion technology are influencing factors in the examination of the marine vessel market. The International Maritime Organization (IMO) has established various local government regulations regarding the pollution and emissions of ships, as well as the strict regulations in North American and European regions, particularly in countries such as the USA, Canada, Norway, Sweden, Denmark, Finland, Australia, and New Zealand. The demand for ships is increasing. It is stated that North America is leading the electric ship retrofit market. Many owners are upgrading or retrofitting existing ship's battery and propulsion systems to provide more operational flexibility in their fleet and minimize fuel consumption. At this point, ABB (Switzerland), Siemens (Germany), Wartsila (Finland), VARD (Norway), Kongsberg (Norway), Corvus Energy (Canada), Leclanche (Switzerland), and General Dynamics Corporation (USA) are among the main players in the market. were found to be located (*Report Brochure, 2021; Milousi, et al, 2019; Dorey and Fireman, 2006; Faber, et al., 2021*). The Figure 2 represents the electric ship markets statistics with respect to a unit of XX, which is just unit due to US dollar. Growth rate and other market evaluation are given by Figure 3 and Figure 4.

Figure 2. By Type, Projection of The Electric Ship Market of The Fully Electric Segment From 2021 to 2030

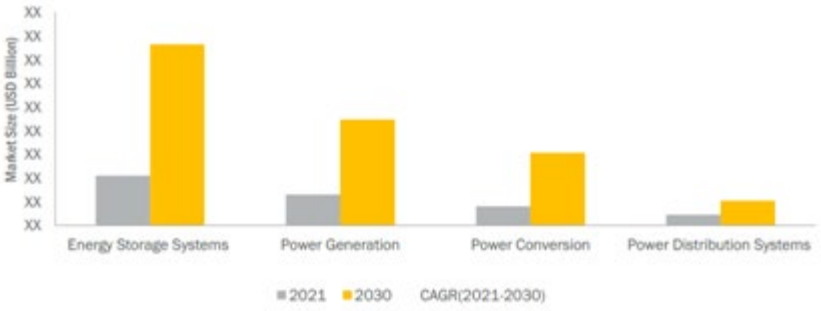


Reference: Report Brochure, 2021, Electric Ships Market Global Forecast To 2030 Report Brochure With Sample Pages Report Code: AS 7444 received from email of sales@marketsandmarkets.com

Figure 3. Electric boat and ship market Growth Rate by Region 2021-2026, and projection of Electric Ships Market in 2021

Reference: Report mordorintelligence, 2021], and [Report Brochure, 2021, Electric Ships Market Global Forecast To 2030 Report Brochure With Sample Pages Report Code: AS 7444 received from email of sales@marketsandmarkets.com

Figure 4. Energy Storage Systems Segment Forecasts By Systems In Electric Ship Markets



Reference: Report Brochure, 2021, Electric Ships Market Global Forecast To 2030 Report Brochure With Sample Pages Report Code: AS 7444 received from email of sales@marketsandmarkets.com

The first solar energy based sea vehicle is MS Turanor Planetsolar. That boat set sail from Monaco port on September 27th, 2010. In 585 days Planetsolar Boat visited 28 countries (*SailWorldl, 2012*, *designboom, 2017*, https://www.planetsolar.swiss/en/world-premiere/boat/). Again, to give an example of large vessels, the very new Ecoship, in other words the planet's most environmentally sustainable ocean cruise ship, is a cruise ship built in 2020 based on solar and wind power. It is stated that the Ecoship can travel to 100 ports per year and carry 6000 passengers per year, while at the same time saving almost 20% energy and 40% CO_2 emissions (*EcboShip, 2017 ; Gursu,2014; Spagnolo, 2016; Uludag et al. 2019*).

