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PROPULSION OF FISHING BOATS WITH SOLAR ENERGY

Ahmed Imad Nadhim DHDH

Master's Thesis

Supervisor

Prof. Dr. S. Aydın ŞALCI

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The thesis titled PROPULSION OF FISHING BOATS WITH SOLAR ENERGY, prepared by AHMED IMAD NADHİM DHDH and submitted on 15/12/2022 has been **accepted unanimously** for the degree of Master Mechanical Engineering

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Ahmed Imad Nadhim DHDH

signature

DEDICATION

First and foremost, I would want to say my gratitude to my parents for their unwavering support and inspiration over the years. My parents will always have my gratitude for remembering me in their prayers. They not only gave me the best opportunity, but they also created a safe atmosphere for me to thrive. My family's ideals have always served as my compass. I'm hoping that finishing my thesis brings give them some of the comfort and enjoyment they so deserve. I appreciate the emotional support I received from my friends and family during my master's program.

PREFACE

I'd like to start by thanking my thesis supervisor. I would like to extend my sincere thanks to Prof. Dr. S. Ayden Şalcı for his direction, counsel, and wisdom during the study process. I have had a lot of support and help while I've been drafting this letter. His knowledge was quite helpful in developing the study questions and techniques. His enlightening comments inspired me to improve my thinking and raise the bar on my job. Since I became a pupil of Prof. Dr. S. Ayden Şalcı, I have learned a lot of new things. I am thrilled to be supervised by such a talented educator. I appreciate all Altinbas University has done. done for me. I am grateful and glad to be one of their students, and I appreciate the thesis committee members for their insightful criticism. While writing this thesis, I gained a lot of knowledge about the propulsion of boats, solar energy, and their calculations.

ABSTRACT

PROPULSION OF FISHING BOATS WITH SOLAR ENERGY

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In particular, in the Köyceiz Lake, at the confluence of the Aegean and Mediterranean seas, fishermen use infantry-type fishing boats for fishing and sightseeing trips for millions of domestic and international visitors. In this way, these boats have evolved into the local community's primary source of income in that area. These boats range in length from 7 to 12 meters and are made of wood. They were built by skilled boat builders in their shipyards over a period of hundreds of years without the use of any scientific or mathematical techniques, eventually taking on their current form. When examining their hydrodynamic form, it is evident that this sort of fishing boat was made possible by the boat builders' experiences, which were determined after several trials and errors. The goal of this project is to motivate boat owners to switch from a diesel to a solar electric propulsion system for their vessels that are used in the Köyceiz region. It also aims to demonstrate to boat owners how this conversion will benefit both the environment and the economy. For the subsequent calculations in this study, the model test findings from earlier theses were used. With the use of geometrical similarity principles, the values for a 10-meter-long infantry-type fishing boat were calculated using the required values from the previous thesis research and they served as the beginning point for the rest of the study. After that, concept design research for a solar electric

propulsion system was created by assuming a service speed of 6 knots. Infantry-type fishing boats measuring 10 meters long were created. Replacing internal combustion engines with electric engines and creating electricity with solar energy sources To meet the demand for an electric motor, an electric engine capable of providing the same brake power was chosen; a solar system capable of supplying the electric engine throughout the journey was established; the cells to be used in the battery pack were chosen; and solar panels. The proposed system was simulated in pvsyst.

Keywords: Köyceiz Region, Fishing Boats, Solar Energy

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

ABBREVIATIONS

GHG	:	Greenhouse Gas
IPCC	:	The Intergovernmental Panel On Climate Change
AFOLU	:	Agriculture Forestry And Other Land Uses
GDP	:	Gross Domestic Product
HFO	:	Heavy Fuel Oils
CARB	:	California Air Resources Board
ECA	:	Emission Control Areas
IMO	:	International Maritime Organization
Tom	:	Tonnekilometer
TFC	:	Total Final Consumption
DC	:	Direct Current
AC	:	Alternating Current
PEM	:	Polymer Electrolyte Membrane
PV	:	Photovoltaic
EPIA	:	The European Pv Industry Association
TF	:	Thin-Film
IR	:	Infrared
UV	:	Ultra-Violet
CIGS	:	Copper Indium Gallium Selenite
Cadet	:	Cadmium Telluride
Gas	:	Gallium Arsenide
OPV	:	Organic Photovoltaic
DSSC	:	Dye-Sensitized Solar Cells
LED	:	Light Emitting Diodes
FQD	:	Fluorescent Quantum Dots
Se	:	Selenium
Gee	:	Germanium
Cadet	:	Cadmium Telluride

CIS	:	Copper Indium Dieseline
Sin	:	Indium Antimonite
Eve	:	The Electron-Volt
USF	:	University Of South Florida
CIS	:	Copper Indium Dieseline
Cods	:	Cadmium Sulfide
CIGS	:	Copper Indium Gallium Desalinize
CZTS	:	Copper Zinc Tin Supplied
QD	:	Quantum Dots
MEG	:	Multiple Exaction Generation
QDPV	:	Colloidal Quantum Dot Photovoltaic
MHP	:	Metal Halide Perovskites
PSC	:	Perovskite Solar Cells
MPPT	:	Maximum Power Point Tracking
PWM	:	Pulse Width Modulation
VRLA	:	Valve-Regulated Lead-Acid
NiCad	:	Nickel- Cadmium
GTR	:	Gross Register Tons
NRT	:	Net Register Tons

LIST OF SYMBOLS

LOA	:	Overall Length Of the ship
LWL	:	The length of the waterline
BWL	:	The hull's widest breadth on the waterline
D	:	Depth
DWT	:	The Deadweight Tonnage
LWT	:	Lightweight Tonnage
RT	:	The amount of Resistance on the ship's hull,
RF	:	Frictional Resistance
RR	:	Residual Resistance
RA	:	Air Resistance
C	:	resistance coefficients
K	:	reference force
EHP	:	Effective Horsepower
DC	:	DC voltage
Tosh	:	The average daily hours of sunlight at the installation location
Ed	:	The watt-hours of daily average energy use
ηb	:	Battery Efficiency
ηi	:	Inverter Efficiency
ηc	:	Charge Controller Efficiency
Pave, peak	:	The Average Peak Power
ID	:	The Total DC Current
Vim	:	Module's Rated Voltage
NM	:	The Number Of Modules In Series
NM	:	The Number of Parallel Module Strings
Irma	:	The Rated Current of One Module
NM	:	The Total Number of Modules
E_{ast}	:	Estimated Energy Storage
D_{aunt}	:	The Number of Autonomy Days

Disc	:	Depth of Discharge
Safe	:	Safe Energy Storage
Vibe	:	The voltage of One Battery
CT	:	The capacity of the Battery System In Ampere-Hours
N_{ab}	:	The Total Number of Batteries
C_{ob}	:	The Ampere-Hour Capacity of One of The Chosen Batteries
Nab	:	The Number of Batteries in Series
Nab	:	The Number of Parallel Battery Strings
Safe	:	Safe Factor
Ice	:	The Required Charge Controller Current
S_{ic}	:	The Short Circuit Current of The Selected Module
P_{in}	:	Power of the Inverter
S_{um}	:	Power of All Loads Running Simultaneously
P_{ond}	:	Power of All Inductive Loads With Large Surge Currents

1. INTRODUCTION

Since the 19th century, greenhouse gas (GHG) emissions from land and fossil fuel use have steadily increased, achieving their potential level since 2019. In 2015, the Paris Accord established a goal of keeping global warming between 1.5 and 2 degrees Celsius above pre-industrial levels. The Paris objectives, however, are in peril based on the existing evolution of emissions, projected obligations to national policy, infrastructure, and. The time window is closing to offset these tendencies across all industries and worldwide areas. Buildings, industry, energy systems transportation, and AFOLU are the five primary sectors that make up global GHG emissions, according to the Working Group III of the Intergovernmental Panel on Climate Change (IPCC) (agriculture, forestry, and other land use). These industries encompass energy demand, energy systems, and supply (industrial, buildings, and transportation), emissions from industrial processes not related to energy, as well as emissions and removals from land (AFOLU).

n terms of climate change mitigation, each sector faces its own set of obstacles. Coal-fired electricity production accounts for the majority of GHG emissions from energy systems, with a small amount of extremely polluting units both politically and lasting difficult to retire. Transportation and Emissions from buildings are more dispersed and distributed over many players; they are tied to urban design, the physical environment, and daily behavior, posing Non-trivial social and technological mitigating issues. Emissions from industry are linked to the manufacturing of metals, chemicals, cement, and other essential resources that our economies require. Numerous of these procedures are ineffective. Provide a significant opportunity for quick emissions reductions. However, others are challenging to completely mitigate. Emissions and removals of AFOLU are connected to producing food, feed, and lumber. Production is a particularly challenging industry since it provides critical services to millions of people on a globally restricted land surface with various conflicting needs.

In 2018, global transportation GHG emissions totaled 8.5 GtCO2eq, accounting for 14% of all direct and indirect emissions. Transportation passenger and freight emissions are the main component and source of this increase (6.1 GtCO2eq, or 73% of total emissions by sector),

then global delivery (0.7 GtCO2eq, or 8%), as well as global aviation (0.7 GtCO2eq, or 8%). (7 percent, 0.6 GtCO2eq). Domestically and internationally, Maritime and aviation pollution is 1.8 GtCO2eq, or 21% of total emissions, total emissions in the industry. Rail indirect emissions, including indirect emissions of N2O. of carbon dioxide from power and heat (e.g., from rail and bus electrification), are all quite tiny, accounting for only 0.5 GtCO2eq or 6% of overall transportation emissions.

Because oil-based fuels account for 92 percent of transportation energy, the percentage of ultimate total energy consumed in transportation (28 percent) and its rapid increase over time weigh heavily on the fight against climate change. These tendencies make transportation among the most difficult areas to mitigate global warming since even the wealthiest nations have yet to achieve meaningful emissions reductions in the sector.

Power for transportation consumption has monitored GDP per person growth more closely than any other industry. Transportation supports people's movement and things, allowing access to important social interactions as well as services while also propelling local and international economies. Since 1990, developments have continued a long-term pattern of growing travel lengths and a move between low- and high-speed modes of transportation. Combined with an increase in GDP, Energy efficiency has only slightly improved, averaging 1.3 percent per year worldwide, while carbon intensity has remained constant. Overall, growth in worldwide passenger and freight travel activities has outpaced gains in fuel economy and energy efficiency, maintaining a long-term trend in the transportation sector. Even though worldwide passenger traffic has increased in all geographical regions, there are significant discrepancies between poor and high-income regions, as well as between urban and rural areas within nations. When comparing regional levels, these differences may be seen in transport emissions.

Between 2010 and 2018, the global energy intensity of the transportation sector fell by an average of 1.3 percent per year, owing primarily to wealthier areas, but remained essentially constant or increased in all other regions. Some governments have implemented regulations to promote vehicle energy efficiency, spurring technical advancements that have gradually

lowered the needed energy usage per passenger kilometer and every tonne-kilometer of goods delivery for all vehicle applications (light, heavy, and rail). Reforming fuel prices, another crucial policy area has made varying degrees of progress. Although fuel taxes are crucial for encouraging people to purchase more fuel-efficient vehicles and limiting the number of trips they take, between 2003 and 2015, they increased in 83 nations while decreasing in 46.

The global transportation system's energy grid is still firmly based on fossil fuels, with diesel and gasoline powertrains representing 92 percent of ultimate energy usage when driving a light-duty car category. In all global regions, the carbon intensity of the transportation industry remained stable between 2010 and 2018. This is due in part to the growing popularity of larger, heavier gasoline-powered cars SUVs, also referred to as "sports utility vehicles," which have outsold sales of electric and hybrid vehicles. These have historically been true in the North American auto industry, but it is becoming more prevalent in Europe and other foreign markets, with SUVs accounting for 39% of all cars sold globally in 2018. In terms of vehicle size and weight, strict material economy and lightweight designs of passenger cars might cut worldwide GHG emissions by 16–39 GtCO2eq till 2060. Since 2011, the market share of more carbon-efficient diesel cars in EU-28 nations has been steadily declining. Beginning in 2017, these changes reversed the previous downward trend in average fuel consumption for recently registered vehicles in Europe.