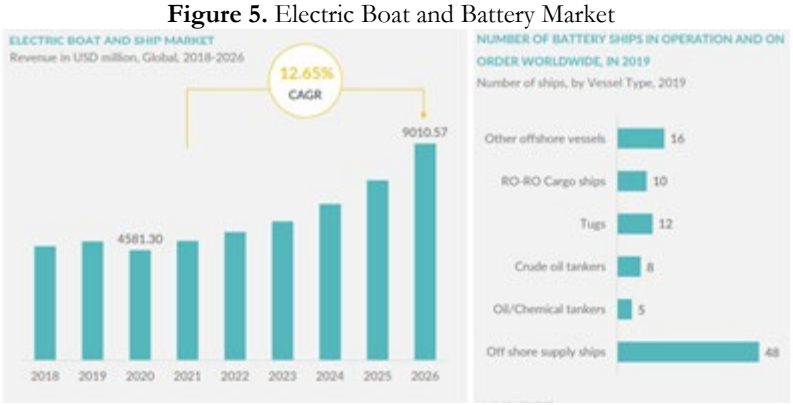
According to the observations of this study, it will not wrong to say that the growth of this market will be driven by significant investments in advanced lithium, nickel and sodium batteries. Therefore, availability of charging stations for electric vehicles is very important. In land vehicles, many people choose to own charger for convenience. At this point, this study should point out that an electric vehicle should be considered integrated with the charging station facilities. For this reason, in this study, the charging PV panels are thought to provide service from the port, not in the vehicle.

2.2 Battery electric vehicle

Electric vehicle is vehicle that use only electricity as fuel and can operate using the possibilities of electricity supply from a PV source or another opportunities. An electric vehicle, generally, consists of three main elements such as Energy Source; Power Converter; Traction Engine. Electric Vehicles in 2017 are BMW, Chevrolet, Ford, Fiat, Honda, Hyundai, Kia, Mercedes, Mitsubishi, Nissan, Smart, Tesla, VW (*IEA, 2021; Deloitte's Global AutomotiveTeam, 2020*; *Baum and Luria, 2010*; *Esteve-Pérez and Gutiérrez-Romero, 2015*).

On the other hand, in 2020, the South Korean government announced a US$870 million initiative to promote the development of environmentally friendly shipping to reduce pollution caused by the country's marine sector. Also, in January 2019, Wartsila signed an agreement with Hagland Shipping AS to power diesel-powered general cargo vessels with battery hybrid propulsion for short sea freight. This will create demand and huge potential for hybrid and all-electric cruise ships in the regions. In addition, the operating cost of an electric ship is significantly lower than that of a diesel ship (*Danfoss, 2021*;*wartsilal, 2021*; *Jansen,et al., 2011; Fuels Institute, 2021*). The Figure 5 represents the battery and boat markets.

Figure 5. Electric Boat and Battery Market



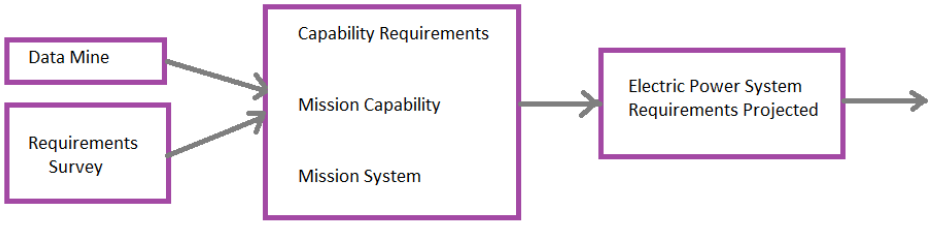
Reference: Report Mordor, 2021, Sample; Electric Boat And Ship Market (2021 - 2026), Mordor Intelligence Industry Reports, , received from email of info@mordorintelligence.com

In this point, almost all batteries are rated for their capacity, especially for renewable energy applications. Besides, typically in a larger scale PV system, the battery pack may naturally sized so that the daily depth of discharge is not an additional constraint (*Smith et al, 2014; BRE and RECC, 2016; Faturachman, 2018*). The battery information used in this study is presented with a table in the result section.