National and international aviation and shipping, while taking into a tiny percentage of overall GHG emissions, are rapidly expanding, with +4.2 percent yearly growth rates. Percent and 3.1 percent, from 1990 and 2018, accordingly. Improvements in efficiency in energy aircraft were far greater compared to road transportation, however, they were overtaken by even more rapid increases in activity. In 2016, aircraft represented 31% of worldwide arrivals of tourists (increased from 17% in 2005) and 50% of transportation- tourism-related CO2 emissions. The epidemic of COVID-19's long-term effects is unknown, but it will have a significant impact on worldwide passenger aviation in 2020, as well as goods and freight modes to a lesser extent.

Overall, transportation trends show a consistent increase in emissions, attributable mostly to increased motorization and road transportation activities. This worldwide trend is the opposite

of what is required, with efficiency increases just marginally offsetting a move from low to high modes. On the other hand, fully electric and hybrid electric vehicles have grown in popularity in recent years, and electrification has progressed faster than expected just a few years ago, particularly in scooters, bus services, and a variety of micro-mobility and light urban freight methods like e-bikes and e-auto rickshaws. While electrified road transport offers a lot of potential, its influence has been limited up to 2018, and it is in danger of being canceled out by rising travel volumes in the future. Growing vehicle size and weight, and other offsetting tendencies mean that more severe rules and measures to combat vehicle dependence, such as demand control policies and technological innovation, will play a vital role. Demand management is important in industries like aviation, where there aren't many ways to reduce carbon emissions with technology right now [1].

Some of the main challenges the present global economy faces are energy security, sustainability, pollution, and the effects of climate change. Some authors and organizations have stated that the greatest strategy for locating a long-term solution to these issues is to move toward a 100% renewable economy. This choice is based on the fact that renewable energy sources are already well-established, advancing quickly, and maybe leaving no carbon footprint at all. They are especially well-suited to combating climate change because of this last quality. Perhaps the most urgent issue facing humanity. Any transition to renewable energy in the medium term most likely benefit from the prudent use of fossil fuels, particularly natural gas, which is a dispatchable low-carbon source that can support sporadic renewables. However, according to certain analyses, our economy needs to become renewable in the long run. It would take between 40 and 50 years to complete a significant infrastructure restructuring and a globally coordinated policy response. Although such a shift is critical to avert catastrophic climate change, governments have yet to endorse a concerted policy undertaking of this magnitude. It was anticipated that the peak of all fossil fuel output, which is expected to occur between 2020 and 2036, would be a reasonable date for the start of a worldwide renewable transition and that it would be completed in the second half of this century. That time frame of 50 years is also consistent with the length of time it has taken for technical advancements to spread throughout the economy in the past. One of the most

challenging components of such a transition appears to be the conversion of the present-day transport infrastructure. Global transportation is still significantly reliant on fossil fuels (primarily oil), which are predicted to diminish in the next decades. Also, worldwide transportation creates a substantial amount of pollution. It is also a source of millions of accidents every year, as well as a percentage of greenhouse gases and pollution in urban areas[2].

On traditional ships, there are a variety of strategies for reducing emissions. They are classified into two categories: decreasing emissions during the manufacturing process and reducing emissions created before they are expelled from the ship. The approaches are based on the premise of decreasing sulfur content in the fuel utilized and lowering the combustion temperature during manufacturing. On the other hand, the reduction of emissions created before they are expelled from the ship is the decrease in the emission rate caused by the use of various chemical processes to react with the exhaust gases. Every technique for reducing emissions has an additional expense, and many of them also raise operational costs by increasing fuel usage. Electric propulsion systems are distinguished by their reduced fuel usage and elimination of fuel-based pollutants. As a result, it is not only environmentally friendly but also a cost-effective strategy for a wide range of ship types. Furthermore, any approach used in traditional propulsion systems may be used in electric propulsion systems if appropriate. Electric drive propulsion systems, like other technical advancements, were created to satisfy specific demands. For a trade that grows with globalization, the importance of timing and speed, the gradual depletion of fossil fuel reserves and the resulting need for renewable fuels, the rise in climate change and environmental pollution, and the regulations put in place to prevent it, a new propulsion system in boats is required. Electric propulsion systems have been built with criteria such as high speed and torque capacity of electric engines; low environmental impact and compatibility with renewable energy sources; quieter; reduced vibration; and high dependability. It's also become the best option for certain ship kinds that require precision placement [3].

The majority of modern maritime fuels are heavy fuel oils (HFO). Global marine fuel consumption is expected to reach over 330 million metric tons (87 billion gallons) per year,

which is more than the 220 million metric tons of jet fuel consumed annually (1.4 billion barrels). Passenger ships, fishing boats, tug boats, naval ships, and other miscellaneous vessels utilize the remaining 10% of the world's marine fuel. Over 90% of the world's shipping products move via marine cargo vessels. Furthermore, due to increased worldwide commerce, the entire demand for marine fuel is predicted to double by 2030. Large two-stroke diesel engines (for inland and coastal transport) and even larger crosshead engines (fueled with high sulfur bunker C heavy fuel oil) are utilized to power these vessels. The maritime sector is confronted with several issues relating to emission standards. Marine fuel is one of the major sources of Sox, NOx, and PM in the atmosphere. The California Air Resources Board (CARB) and other state agencies in the United States have created laws that restrict the sulfur content of gasoline used in coastal areas (known as emission control areas or ECAs) to 0.1 percent. Due to the decreased sulfur content, ship operators have had to switch their engines from lower-cost bunker C heavy fuel oil to far more expensive distillate fuels like diesel. Furthermore, ship owners are increasingly operating their boats at low speeds, which stimulates the development of sulfuric acid in the combustion chamber. Because of this combination (lower emission goals and slower speeds), the maritime industry is working hard to find alternatives with less sulfur and carbon [4].

Approximately 90% of world commerce is transported by the maritime sector. These items include energy, food, consumer products, and raw materials. The International Maritime Organization claims that (IMO) there is no more efficient, safe, or environmentally friendly manner of delivering things across the globe. CO2 emissions per tonne-kilometer (tom) 1 are 31 gCO2tkm for maritime transport, 602 gCO2tkm for air freight, and 62 gCO2tkm for road freight. As a result, shipping products by plane and truck generates 20 and 2 times as much CO2 as shipping goods by ship, respectively. However, as shown in the table, the global marine sector contributed only about 3% of annual global CO2 emissions from 2007 to 2012.

Table 1.1: Global shipping CO2 emissions in relation to the world CO2 emissions, values in a million tonnes CO2

Year	Global CO_2	Total shipping	% of global	International shipping	% of global
2007	31, 409	1,100	3.5 %	885	2.8 %
2008	32, 204	1,135	3.5 %	921	2.9 %
2009	32, 047	978	3.1 %	855	2.7 %
2010	33, 612	915	2.7 %	771	2.3 %
2011	34, 723	1, 022	2.9 %	850	2.4 %
2012	35, 640	938	2.6 %	796	2.2 %
Average	33, 273	1, 015	3.1 %	846	2.6 %

From 2007 to 2012, the table shows total worldwide shipping and international shipping CO2 emissions. In addition, it displays total and international shipping CO2 emissions as a fraction of world CO2 emissions. Total shipping CO2 emissions decreased during this time owing to lower emissions from bulk carriers, container ships, and oil tankers sectors. As seen in figures 1.1-1.2, the oil tanker industry cut its overall fleet's CO2 emissions by nearly 20%, compared to the bulk carrier industry saw a 5% drop with the field of container ships seeing a 2% decline. In addition, as shown in figures 1.1-1.2, These three industries have been successful in lower fleet transport CO2 intensity while expanding demand tone-miles, total installed power, and overall capacity for deadweight tons in a fleet.

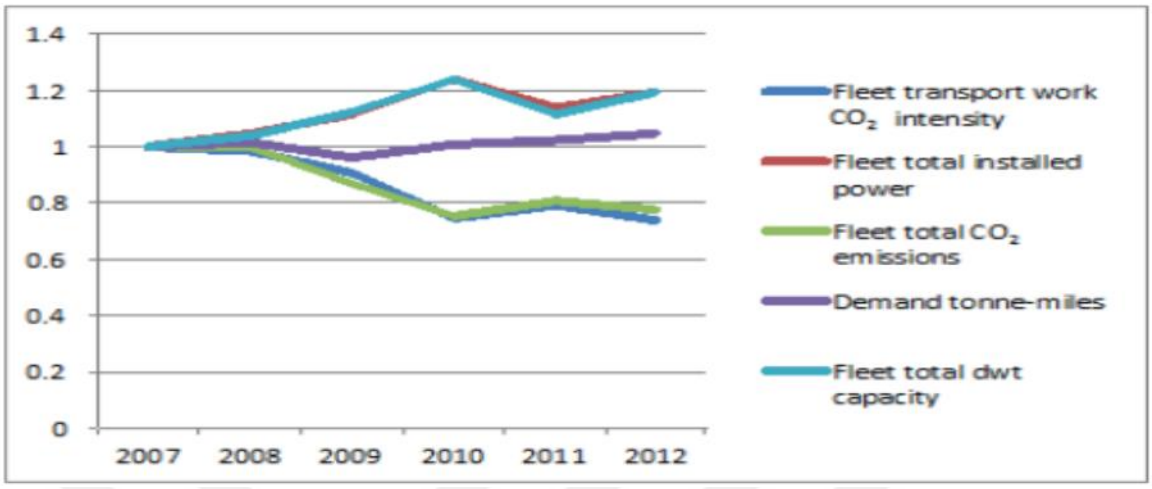


Figure 1.1: Fleet total trends in the tanker sector from 2007 – 2012

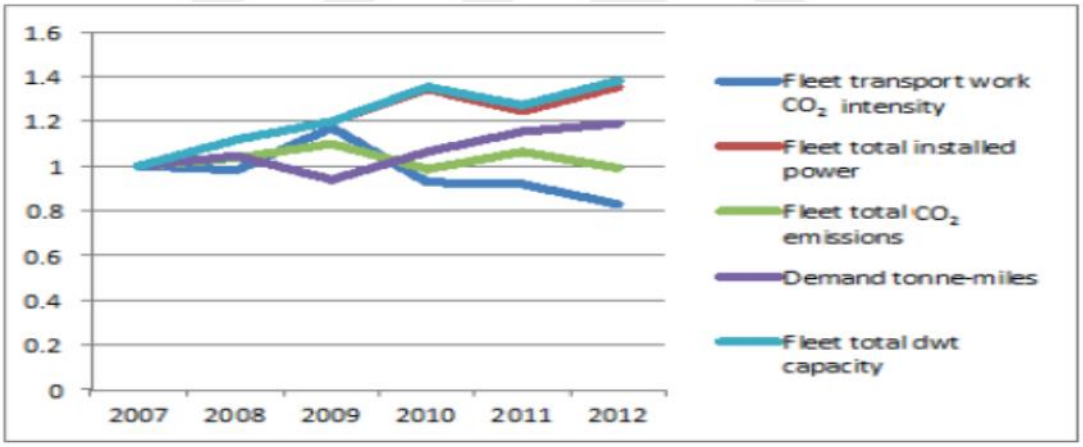


Figure 1.2: Fleet total trends in container ship sector from 2007 – 2012

The reduction in CO2 emissions is primarily due to a decrease in typical days of travel and the proportion of average sea speed to design speed for the oil tanker industry between 2007 and 2012. Average days of travel and the for the oil tanker industry, the ratio of average sea speed to design speed decreased by 15% between 2007 and 2012. The bulk carrier sector witnessed a 22% drop in the typical days of travel as well as a 12% drop in the average sea speed to ratio to design speed between 2007 and 2012. However, the container ship sector experienced a 5% increase in average days of travel and a 10% reduction in the ratio of average sea speed to

design speed between 2007 and 2012. The decline in both speed and days at sea is what causes the trends in average fuel usage per ship. This, together with the number of ships in operation, has resulted in a decrease in overall fleet CO2 emissions. The trends in speed and days at sea, in addition to tracking production levels, are approaching a record low (transport work per unit of capacity). As a result, the number of ships in operation, total installed power in the fleet, and demand tone-miles have all increased but are tempered by an oversupply of ships and high fuel costs. Productivity suffers as a result of these growing tendencies.

As shown in Figure 1.3, the world's fuel's overall final consumption (TFC) in 2015 was 9 384 Mote, which included worldwide bunkers for aviation and ships. Figure 2.1 displays the fuel shares. They are separated into six categories: Coal is ranked third, followed by biofuels, natural gas, oil waste, and electricity.

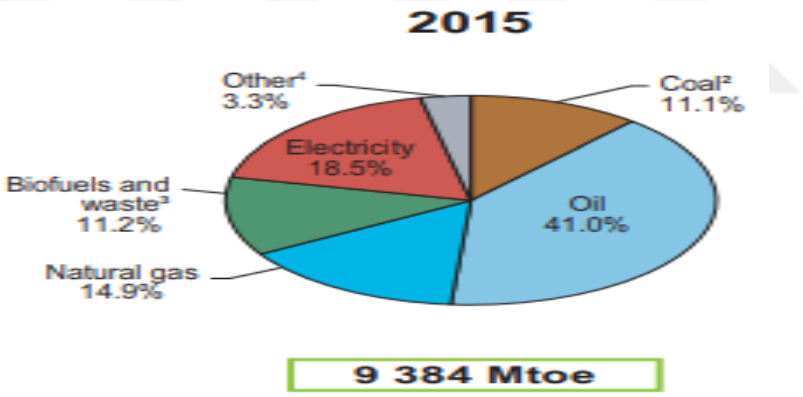


Figure 1.3: Fuel shares of total final consumption in 2015

Figure 1.4 depicts oil TFC shares over the globe in 2015. As seen in the graph, boating in the water utilizes 6:7 percent of TFC oil or 257 Mote. The navigation industry consumes roughly 830 million tons of CO2 based on a conversion ratio of 3 to 223 kgCO2 tone of fuel oil. This is a decrease of more than 10% from 2012 [5].

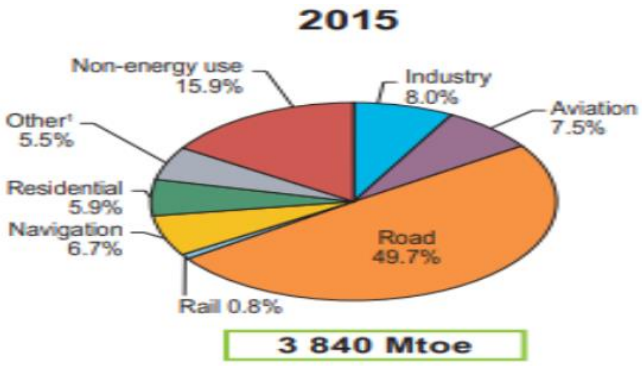


Figure 1.4: TFC shares of oil in 2015

1.1 ELECTRIC PROPULSION

Electric propulsion for ships is not a new notion; it has been used in ship design for over a century (albeit in a few vessels). An example of an electrically operated ship is the river tanker Vandal. It was the first ship to be propelled by a diesel generator since most boats had been operated by steam turbines up until that moment. A revolution in solid-state and semiconductors happened in the 1980s, allowing for speed control of big electric motors, and making electric propulsion more realistic for shipbuilders. Initially, DC motor speed control was introduced, but this was eventually superseded by accurate AC motor control employing complex control techniques. For boats, an electric propulsion system enables excellent dynamic maneuverability. This is especially critical for icebreakers and other boats. Due to their low speed and high torque, electric motors can respond quickly to sudden changes in how much power they need. This can make them much easier to move around [6].

Over the previous few decades, environmental awareness has grown globally and has transformed into a screaming necessity. Engineers have a responsibility to maintain environmental friendliness and long-term development of the environment. The current tendency among energy experts is to learn about alternative energy sources when the principal supply of fuel becomes scarce. Solar, wind, water, tidal flow, geothermal, and biomass are all forms of renewable energy with vast amounts of resources for power generation. As a result, it is becoming increasingly important to develop and implement more ecologically and eco-

friendly technologies that make use of alternative, renewable energy sources. Solar energy is the most common renewable energy source since it is easily obtained from nature. We may develop the gear and install the solar boat for tourism purposes on a maritime vessel using this solar energy. Figure 1.5 depicts a schematic illustration of the solar power system used onboard the vessel for both propulsion and support equipment.

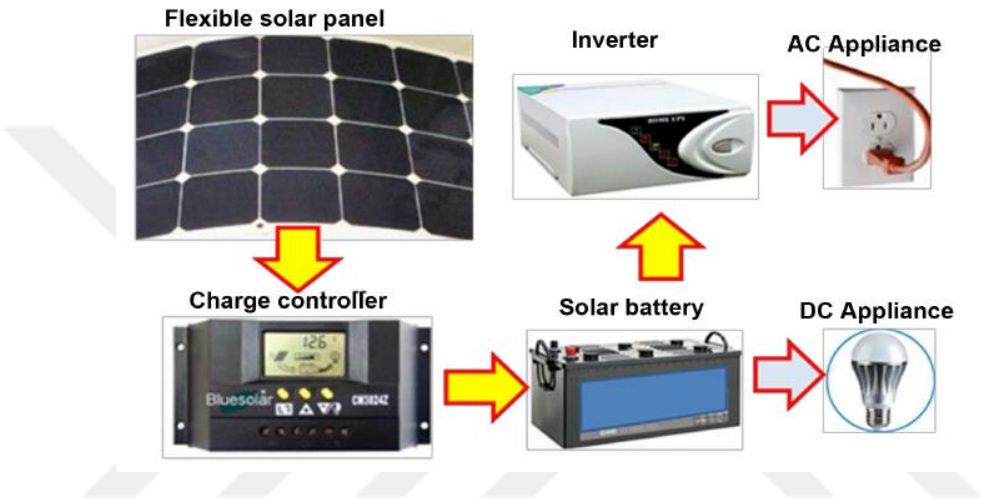


Figure 1.5: Solar power system

Solar energy is a huge renewable energy source that has a lot of energy in the form of heat and light that can be converted into electricity. Aside from domestic purposes, solar electricity may be used as a replacement for oil in boat fuel, reducing water pollution and fuel costs. Solar-electric-powered boats have the potential to provide zero-emission aquatic transportation and pleasure on the global seas. The battery, solar panel, electric motor, and propeller are the main components of solar-powered boats. This research looks at the feasibility of installing photovoltaic solar panels on a ship to lessen its reliance on fuel. The vessel's electricity consumption is estimated, as is the electricity generated by the solar panels. A solar boat design method is so unlike that of a traditional boat that it is referred to as "solar boat design." Because available solar energy varies throughout the year, the design conditions are critical. It also fluctuates depending on whether it is sunny or overcast [7].

1.2 PROJECT OBJECTIVES AND SCOPE

This idea proposes an electrical propulsion system using solar panels to reduce pollutants produced by gasoline engines while also utilizing the possibilities of renewable energy in the boating industry. Another of the key goals is to comprehend and define all of the components.

This project's scope includes a variety of tasks aimed at achieving the above-mentioned goal.

These are the following:

a. electrification of boat propulsion system
b. Components for electric propulsion research and selection (motor and batteries).
c. Solar panel research and choosing.
d. Implementation of the proposed system through a simulation program.

2. LITERATURE REVIEW

The literature has many studies on the spread and use of renewable energy, particularly solar-powered boats. Because of the shortage of technology, energy sources, and energy-storage facilities in the electrical system, the electric motor revolution stalled in the previous century. In addition, the efficiency of electric motors wasn't really up to the mark [8]. Because of sophisticated, high-efficiency solar PV modules, solar energy is the most common electrical power source. Solar PV modules are now being used in developing countries like Bangladesh to create solar household systems and have enormous usage in telecommunication towers in off-grid regions. Solar PV modules are being used globally to achieve total electrification.

Postilion et al. [9]. demonstrated a zero-emission electric propulsion boat powered by a synchronous permanent magnet motor (PMSM) that may be utilized for public transit and water activities. They unveiled two motors, two PMSMs, each rated at 12kW and equipped with the DC-DC converter to maintain a constant Bus voltage in DC. The wave is the boat. -piercing catamaran with the use of lithium-ion batteries' ability to charge in the port, as well as photovoltaic solar panels on the roof. This research focuses on boat speed and the length of power delivered by the battery, but it does not go into detail on charge management and motor control.

Ahmed et al. [10]. Investigated the feasibility of employing solar and wind energy aboard ships. A photovoltaic panel diesel, wind turbine engine, AC/DC converters, Battery, and DC/AC inverter bank make up the system. They demonstrated that a solar photovoltaic panel could be put on the ship's available area and provide a considerable amount of energy production.

Walled Obadiah et al [11], [12]. Proposed a hybrid vehicle system for the electric boats that includes photovoltaic panels with MPPT innovation, storage of hydrogen container, a water-filled polymer electrolyte membrane (PEM) fuel cell electrolysis to create hydrogen, and a synchronous diesel motor. He employed a Batteries system based on fuzzy logic to regulate fuel flow in the fuel cell depending based on battery charge and a forecasting system utilizing a using neural network to attain solar irradiance by gathering climate, humidity, and

environmental statistics on wind speed. Finally, using MATLAB SIMULINK, the system was verified. The new method has been tested in different kinds of weather while keeping the speed of the boat steady instead of changing.

The paradigm for regulating the hybrid energy and momentum of intelligent boats was evaluated by RD Geertz and others [13]. He classified the ship based on its power structure, which included a hybrid energy source (solar photovoltaic and other sources), storage ignition, battery, electrochemical, and drive topologies. The suggested system might cut gasoline usage and emissions by 10%–35%, reduce the noise and enhance the availability of power according to advanced control methods using hybrid energy systems and vessel propulsion systems. The key problem is to integrate the whole control system, and additional studies will need to do this.

An optimistic control strategy for a PV system ship powered by a reductive indirect vector induction generator was presented by Sermonette et al. [14]. A test driving load was used to link and test inside the laboratory to guarantee the expected procedure. This research lacks significant field data on the performance and effects of solar electricity and induction motors.

By installing solar photovoltaic and storage systems aboard a ship, Liu [15]investigated a model for reducing CO2 and Knox greenhouse gases and increasing energy production. The effects of solar irradiance variation and battery aging are reduced. It has been shown that the proposed energy storage technology might save at least 25% to 35% on battery replacement.

Richard Leaner [16] demonstrated a zero-emission hybrid-powered boat for maritime use. Solar photovoltaic cells, on the other hand, are accustomed to making the gas hydrogen using an electrolyze and storing it in a tank so that fuel cells may generate electricity while assuring optimum hydrogen consumption through a system for managing energy. In addition, a system for managing information was developed to gather data remotely using GSM engineering. The key challenges are making sure the fuel cell works safely, figuring out how much pressure it can take, and predicting how much energy will be in the battery.

The solar racing boat was suggested by Tim Garter [17]. He adjusted the solar boat adjusting motor to gain maximum ship driving from the supplied solar energy by taking into account hull resistance at different speeds and the greatest feasible efficiency of electric engines in this research. When compared to a comparable racing boat that had not been improved, a 15% gain in efficiency was recorded. The main flaw is that designing a motor for a PV boat is difficult since this improved solar boat might not perform well if various voltage (if solar PV output isn't constant) and torque are applied.

Alexandra's Galyaks et al. [18] investigated the installation of a cost-benefit evaluation, a solar hybrid power system aboard a commercial ocean-going vessel. They spoke about the possibility of installing a photovoltaic solar system on the ship and the retaliation time in terms of saved fuel. The most significant difficulty is raising oil prices, which lengthens the payback period. It was shown that a 10% to 15% rise in yearly oil costs results in a payback period ranging from 16 to 27 years. Further research is needed on the design, integration, testing, and st, and control systems evaluation of photovoltaic systems in ships for maritime transport.

[19], evaluated the performance of a hybrid power system in Stockholm, Sweden, a cruise ship that included photovoltaic panels, a PEM fuel cell, an electrolyze (hydrogen generation), an H2 tank, and a diesel engine to support the primary and backup power. This research aims to make marine transportation more environmentally friendly and sustainable by introducing renewable energy sources into small and large boats. During the inquiry, he assessed the cruise ship's power demand and used modeling and simulation to figure out the power system's regular and annual efficiency, cost of production, and power conversion capacity factor. The results of this analysis showed that the suggested system is enough to meet the energy needs of the cruise ship and is close to a reasonable percentage of renewable energy sources for naval use.

In Kuala, Terengganu, N. A. S. Salah et al. [20] addressed the possibility of employing solar and wind energy in grid-connected electric charging boats. In HOMER software, he simulated several configurations of wind power, photovoltaic, converters, batteries, and grid electricity.

He discovered that a hybrid grid-PV is the most cost-effective and high-performing design. There is no advice on how to achieve the maximum output power from a solar tracking device.