3. Material

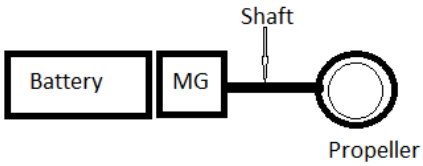
Capability requirement groupings in the methodology for the new design have evaluated in terms of overall effects on BESC Power Systems. Meeting the average power and impact power requirements has the greatest impact on the BESC. Thus, advanced sensors and advanced batteries have thought as "Primary Drivers" for BESC as illustrated on the Figure 6.

Figure 6. Capability requirements methodology



This study's one aim is finding eco-friendly alternative energy sources under current conditions for especially sea transportation. The sea cab has a motor powered by stored energy the components schematic diagram is illustrated in the Figure 7.Considered design sea cab is equipped with many batteries to increase its range. These batteries have been studied as lithium-ion batteries to save space and weight. In addition, large-capacity film Li-I batteries (Large-Capacity Film-Type Lithium-Ion Battery) and solid-state batteries (solid-state battery) have considered as backups.

Figure7. Components of the sea cab that combine of renewable technology with a pure electrical vehicle (EV)



The main source of electricity for the considered cab is batteries. They will be connected in series with the batteries to obtain the voltage demanded by the EV. The designed battery electric cab (BESC) is going to operate entirely using an electric motor and battery, without the support of a conventional internal combustion engine. Electricity generation capacity of utilities could face significant problems if vehicles' batteries are charged from the grid. A possible solution to this problem is usage time management; it would not wrong to say that the better solution would be to use a solar panel manufacturer that offers off-grid support. Therefore, in this study, the recharging of the used batteries has designed to be recharged from a PV panel stations which have been located in the port.

Thus, No emissions; No gas or oil changes; Ability to conveniently charge at port; Fast and smooth loading; It will offer advantages in the form of low cost of operation. Charging with PV is an easy and fossil fuel-free way of providing energy, so an electric vehicle stored using solar energy needs a one-time range. Compared to a typical fossil fuel engine vehicle that can refuel once a week or once a month, it has very advantageous aspects and offers convenience. Lithium-Ion batteries can always be recharged; they do not need to be completely discharged. They do not release harmful gases and their power/weight ratio they are very high. Considering these advantages, in the design, Lithium-ion batteries have preferred as batteries which have opportunities such as thin construction, Protected Metal Casing, Long Life Span (Most manufacturers offer 10+ Year Warranties). The batteries will install under floor for less placed and centered weight distribution. While the Lithium-Ion Technology batteries are charging in the port, it will always be possible to cruise by fully charged batteries group with the batteries loaded with backups.

A sea vehicle design process is complex and involves many requirements. Many of these requirements cover items such as Resources Capability Certificates, Instructions, Policies, Rules, Standards, etc. The design team should adopt the process of developing derived requirements that apply to their various systems. Knowing all this, it is desired to present a newly designed prototype idea made in this study to the opinion of the practitioners and to be a pioneer in the proposal to establish a new system, in this study. In this point, in the below what has been done about the new design will be summarized in this study.

4. Results

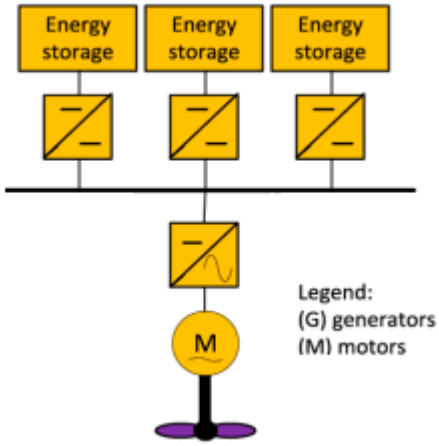
The data analysis method is record and document method which involves extracting and analyzing data from existing documents. The documents are some internal to an organization such as marketing reports and some external such as administration reports. The data analysis method in this study is the recording and document method, which includes extracting and analyzing data from existing documents. Some of the documents are internal to an organization, such as marketing reports, and some are external, such as management reports. With this review analysis, it has been demonstrated that there are rapid advances for emission reduction in shipping.

This study's aim is finding alternative energy sources under current conditions for especially sea transportation. Therefore, the prototype of sea cab has considered, the sea cab is equipped with many batteries to increase its range. The planned cab is going to considered as 14.95 meters long and 4 meters wide. Considering the average resistance value for 16 knots speed, it is thought that the motor to be used should provide approximately 200 HP power. As shown in the Figure 8 electric propulsion, integrated battery power generation and thrusters with fixed/controllable pitch propellers are used. The specifications of the cab are illustrated in the Table2. According to Kukner, resistance of the boat which has long of 15 meters is equal to 21031.64 N. When it is taken into calculation, motor power can be calculated with $Resistance * Speed = Power$. Where, 16 knots is equal to 8.23 m/s. Therefore, value of (21031.64 multiple by 8.23) divided by 735.49. Hence, we get obtain that 235.34 HP.

Table 2. Specifications of BESC

Length Overall	14.95 m
Length of Hull	13.6 m
Length of Waterline	12.8 m
Beam Overall	4.6 m
Beam Moulded	4.1 m
Drought, approx.	0.9 m

Figure 8. Fully Battery Electric Sea Cab (BESC) configurations of the propulsion and electric power system



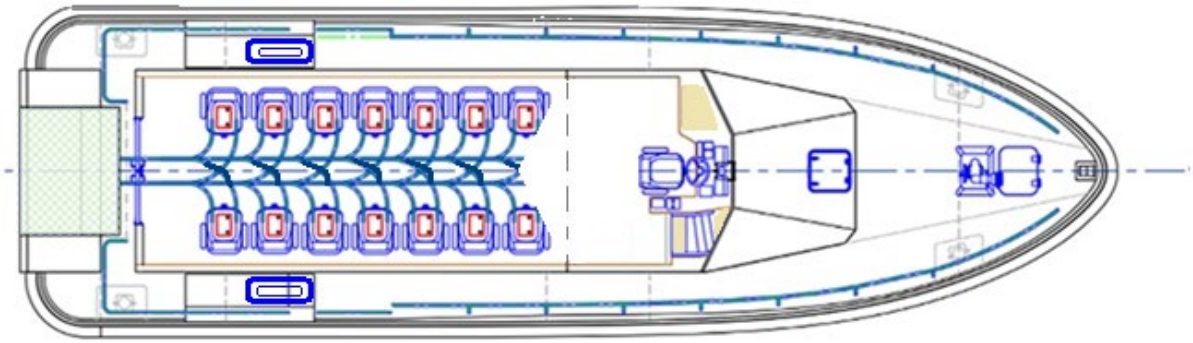
In this study, solar panels are placed in ports instead of on the cab. The solar panels' system that will provide 400 kW of energy by installing a 50 kW solar panel system on the roof of the port, which will be an area of approximately 1000 m², assuming, that it receives an average of 8 hours of sunlight per day, is considered. In an average day, enough energy to meet the energy needs of the vehicle for approximately 8.5 hours can only be met by using these panels. The properties of the prototype are given by the Table 3.

Table 3. Properties of BESC

	Li Battery Module
Battery Module	4.38 kWh
Modul-min	36.0 V DC
Modul-nom.	43.2 V DC
Modul-max.	50.4 V DC
Height Rack	102.625 mm
Weight	43.34 kg
Total Number of Battery	3*4=42

In line with the calculations, this sea cab, which will have a maximum speed of 16 knots with a 60 kW electric motor, will be able to move actively for 3 hours with a total of 42 batteries with high-tech batteries. The calculations are average values form the online calculators (*radiocontrol, 2019*, *PowerCalculation, 2021*). The constructed new design cab is illustrated in the Figure 9. The limitation of our study is that the cabin, which was designed based on financial possibilities, could not be produced.