Mahmud et al. [21]. offered solar-powered electric boats with specified weight and distance transportation, but they did not provide a thorough design approach. The lightweight composite material was evaluated for use in the construction of a watercraft. They estimated the dimensions and hydrodynamics of the boat, as well as the propulsion system, photovoltaic capacity, and size of the battery bank. The motor-driven engine was used to propel the boat forward. The control system, on the other hand, was not found to be able to maintain a consistent boat speed when the number of people on board increased.

Tamunodukobipi et al. [7] demonstrated a solar PV-powered naval vessel. An electric motor and a storage battery system (235Ah, 12V) were used to move the boat. They had a hurdle in putting up solar PV panels owing to a lack of room Due to the suggested technology of either extending the boat hull's length and width or replenishing the batteries from the grid for the land,

Wen et al [22], [23]. Investigated solar energy power variations. They developed a potential strategy for implementing solar photovoltaic electricity and an energy storage device on a large vessel. The technique used to regulate the optimist energy storage system has resulted in lower investment costs for energy storage devices and gasoline, as well as a reduction in pollutants. It also took into account the vessel's weight variation and various operational conditions.

A country boat operated by a stand-alone solar system was suggested by Soma Dada et al. [24]. A buck-boost converter was employed to optimize the power system that keeps the economic factor consistent. When the PV array produces too much voltage, the Chopper switches to buck mode, and when the voltage falls below the reference, the Chopper switches to increase mode to increase the voltage to a precise amount. They employed the solar cell to provide necessary shading to protect the guests on the boat from rain and harsh sunshine. This strategy reduces the overall weight of the boat while also conserving energy and increasing passenger capacity.

Used numerous methodologies and processes to investigate a current energy management strategy. The goal was to reduce environmental impact while maintaining a balanced power use on board and in port. This research utilized sources of renewable energy, power grid power, storage at the shore, and different marine fuels for both boats and the port. The selected energy management approaches were found to be beneficial to the port, boats, and the further expansion of balanced communities.

Hay Land et al. [25]. Investigated a hybrid electric vehicle that combines an electric generator, a backup battery device, as well as a solar photovoltaic array to power up a ship. In this research, the minimum asset cost, fuel cost, and greenhouse emissions were taken into account while designing an unplugged hybrid power supply, as well as looking at how the output of the PV module changes when temperatures and solar irradiation vary. Therefore, the net present cost (NPC) of generating electricity using solar photovoltaic panels and an engine-powered generator is more significant compared to a hybrid power generation system.

The strength of a PV solar system and a financial return scheme to be installed on a traveler tour ship in the Indian citizen canals was detailed by Seem Kumar Sharma et al. [26]. Assessment of the Indian National Waterway situation, integration of solar-powered boats, advantages and arguments over the model and potential financial gains of MW and decreasing the number of greenhouse gases utilizing solar energy PV boats, and a worldwide extension of solar PV innovation for boats are among the methodologies that have been evaluated for the conclusion. Standard codes, specs, and regulations for solar-powered boats are not discussed in this study. The key problem is to directly affix the solar cell to the fiber-framed boat to reduce vascular mass.

Ahmad Nasirudina et al [27]. Devised a technique to optimize a solar-powered vessel to determine the most cost-effective solar PV system. To have the least powerful propulsion from an existing passenger on a catamaran, the ship design utilized Taiwan's golden search section algorithm approach was applied. The simplex method is accustomed to grasping the solar system to acquire the cheapest solar panel with a battery. Following The simulation was discovered that the best vessel is more slender and has a lower propelling force (about 1.75

percent) as well as more solar power, lower battery capacity, and a lower yearly investment cost (around 16 percent less than the existing vessel). They had to deal with the weight of photovoltaic modules and battery banks, and they didn't think about the effect of solar irradiance fluctuations.

The effects of the hybrid energy roll-on, roll-off freight system boats were investigated by Janice Ling-Chin and others [28]. Hybrid power technology includes diesel generators, solar photovoltaic arrays, battery systems, cold ironing, propeller and thruster, motor, transformer, VFDs, rectifiers, inverters, and AC-AC converters. The environmental and equipment life cycle l problems were investigated in this research. To obtain the results, they burnt marine diesel fuel and released CO, CO2, particulate matter, hydrocarbons, NO, and SO2. Most of the ship's standard power systems then compared the results to a newly built hybrid power system. They concluded that the plan has a big effect on the echo system, biological resources, and people and that good management should be a top priority.

[29], Investigated if a small electric ship might reduce power needs from dispersed energy sources such as fuel cells, solar panels, and batteries. The suggested system consists of an electric motor, a photovoltaic solar system, a fuel cell, and a self-contained battery bank. Consequently, the research on a compact electric boat might run in the summer using electricity and an array of solar PV, assuming the ship isn't too difficult to operate.

Tang [30][31] has proposed a revolutionary solar PV array layout using a maximum tracking power point (MPPT) system for extensive use of renewable energy in the vessel. The MPPT was governed in real-time using a control technique and a meta-heuristic optimization procedure, which resulted in increased output power in diverse environments.

A hybrid vehicle system for an electric boat has been developed by Walled Obadiah et al. [32]. He generated electricity for the suggested electric boat using solar PV panels and a wind turbine system, and the first, second, and third renewable energy sources are polymer electrolyte membrane (PEM) fuel cells. Sources, respectively. SIMULINK was used to model and assess the proposed electric watercraft. During the experiment, the difference between s the sun's output and the wind speeds were thought of as flawless switching, continuous

operation of various hybrid power systems mechanisms, and consistent speed. There is nothing to report on the system of motor control or the power source's influence on changing speed.

Camilla et al. [33]. Evaluated wind and solar systems to describe the current trend of electric propulsion for boats. He described the power supply system for moving boats using hybrid electricity (generator and battery), simply with a battery; a variety of resources such as LNG, diesel, FCs, wind, and PV are examples of fuels. The difficulty in improving battery engineering is to find a way to make batteries last longer and make it easy to charge them.

An adequate water transportation system was devised by Banker Jay dip Deli et al. [34]. Boats, on the other hand, are powered by photovoltaic solar cells installed on the canal's exterior, which charge the power supply. The traction technique is used to gather electricity through the ceiling wire linked to the battery bank by boats. Maintenance is the main problem; if there is a problem with the line, all of the traction boats would be useless.

Salish Babe and others [35] designed a solar energy method to meet the built-in power requirements of fishing trawlers. The goal was to provide reliable ecological electricity while lowering present prices. The ADSGAF business assessed Indian fishing vessels and evaluated their onboard load and fuel usage. The planned system was implemented and commissioned for testing with the help of the BOBP-IGO firm, ensuring it uses less energy and is cleaner. Lucrative and impartial. They proposed that further study and evaluation be done to ensure that the solar PV module's structural and electrical equipment are perfectly integrated into the fishing boat.

Triage B. Seiko [36] proposed a solar-powered electric boat charging system based on power electronics. High-frequency half-bridge digital converters that are interleaved with interphase transformers and FET semiconductors made of gallium nitride are used in the system. In the lab, he mimicked all of the hardware. The results revealed that the Gann FET and interphase transformers converter work well together, with the greatest results obtained at high operating frequencies. A highly qualified technician is required to troubleshoot power electronics equipment.

[37], investigated the development and evaluation of hybrid forms of renewable energy for use on the earth and at sea. It was decided how long it would take for the renewable energy system to pay for itself, and it was noted that less gasoline would be used and less greenhouse gas would be released.

Maria D. Margarita and others [38] looked at the emitted gases from seagoing vessels and how to reduce them by putting a hybrid energy system aboard that included a windmill and solar photovoltaic array.

Reza et al. [39], used a mix of HOMER, PV system software, and manual computation to examine a solar-powered boat for ocean photovoltaic for Bangladeshi fishing purposes. The key problem is to maximize the solar panel's output while moving.

Leung et al. [40] created a solar-powered watercraft that emits no greenhouse gases. They conducted case studies (overall cost analysis and CO2 reduction) using different solar efficiency levels. This technique saved money while also lowering emissions of CO2. The creator also explored the disadvantages of an engine-driven watercraft. The biggest issue in terms of PV efficiency and weight is increasing battery capacity.

Hue [41] discussed the viability of renewable energy for marine transportation, as well as its extension and inclusion. Solar PV is the first feasible and substitutable source of energy for commercial vessels in Taiwan's marine sector. He showed that the system of renewable energy and the consolidation of maritime shipments were both working well.

Sahib Chakra booty and others [42]. Investigated the feasibility of solar energy installation on the fishing boats open there is Bangladesh's Chittagong region. He inspected 200 fishing trawlers to gather information on The cost of rooftop area. Solar tilt is a fixed position for the greatest solar energy during the year PV panel power production Life Cycle Price Estimation With the use of MPPT is not discussed in this study.

To fulfill Dubai passengers' primary and auxiliary power needs, Chennai and others [43]. Built a hybrid power system using fuel cells, diesel, and solar energy. He utilized software for the

HOMER setup simulation, too. He displayed that the hybrid power system he suggested was the best for the environment, but he didn't talk about how the money would be paid back.

Solar boats were designed by Peter Jorge et al. [43]. for long-distance drifting. He suggested the development and design of a solar boat timed race. A timeline for the solar boat's noteworthy rivalries has also been included, as well as recommendations for upcoming boat designs. This report was not discussing design techniques; instead, it gave a collection of project details.

Obadiah et al. [44] built an Asynchronous three-phase machine driven utilizing hybrid solar-diesel power sources for an electric boat. To drive the electric boat, they employed the MPPT technology to acquire the highest PV array output. When solar irradiation was insufficient, a diesel generator was employed as backup power. They also used a neural network to demonstrate previous solar irradiance projections, which aids in planning hybrid power activities for operating the electric boat.

Rumen Chao and others. [45], Plotted outgoing ship propulsion using a dispersed solar system that is self-contained. For system integration, he employed MPPT innovation, an enhancer of power (PO), a PV power manager, a motor governor, a BMS or battery management system, and a for onboard control, he used UART. The weight of the battery system and the cost of replacement are the two most significant obstacles. A reform PV boat was used to test the system on the River of Love in Taiwan's Kaohsiung City.

Spangle et al. [46], presented a pollution-free, low-cost electric tourist boat powered by innovative management technologies for using energy storage batteries to charge and discharge them. For the suggested solution, they utilized solar PV arrays, a 45Ah battery, a 14m5.5m catamaran boat, a controller for MPPT, a (DC-DC) boost converter, a switcher (DC/AC), a control over charge-discharge, and a power-management device. In a nutshell, it describes the combination of solar boats' pioneering mechanisms, engineering approach, and understandable design, safety, and trustworthiness processes. Defects were also discovered when developing the system design.

3. SOLAR ENERGY IN GENERAL

3.1 ITRODUCTION

Energy, like food, is a requirement. Everything in our environment necessitates the use of energy. The world's population has grown over time, which is directly proportional to the amount of energy consumed. All of the available devices and equipment require some form of energy to operate. With fossil fuel stocks decreasing, it is becoming increasingly important to discover feasible renewable energy options that may reduce reliance on fossil fuels. The most plentiful source of energy available to humanity is solar energy. In a single day, around 10,000 TW of sunlight is incident on the ground. According to research, global energy consumption was 17.4 TW in 2015. Every year, there is a small rise in energy usage, about 1–1.5 percent on average. By 2040, the world's total energy is predicted to increase by 56%. We can only conceive the potential solar energy has when we compare present consumption, expected growth over the next two decades, and the quantity of solar radiation received in one hour. The overall energy consumed is a significant portion of the total energy we get in an hour. Even though people have access to a lot of energy, less than 5% of the world's energy comes from the sun. Apart from extracting the resources and reducing reliance on fossil fuels due to their scarcity, one must also be aware of the effects of consuming fossil fuels. The use of fossil fuels to generate energy hurts the environment. The greenhouse effect is caused by the emission of CO2 into the atmosphere. Furthermore, it contributes to the depletion of the ozone layer. These processes can result in various events, such as acid rain, air pollution, land contamination due to excavation activities, and so on... [47] According to the Renewable Energy Map, the proportion of fossil fuels in total global energy consumption must decrease from 65 percent in 2018 to 19 percent in 2050. Another option is to employ nuclear energy. Heavy atomic nuclei are split in nuclear fission, which releases a massive amount of energy. However, due to past catastrophic incidents and the constraints of managing nuclear waste, society is polarized on using nuclear fission to fulfill energy demand, necessitating the development of more sustainable alternatives. Solar energy is one of the most attractive and scalable means of achieving a sustainable energy transition. The heat created when light strikes a surface may be used to gather solar energy. This is frequently accomplished using

"solar concentrators," which consist of a series of mirrors that focus sunlight on a single point. Photovoltaic, which converts photons emitted by the Sun directly to electricity, may also be used to capture solar energy. Only 3% of total energy was produced by solar energy in 2020 [48]. Humans have been using solar energy for hundreds of years. Solar systems, for example, were created 2000 years ago to recover salt from saltwater. For heating and cooling houses, Harnessing the sun's energy now encompasses a wide range of technologies, from basic sun-drying of crops to photovoltaic cell-based direct generation of electricity. Solar thermal applications convert solar radiation to thermal energy, which may be utilized immediately (e.g., solar hot water systems) or converted further into electricity. In contrast, photovoltaic applications generate electricity directly from sunlight using the photovoltaic effect. Solar energy, in its broadest definition, refers to any phenomenon that may be traced back to solar energy and harvested as usable energy, either directly or indirectly. Solar energy can also encompass processes like wind and photosynthesis in this regard. However, we confine the word "solar energy" to "energy sources that may be directly linked to the light of the sun or the heat that sunlight creates" for our purposes. As a result, solar energy technology may be classified into the following categories: There are several types of energy: passive, active, thermal, and photovoltaic, as well as concentrated and non-concentrated. Passive solar energy technology just absorbs energy rather than turning it into heat or light. It has been widely practiced and incorporates factors such as site selection, window location, dark walls, and other factors to enhance heat and light gathering. Active solar energy technology, on the other hand, relates to the use of solar energy to store or convert it for other purposes and is divided into two categories: photovoltaic and solar thermal. Among many active solar energy technologies, solar photovoltaic (PV) is the most advanced. Solar photovoltaics were first utilized to generate power on space missions in the late 1950s. While this application kept a niche market that was mostly unaffected by cost, it did contribute to the development of the solar PV sector in the United States. Following the oil crises of the 1970s, the technology's applications grew. From 1983 to 1999, the PV sector's exports of photovoltaics grew by about 15% per year, which wasn't a very fast rate of growth [49].

Several nations have enacted laws and incentives to encourage the growth of solar PV programs, resulting in a significant rise in total installed capacity. Due to its plentiful supply and technical advancements in PV cells, such as the rapid drop in PV module cost, photovoltaic solar (PV) has the fastest rate of growth Figure (3.1) depicts the global yearly rise in energy consumption via source. The price of solar photovoltaic (PV) decreased by 99 percent during the last four decades. In 1972, The typical module cost was US$74/W, but by 2014, it had dropped to less than USD 0.70/W. Chinese thin-film (TF) solar panels cost an average of 0.75 Super watts in 2012. By 2020, it is expected that the cost of PV modules will have decreased by more than 40%. German solar power systems had a small cost of under USD 2200 per kW in 2012. The Association of the European PV Industry (EPIA) predicted in 2012 that by 2020, the cost of rooftop PV on modest-scale systems and substantial PV projects would be, respectively, $1750-2400/kW and $1300-1900/kW. The installation of solar PV systems has been increasing in popularity, especially in energy-scarce nations throughout the globe, due to rapid reductions in module costs and the disparity comparing the price of renewable energy production and the price of producing traditional power. According to the EPIA, PV energy could contribute 4.9 to 9.1 percent of the world's energy output in 2030 and 17-21% in 2050. PV cells and modules are now produced by over 1000 manufacturers globally, the majority of whom are situated in the United States, Japan, Europe, and China. PV is currently rivals with electricity powered by diesel systems[50].

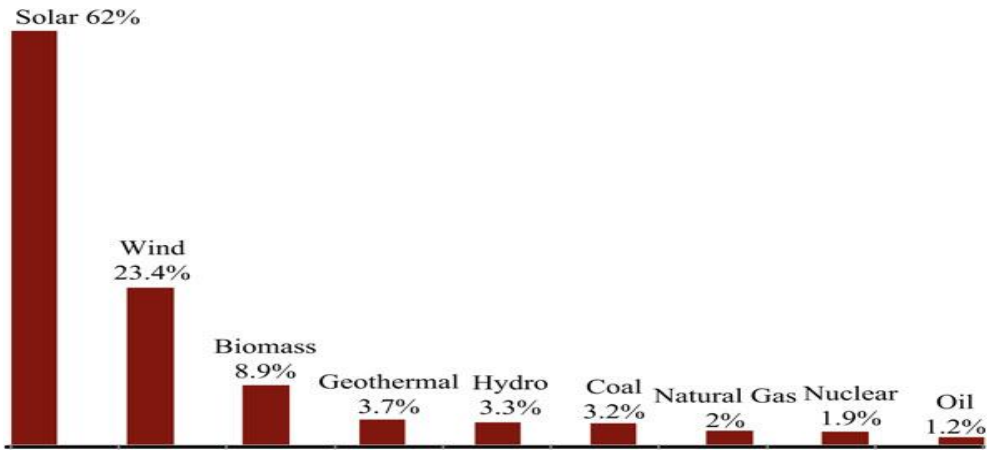


Figure 3.1: World annual growth of energy use by source (2008–2013)

Between 2000 and 2013, the typical effectiveness of commercially manufactured PV cells made on mono-crystalline silicon improved to 16% from 11%. Simultaneously, the top study cell efficiency increased from 32.5 percent to 44.7 percent. By stacking numerous technologies, the top research cells attain efficiencies more significant than the silicon p-n junction Shockley-Queasier limit (29. percent), allowing an expanding fraction of that solar radiation- between infrared (IR) and ultra-violet (UV)-advanced technology to get close to 50% efficiency. The disparity between the typical efficiency of commercial cells (16%) and the top Efficiency of research cells (44.7%) in 2013 implies that there is still potential for commercial cell efficiency increases. The efficiency of commercial solar PV cells has improved and grown virtually linearly for over ten years, as seen in Figure 3.2.

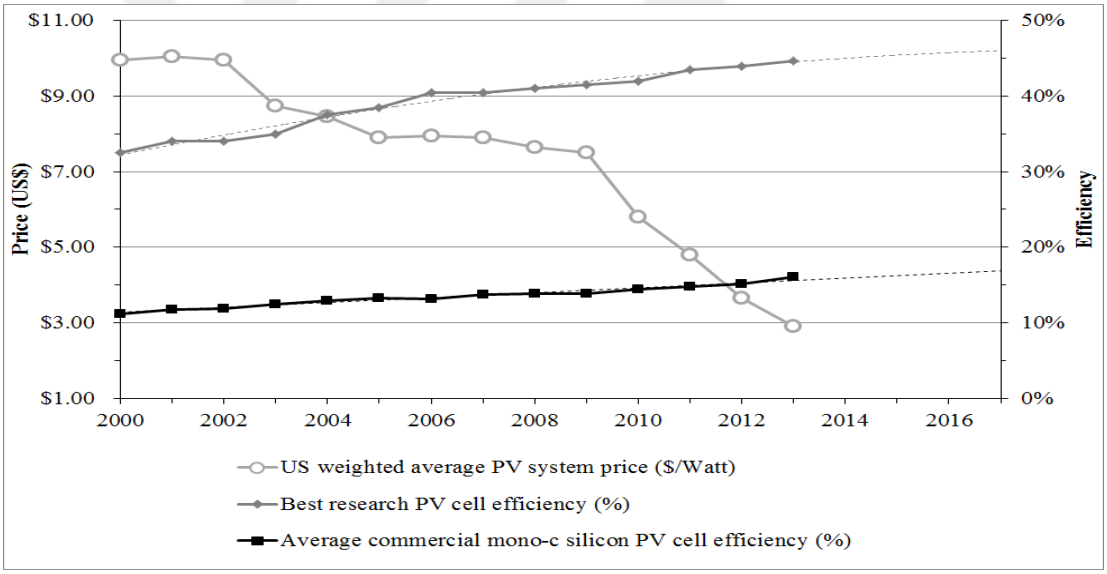


Figure 3.2: Solar PV efficiency and price, 2000 to 2013

Figure 3.3 depicts potential prospects, with further information available in a paper from the EU Photovoltaic Technology Platform's Group for Science, Technology, and Applications The cost of installed land-based PV systems, weighted average in the United States has dropped dramatically, from roughly 2000: US$10 per watt; 2013: US$3 per watt or less, owing to lower PV module prices Solar PV technology costs are expected to keep going down at least the upcoming ten years, thanks to increased worldwide manufacturing efficiency and

advancements in manufacturing, increased cell functionality, and the release of less expensive technology.

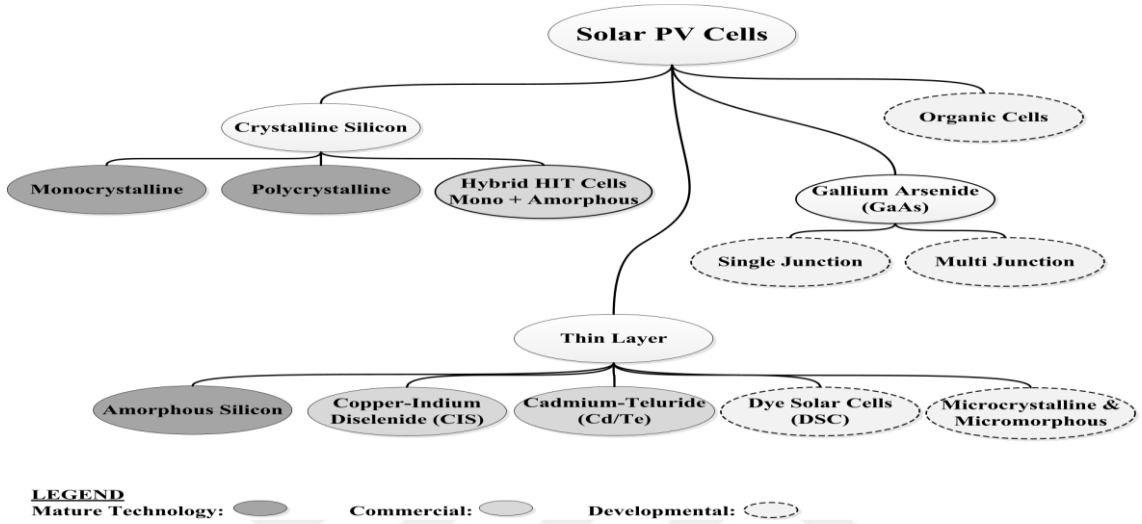


Figure 3.3: Photovoltaic (PV) technology. The grey scale indicates the level of technological development.

Mono-crystalline or even multi-crystalline silicon panels, as well as other mature solar PV technologies, are affordable and widely accessible. Amorphous silicon cells with thin layers are presently more costly than thick-layer amorphous silicon cells, but they can be employed along curving edges. Solid-state dye solar cells appear to have potential in terms of lowering PV manufacturing costs even more [51].