Figure 9. New Considered to be DesignedBattery Electric Sea Cab (BESC)



According to the literature review of Serra and Fancello 2020-Olmer 2015-Sims and et all 2014-Milousi and et all 2019-Faber and et all 2021, it is stated that in BAU (Business as Usual) scenarios, high-emission ships are expected to cost as much as a zero-waste ship. When we compare our work with this source, we can state our assessment at this point as below:

The cost of fully charging an electric vehicle's battery can vary depending on when and where you charge it. For the bigger picture, it is necessary to include the amortized cost of purchasing and installing a charging station and the rates your utility company charges.

According to the 2018 report of the OECD International Transport Forum, literature of Sisson et al., 2019, and declaration of KfW IPEX Bank, it is stated that important ports offer specific financial incentives for green ships. In this context, when we compare this study with these references, it is seen that the newly designed cabin will be a sea vehicle that will benefit from financial incentives.

According to the literature review of IEA, 2021; Fuels Institute, 2021; Lan et al., 2015; Hou, 2017, Report Brochure, 2021; Milousi, et al, 2019; Dorey and Fireman, 2006; Faber, et al., 2021; BlueGreen Alliance,,2012; Tatar and Ozer, 2018; Serra and Fancello, 2020; Deloitte's Global Automotive Team, 2020; Jansen and et al., 2011; Fuels Institute, 2021; BRE and RECC, 2016; Smith and et al., 2014; Curtin and et al 2019, it is stated that worldwide electric vehicles registrations' increasing citations, operating cost for vehicles, CO_2 per mile for the average new vehicle by 2025 and the main players in the market. In line with all these determinations, this study shows that both the market reviews and our newly designed cabin proposal which the sea cab has a motor powered by stored energy components for eco-friendly alternative energy sources under current conditions to sea transportation. Therefore, the analyzes in this study, we have made have made this study integrated as mentioned in the literature review above.

5. Discussion and Conclusions

Ships handle is about 80% of global trade. This study presented the analyzes that will take place in this ratio, which is the most important indicator in trade, and presented the new design to transfer the gained inferences to practical application. With the increase in trade, volume ships will be included in the system, more fuel will be consumed and more emissions will be emitted. Therefore, the International Maritime Organization (IMO) reduces the negative effects caused by ships and energy draws attention to energy efficiency activities to reveal savings potential, and encourages the sector in this regard. Shipping rates and transportation delays affected by the COVID-19 pandemic are expected to increase global shipping. On the other hand, the reflection of these increases, the shipping is expected with some limitations of increased availability and increased shipping costs. In this respect, there will be an interest in marine vessels capable of making short and intense expeditions. In this study, to reduce fuel consumption and minimize exhaust gas emissions renewable energy sources such as solar and wind sources are recommended, and also the importance of the subject is presented with statistical analysis evaluations. In the statistics of its emissions, the statistics are encountered maritime transport, which accounts for almost 11-20 percent of all transport-related CO_2 emissions in the world in 2018. Because of these considerations, environmental regulations are becoming more and more stringent in the maritime industry. More recently, the International Maritime Organization IMO (January 1, 2020) regulation has set an upper limit for the maximum allowable sulfur content SO_x in fuels: 0.5 m/m (in mass) for the fuels, and the current Heavy Duty Ships using Fuel Oil (HFO) is required to install exhaust gas scrubbing systems to meet the rules. In this solution, scrubbers spray seawater into the ship's exhaust gases to remove pollutants, which can create environmental problems. In the light of all this information, argued that environmental problems in short-distance shipping should be developed with renewable energy technologies that offer zero-emission opportunities.

Consequently, with this study, it has been determined that, on a good navigation day, this sea cab with a maximum speed of 16 knots met the energy need for approximately 8.5 hours, but with the ability to change the battery, transportation without environmental emissions was ensured. Therefore, in this context, it can be said in terms of metrics that; an estimated 25% of people using electric transport, bicycles, or water vehicles are of our opinion that they will make up the majority sympathetic to this facility. Additionally, it would not be wrong to express that electric vehicles will create additional economic development opportunities by increasing the quality of life, reducing energy expenditures, and reducing dependence on oil. As the future of your work, it is aimed to prototype the designed cabin and publish its outputs.

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