Solar energy is superior to every other energy source in terms of environmental benefits, and it is the cornerstone of any real, sustainable development program. It does not consume natural resources, emit CO2 or other gaseous emissions into the atmosphere, or produce liquid or solid waste. In terms of sustainable development, the main direct or indirect benefits of solar energy are [52]:

a. No greenhouse gas (CO2, Knox) or hazardous gas (SO2, particles) emissions.
b. increased regional/national energy autonomy;
c. Reclamation of degraded land
d. Transmission lines from power systems are being lowered;
e. Improvement of water resource quality

3.2 PHOTOVOLTAICS

3.2.1 The History of Photovoltaic

Alexander Becquerel, a young scientist at the Museum National historied Naturally in Paris, made a stunning discovery in 1839. After dipping them in an acidic solution, he evaluated the current between two silver halide-covered electrodes. He discovered when the electrodes were exposed to light, a current was created and that the largest currents were obtained when employing blue light or sunshine. He coined the term "photovoltaic effect" to describe how photons striking electrodes create a voltage between them. Becquerel was well aware that he had made a significant discovery, but he could not have predicted that his innovation would spark a transformation in the field of renewable [53]. Charles Frits built the first working solar cell in 1883, some fifty years after Becquerel's conception, utilizing a copper/selenium film/gold connection. The fact that the selenium film was a "semiconductor" was not recognized at the time, but Frits understood the device's potential and constructed the first photovoltaic panels on his roof a year after its discovery Einstein identified the photoelectric effect twenty years later, which would explain the photovoltaic effect as well. It appears that this finding will pave the way for solar cell development and industrial manufacture. The growth of the fossil fuel sector, on the other hand, swiftly put an end to any widespread interest in solar cells. During World War I, the use of so-called "Cat-Whiskers," which are crystal sensors used in radio receivers, reignited interest in semiconductor technology. For radio telecommunications, the semiconductor was utilized as a diode to correct current. Alexander Bell's laboratory further improved the Cat-Whiskers for radar systems during World War II. Russell OH created and patented a photovoltaic cell based on silicon modified with aluminum and phosphorous in this laboratory in 1941. The p–n junction, which lies at the core of every solar cell, was produced as a result of doping; the Cold War then accelerated the growth of solar cells. Modules

For the United States to win the Space Race, solar-powered spaceships had to be developed. The solar cell's power conversion efficiency (PCE)—the performance with which solar energy is transformed into electrical energy—improved from about 1% in 1960 to over 15% in 1970 as a result of external political pressure. Since 1991, a slew of technological advancements has

been made to boost solar cell efficiency even more. The group of Kaneka has the current record for the highest single-junction solar cell depending on silicon, achieving 26.6 percent in 2012, while the group of Yablonovitch holds the record for the highest single-junction solar cell, reaching an astounding 28.8 percent in 2017. Solar cells with high efficiency are still primarily utilized in aircraft, whereas solar cells with lower efficiency (15%) and lower cost are commonly employed in the energy industry. Martin Green created the phrases first-, second-, and third-generation solar cells in 2001 to categorize the different types of solar cells based on their prospective power production and prices. First-generation solar cells have an excellent efficiency of around 20% and the highest prices (US $3.50/W1). Second-generation solar cells encompass all thin-film techniques that allow the fabrication of bigger modules at a cheaper cost (US $1.00 W1) and with a lower efficiency of roughly 10%. This class contains copper indium gallium selenite (CIGS), cadmium telluride (Cadet), and gallium arsenide (Gas) (Gas) Finally, there are third-generation solar cells, which are designed to achieve high efficiency at a cheap cost. Multi-junction solar cells, hot-carrier solar cells, perovskite solar cells, tandem solar cells, organic photovoltaic (OPV), and dye-sensitized solar cells are all part of the third generation (DSSCs) [54].

3.2.2 Solar Panels Work (Photovoltaic)

With the growing interest in renewable energy in general and solar energy in particular, efforts have been made to offer solar energy technologies with a quantity of energy equal to or near to that consumed. It has gained popularity, changing buildings from energy-consuming plants to produce structures that depend on the sun as a cost-effective source of energy, and it is now widely utilized even in places with high levels of solar radiation or short hours of sunlight. The four essential parts of a solar system for electric power production are as follows (see Figure 3.4):

a. PV photovoltaic
b. Charger controllers
c. Inverters
d. Batteries

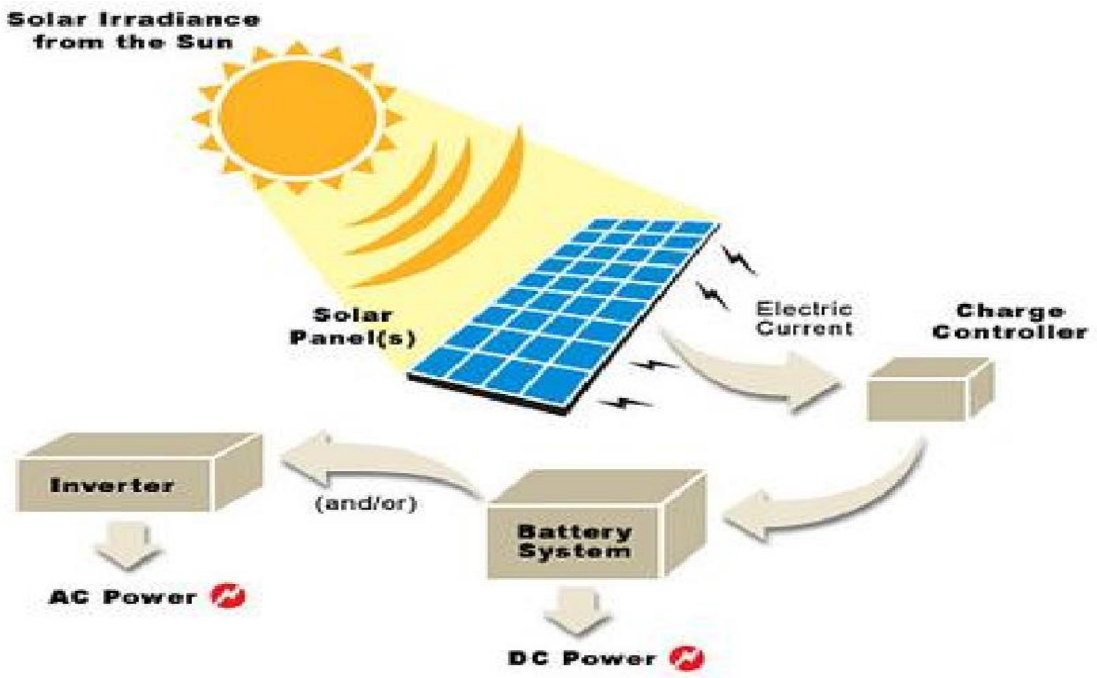


Figure 3.4: Elements of PV system

Photovoltaic (PV) energy is a kind of solar energy that is used to create electricity. Figure 1 depicts the components of solar panels. A solar panel is a collection of solar cells that create DC energy that may be used to power equipment or stored in rechargeable batteries that can be used several times. The measured power of the cells is measured in watts. The basic component of the solar system, the solar cell, is discussed to demonstrate how solar panels function.

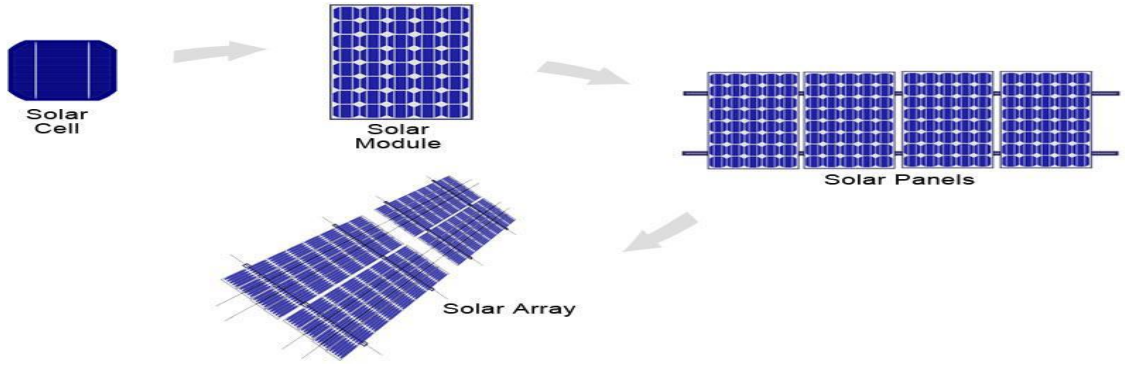


Figure 3.5: Components of PV panel

3.2.3 Photovoltaic Cell

It is both the largest and smallest component of the solar system. They convert solar radiation into electrical energy in response to direct and indirect solar radiation. Solar panels generate electricity by allowing sunlight to excite electrons inside a cell. The semiconductors in a photovoltaic cell are compressed onto a carefully prepared chip to generate an electric field that is positive on one end and negative on the other (see Figure 3.6). To create electricity, electrons are driven to a higher level of energy, and if electrical conductors are linked to the negative and positive ends, electrons are collected as electric current. The electricity that is made is called DC energy, and it is stored in batteries of different sizes so that they can be used when the sun goes out [55].

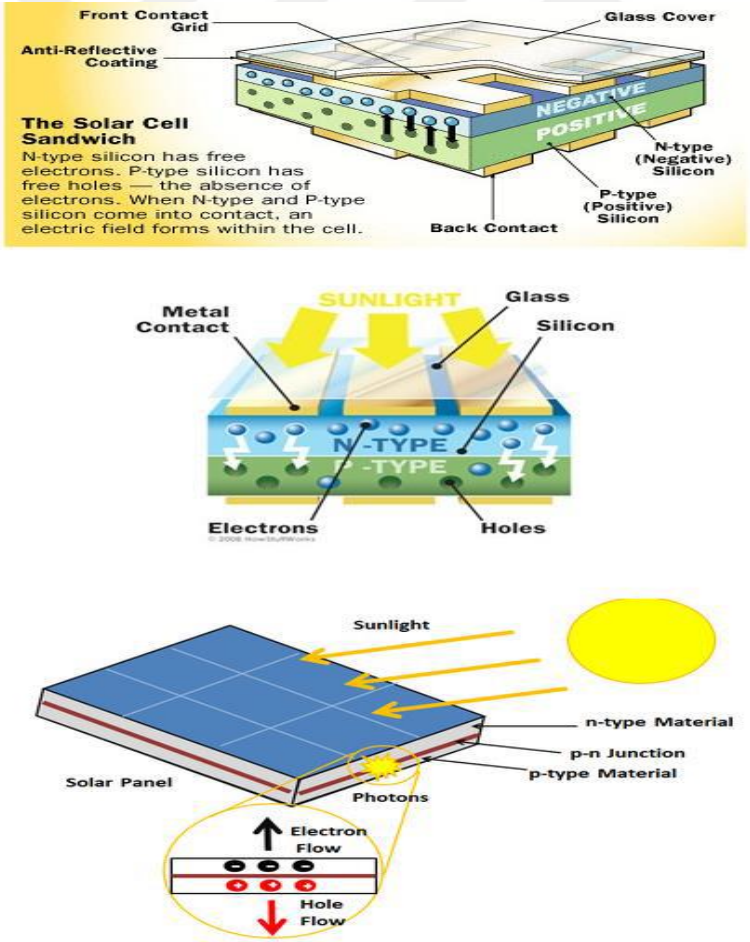


Figure 3.6: PV cell working principle

3.3 SEMICONDUCTORS

3.3.1 Introduction to Semiconductors

A semiconductor is a poor conductor of electricity because it does not have enough electrons to cover its valence bands completely. A semiconductor can be changed to have an excess of electrons or a shortage of electrons, resulting in an n-type semiconductor or a p-type semiconductor. When a semiconductor is multiplied by a million times or more, it becomes significantly more conductive. This phenomenon is used by semiconductor devices to generate electrical current. When doped semiconductors are coupled with other semiconductors, the resulting junction separates the electron excess or lack thereof from the semiconductor near the junction. This discharge area forms electrical currents in semiconductors by allowing current to pass in one direction. Various methods can be used to stimulate electrons across a semiconductor's energy band gap. These electrons can transport their surplus energy over micrometer-scale distances before dissipating it as heat, which is substantially longer than metals can do. This feature is required for the operation of bipolar junction transistors and photovoltaic cells, among other things. Excited electrons in some semiconductors can relax by generating light instead of creating heat; these semiconductors are also used to make light-emitting diodes (LEDs) and fluorescent quantum dots (FQDs). Semiconductors have high thermoelectric performance parameters and large thermoelectric power factors, making them valuable in thermoelectric generators and thermoelectric coolers [56]. The photovoltaic effect, or the transformation of solar light energy into electrical energy, is the basis for photovoltaic conversion. Solar cells de up of semiconductor components when a continuous synthetic electric field has been created. Produced are employed to carry out this conversion (utilizing a PN junction). Silicon is the most abundant semiconductor material on the planet, accounting for 60% of the crust of the earth and having a high silicon concentration in addition to its intriguing electrical characteristics. We'll focus on silicon since it makes up 90% of existing solar cells and is regulated by the same physics as the others. Other resources, however, as well utilized. Worthwhile noting that Arsenic gallium (GA) has superior attributes for producing electric power than silicon. However, very limited in supply. causes it to be so pricey that it’s confined to uses where expenses are low aren't a factor, such as in space applications, where solar cells made with As GA are commonly used due to their high

efficiency. Germanium (Gee), Cadmium Telluride (Cadet) Dieseline, Copper Indium (CIS), and Indium Antimonite are some examples of metals (Sin), and other minerals are also used. The chemical characteristics of elements are primarily determined by the number of electrons in their outer layers and the number of electrons required to complete them. There are 14 electrons in a silicon atom. There are four electrons in the outer layer (3), and there are four more. Needed to finish it. The 4 electrons in its exterior (of valence) consist of a free bond with additional atoms. Silicon forms a diamond-like network as it crystallizes. Four additional atoms share one of each silicon atom's four valence electrons. through covalent,

which are very stable and strong (thus maintaining its stability and having an outer layer filled with 8 electrons). Because electrons prefer to inhabit the lowest amounts of energy, the majority among them are connected, and all of them are coupled at an absolute zero temperature. Some get enough energy to break free from the binding and migrate through the material at room temperature (conduction). This action is seen in all materials, not only semiconductors; what is unusual is how much energy there is. Required to declare one electron from the connection. Energy band diagrams are used in quantum theory to explain the distinctions between semiconductors and conductors (metals). Only permissible energy levels may be inhabited by electrons in an isolated atom; forbidden levels are those that cannot be occupied. When a single atom joins a crystalline structure that has already been set up, it interacts with the atoms around it. This causes the energy levels to split, creating energy bands. The energy of electrons is divided into bands. Whether the electrons are in an atom or the in a crystal, electrons cannot have or use force. Figure 3.7: The previous energy levels of an atom set the atom's chemical composition, just like the final energy levels of a crystal set the electrical qualities of the crystal. The electrons are open to the outermost energy band and migrate amongst the various atoms. The conduction of a band is the most dynamic band. This conduction band's electrons are the ones that contribute to the current flow. This band is somewhat filled with metals, while it is vacant in semiconductors at absolute zero temperatures. Only one in every conduction band contains 1010 electrons. at room temperature.

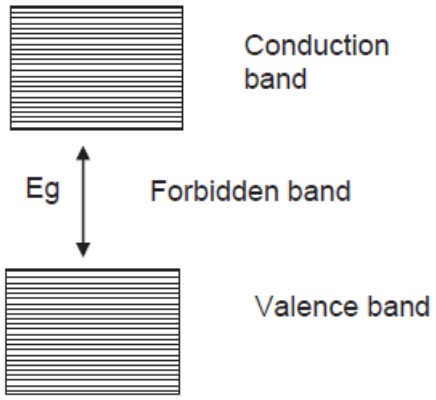


Figure 3.7: Band scheme.

Valence electrons, the electrons in the topmost layers that affect chemistry bonding, take up an energy band. (The Valence Band proceeding in terms of energy levels, conduction) that may overlap or stay separated from the conduction band. Allowable bands are separated by banned bands. The one which divides the transmission line from the whole energy band outside is the most essential. For example, gap energy is the amount of energy required for an electron to leap across a prohibited band. The electron-volt (eve) is the unit of measurement for the amount of energy gained by an electron when its voltage rises by 1V (1eV=1.610-19 J). The electrical behavior of materials varies Depending upon breadth. Conducive materials are produced as a result of the band gap's (gap width) (energy). (The permissible overlapping of the conduction band), and insulating components (the prohibited band is large, on the scale semiconductor materials, and energy levels of 10 eves) (the band gap is of the order of 1 eV). In summary, the energy content required is to let an electron out of the link property of each material and is known as the energy of the band gap since there is no energy value permitted between the bound electron and the liberated electron. This energy is 0 in metals, which means that all electrons are free to travel through the substance. Even at high temperatures, insulating materials require so much energy that the amount of liberated electrons is negligible. The amount of energy required in 1.12 eV for silicon at 25 °C in semiconductors enables good charge flow management, which is why these materials are so well suited to electronics as well as creation when electrical energy exposed to sun exposure

3.3.2 Doping

It is important contamination of a silicon crystal regulated way to be able to construct an efficient solar cell. Two kinds of impurities are introduced in such a tiny proportion of the total how many silicon atoms they contain have little effect on the crystal lattice. Extrinsic semiconductors are formed when impurities from an element whose valence electrons are different are introduced into the crystallization of an unadulterated (intrinsic) semiconductor. When a modest quantity of phosphorus (on the scale of a part per million) is added to a silicon crystal, the Atoms of phosphorus reside in a spot in the silicon crystal's crystalline structure. The crystal is said to be with phosphorus added. Because it possesses five valence electrons, phosphorus belongs to the periodic system's group V (one more than Si). The P atoms' inner electrons and nuclei are fixed in their crystal locations. Of the five electrons, four of them form covalent connections four electrons are used. Nearby Atoms of Si. It is the fifth electron. So loosely attached phosphorous atom to which it is thermally stimulated and liberated at ambient temperature. Doping with elements having an Atomic valence greater than the atoms in the crystal, known as the dopant, is doping of type n (n of negative), known as a donor since it readily supplies electrons. The reverse effect is produced by doping Si with Boor. Boron is a group III element, meaning it possesses the third valence electron (one less than Si). It is found in the design of the Si crystal (two for every ten million Si Atoms), although it lacks enough electrons to make triple valet connections with its neighbors, creating a gap. At normal temperatures, it readily travels through the crystal structure. A type p (positive) dopant is boron. Silicon is known as an acceptor as a result of creating a void that readily catches unbound electrons. The two substances that were used to taint silicon contain three and five, in turn, valence electrons. Boron and phosphorus are often utilized in either instance since the atoms in them are comparable to silicon in size. The cheating technique is conducted on glass that has already been tainted with one of the two elements during its production. Finally, one more is added such that the glass wafer's sides are each flat. Has some imperfections. Because there are numerous unlinked electrons in the phosphorus area, zone n, the Atoms of phosphorus are readily ionized. That is, each phosphorus atom has one unbounded electron. Need hardly any energy is required for mobile charging; room temperature is adequate.

Boron's area, called zone p, doesn't have full connections, so electrons that are in a link can move to an unfulfilled linkage

3.3.3 Diodes

Photovoltaic cells are sun-exposed diodes with a wide surface area. Each zone contains moving particles with varying charges. An n-type layer is connected to a player to form a diode. The junction is the area where the two layers meet. The trillions of free electrons at the junction in the n-type material race to fill the gaps in the p-type material as soon as the diode is formed, leaving the n-side (which was electrostatically neutral) with a net positive charge.

Similarly, the p-side gaps migrate to the type n material, leaving a net negative electrostatic charge on the p-side of the connection. As though there was a high electron pressure on the n-side. At the same time, the p-side had a low one. The valve is opened when the union is created, allowing the electron gas to pass pressure drops from the high to the low zone. The atoms decay their charges and ionize, and non-mobile charge regions are formed. It produces a dynamic as a result. Equilibrium in between motions of electrons and holes and the production of a dipole electric surrounding the device interface creates an electric field that is parallel to the interface, and that pushes the stray particles moving against each other (charges of the same sign are repelled; charges of the opposite sign are attracted). The process achieves equilibrium in milliseconds because the force of the electric field formed by the electrons and holes that have been transported from their native materials balances the statistical force that drives the p-side gaps with the electrons on the side. A barrier is produced by the electric field that prevents the majority of carriers from passing (Holes are on the p-side, and electrons are on the n-side). On the other hand, a union does not obstruct the flow of minority carriers. If there are electrons on the p-side (which there won't be many since there are more holes), they will be propelled across the junction to the n-side. There will be no electrons on the p-side adjacent to the junction (since they are promptly moved n-side), meaning that electrons will arrive more distant away to fill the vacancies. This current is known as diffusion current. A similar thing occurs more distant with the holes, minority carriers. The previous explanation makes it easy to understand how the pn junction works, which is a key part of all solid-state electronics.

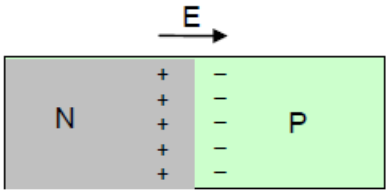


Figure 3.8: p-n junction.

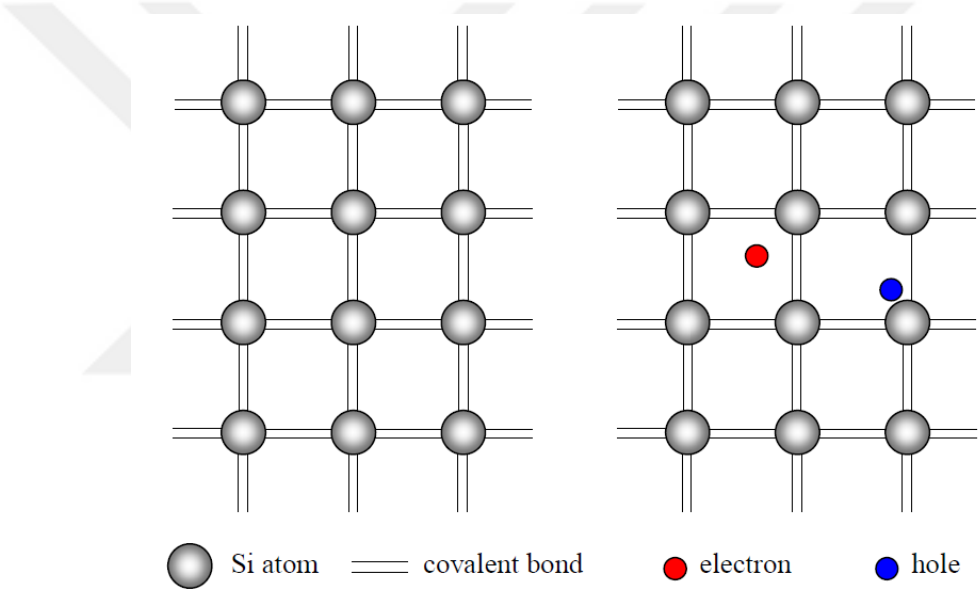


Figure 3.9: The Bonding Model for c-Si No bonds are broken. (b) A bond between two Si atoms is broken, resulting in a mobile electron and hole.

3.4 SOLAR CELL TYPES

3.4.1 Mon crystalline Silicon Solar Cells

On crystalline cells, we commonly refer to as silicon cells are silicon cells. As the name suggests, the entire volume of the cell is made up of a single silicon crystal. This is the kind of cell whose commercial use is more widespread nowadays (Figure 3.10). The silicon is first removed from the sand to create the wafer, which is made up entirely of a single silicon crystal and will make up the cell. Metallurgical grade silicon is the term used to describe silicon that has through the initial extraction process and still has a significant amount of undesirable

impurities. The manufacturing step is the first in the subsequent refining process. SiHCl3 the addition of (trichlorosilane), which There will still be many undesirable components in the first phase. Sic 3 is a liquid, and liquids are easier to purify than solids. Therefore this is. High-purity SiHCl3 is produced after this purification procedure. Then it's required to "recover" silicon in solid form. Polysilicon (solid) and Hall are produced by heating a mixture of SiHCl3 and H2. Despite being purer, this polysilicon still does not consist of a monocrystal. The Czochralski method can be used to produce monocrystals in their ultimate form. A circular silicon bar (ingot) with a diameter of several inches and a length of several meters is the end product. The wafers used to create monocrystalline silicon solar cells are ultimately removed from this bar through a cutting procedure. A significant amount of silicon-cutting process material is lost (40%–50%) [57] The cells are just a few inches wide, and they're arranged in a grid to form a panel. Which is ideal for deployment in small areas, and has a laboratory efficiency of approximately 25% but a real-life experience efficiency of between 12 and 16 percent. The loss of material is a drawback of this kind during the construction process. [57], [58] the purity of the silicon crystals from which the cells are produced distinguishes mono-crystalline from monocrystalline panels (Figure.). The panels need to be able to make the same amount of power as other types, work well in low light, and last a long time [59].

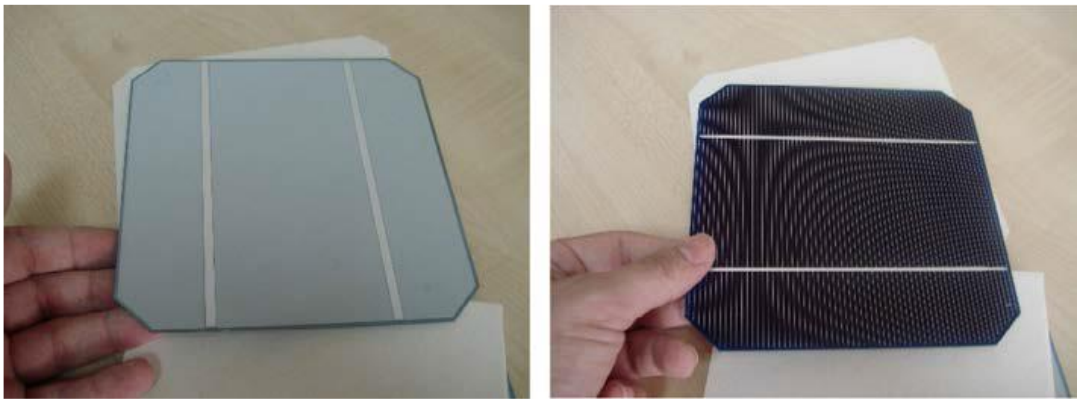


Figure 3.10: Back and front of a monocrystalline silicon cell.

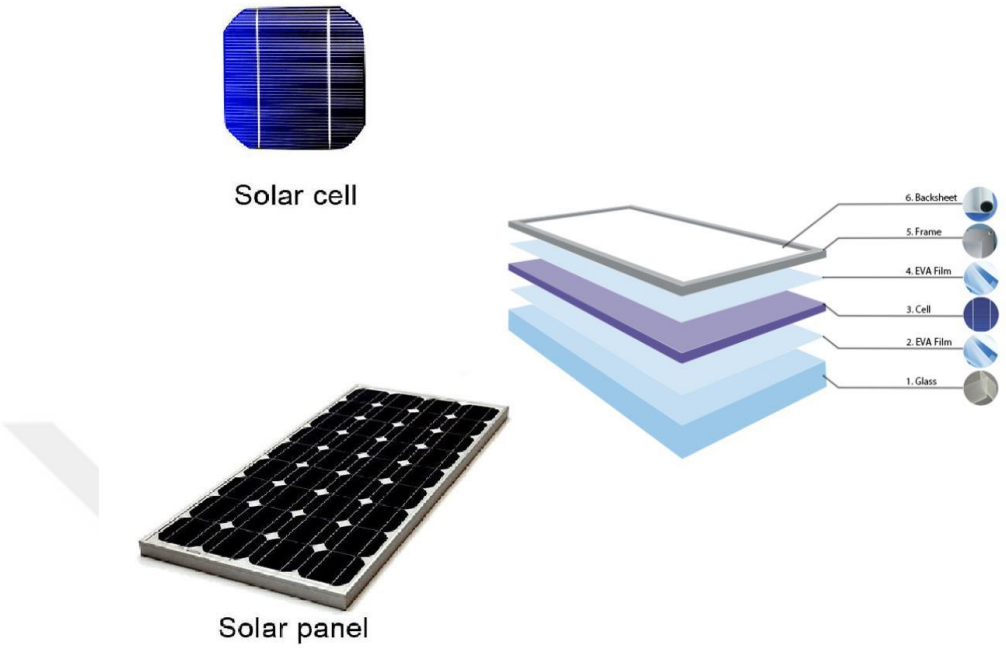


Figure 3.11: Mon crystalline solar panels.

3.4.2 Polycrystalline Silicon Solar Cells

Polycrystalline silicon cell usage is a cost-cutting method that lowers the cost of wafers. Silicon made up of crystalline silicon grains is known as polycrystalline silicon. In theory, you may use the same production procedures on this material as you would on monocrystalline silicon cells, but keep the following in mind: Because the border of polycrystalline silicon grains adds another the recombination's source, the These cells' effectiveness is projected to be lower than that of their counterparts who are monocrystals. Since polycrystalline silicon cells have been demonstrated to cause Vic, the loss caused by Vic. may produce almost similar short-circuit current to that of monocrystalline silicon cells (Figure 3.12). The requiring shorter diffusion durations causes certain changes in the cell design, as seen in Fig. 2, where the presence of a double union improves the device's collection efficiency. Some technical operations are made more difficult by the multi-crystalline material, particularly those that rely on the crystalline orientation of the material, such as texturing. Large-area cells have been used in the lab to attain efficiencies of 16.8 percent. The maximum efficiencies of this sort of cell at the level of production are about 17% [60].

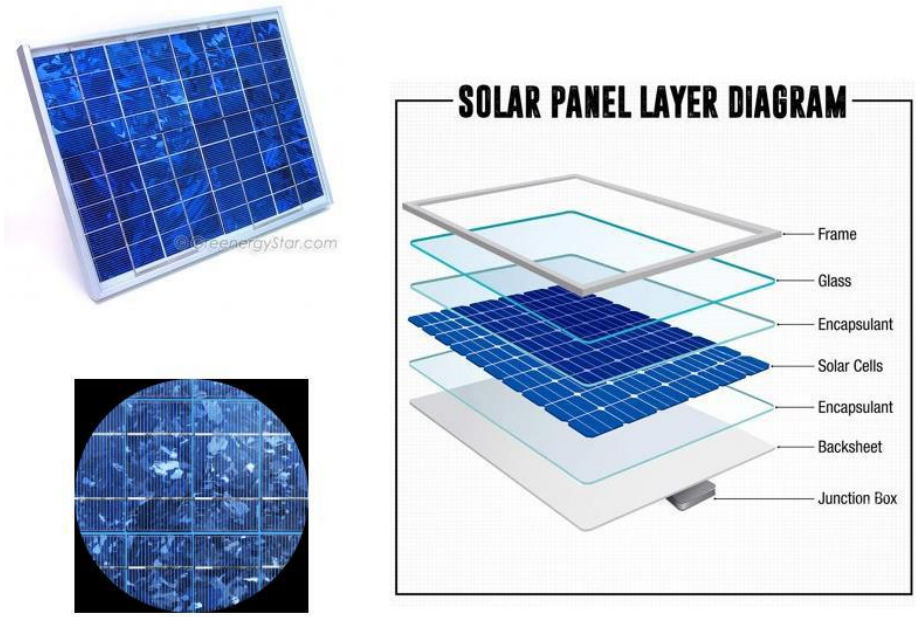


Figure 3. 12: Polycrystalline silicon cell.

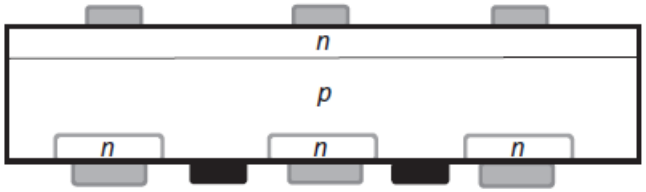


Figure 3. 13: A multi-crystalline silicon cell with a double union structure.

3.4.3 Amorphous Silicon Cells

a. The structuring of crystalline lattice composed of silicon atoms is absent in amorphous silicon. As a result, this attribute without any semiconductor properties can be predicted from this information. However, it is important to note that when discussing amorphous silicon In relation to1 solar cells, a particular quantity has been of hydrogen integrated enters the substance. Then it's called hydrogenated amorphous silicon, and it's labeled with a Sigh. (Figure 3.14). Amorphous silicon solar cells are employed in most gadgets, particularly in tiny electronic applications like calculators. In this type of silicon solar cell,

silicon is placed in a thin layer onto a supporting substrate, like metal, glass, or plastic. In this type of silicon solar cell, that is accomplished simultaneously with silicon crystals developing. Because they are so small, they can be made flexible, and their performance in low light is superior to crystal panels. It is amorphous silicon. Significantly higher absorption than crystalline silicon (1.7 eV gap width as opposed to 1.1 eV), requiring just micron-thicknesses to collect most of the sunlight. Amorphous panels, on the other hand, convert sunlight into energy with a lower efficiency (10%), making them unsuitable for roof installation. Thin-film solar cell technology has many benefits.

b. Material use is minimal.
c. Energy payback time is shorter.
d. Integration on a monolithic scale
e. Modules with a large surface area
f. Material qualities that can be changed
g. Processes that take place at low temperatures
h. Modules that are transparent may be created [61]–[63].

Figure 3.14: Amorphous silicon

3.4.4 Gallium Arsenide and Semiconductor III–V Solar Cells

Gas material is a straight-gap filler, which means it is particularly absorbent. All of the incoming light can be absorbed by a few microns of material. As a result, the layers in this cell

that are photovoltaic are on the top section of the surface. They are speaking of form, which serves as electronic support. The Gas cell explored their usage with their due to their high cost. Because of their radiation resistance, solar cells made of Gas often employed applications for space from an industrial standpoint. Because of their radiation resistance, the P cells are employed in space applications. In light of the high expense of glass processing and property management, their uses on land have been abandoned [58].

3.4.5 Cadmium Telluride Solar Cells

The energy of separation between the valence and conduction bands, the power of the "gap," which equals 1.4 eV and is associated with the ideal theoretical benefit of solar energy radiation, is the biggest attraction of Cadet an applicant for absorbing solar energy material in principle, so the scientific community was very interested in it in such a way that its research ranged from small-scale lab work to preindustrial development. In a few years (Figure 3.15). In 1982, Kodak created the first Cadet cell with a conversion efficiency of more than 10%. Several organizations have been working on the creation of these cells since then. First Solar is now the largest producer, with efficiency levels above 15%. Researchers at the USF, a university in South Florida, made the most significant advances Throughout the creation of solar cells, on Cadet in recent years, achieving 15.8% efficiency, which means they are the first solar cells made with non-monocrystal materials to surpass a ceiling of 15% efficiency, which is assumed to be the upper the time restriction for discussing high-efficiency cells. [58] The development of the Cadet solar cell is complicated by the P-type doping process and the reduction of the resistance connections process, as well as the fact that the junction interface might be united in recombination losses. There is worry regarding the Cadet solar cell, which uses the cadmium element since cadmium is a hazardous element that poses a health and environmental risk. [59].

Figure 3.15: Partial view of a photovoltaic plant of TeCd.

3.4.6 Copper Indium Dieseline (CIS) Thin Film Solar Cell

Copper Indium Dieseline (CIS) is another crystalline solar cell material that may be utilized as a solar cell due to certain properties such as adhesion, density, and composition. Its manufacture is tough and sophisticated, and it necessitates safety considerations. CIS, sometimes known as copper indium dieselize, is a p-type sun cell that can absorb almost all of the sun's energy using only one micrometer of the CIS absorber layer. In most CIS cells, the junction between semiconductors is produced by distinct band gaps, which is known as a heterojunction. Cadmium Sulfide (Cods) is often employed as a window layer in CIS solar cells, and Zing (Zn) is sometimes used to increase transparency. Copper Indium Gallium Desalinize (CIGS) solar cells are made by adding gallium (G) to the lowest absorbing layer of copper indium desalinize. Gallium, in reality, causes the band gap to expand to 1.15 eV, which improves the cell's Vic and efficiency. The ZSW lab in Germany claims a CIGS efficiency of 20.1 percent, whereas the NREL lab in the United States claims 19.2 percent. Manufacturing costs are low, payback times are short, and CIGS solar cells have a long life span (over 20 years). In the modules, CIGS thin-film solar cells show the best stability and radiation capture on bright days, making it a viable low-cost technology. [59]

3.4.7 Copper Zinc Tin Supplied (CZTS)

thin-film photovoltaic 's investigation and production of Tin, copper, zinc, and Sulfur (Cu2ZnSnS4 or CZTS) were spurred by the difficulty of discovering substitute solar cell earth-based minerals that are abundant and safe metals. CZTS is a superior-performing quaternary compound semiconductor. Optical amplification features, such as 1.5 eV, is the direct band gap energy and a significant absorbing capacity, allowing it to take in the majority of the apparent sun in the spectrum. The film is devoid of special metals and harmful elements, and it may be paired with a cadmium-free buffer layer to create entirely non-toxic solar cells. The current maximum Efficiency of sunlight conversion for CZTS-based solar cells that have been solution treated is 10.1 percent. The action disorder management flaws, which are created by unchecked intersubstitution of copper and zinc captions, leading to specific flaws that obstruct charge removal and lower voltage in an open circuit, is a key technical problem with CZTS solar cell technology. [60]

3.4.8 Organic Solar Cells (OSC)

There are organic solar cells gained popularity over time as a result of their potential for inexpensive substrates, inexpensive active layer materials, inexpensive energy input, and simplicity of industrial upscaling. They could be able to create low-energy, earth-abundant PV solutions. They absorb light utilizing tiny molecules of organic compounds or polymers and are generally made up of elements abundant on Earth that may be manufactured using thin films and cost deposition processes like both inkjet printing and thermal evaporation. Those are promising for uses incorporated into buildings because they allow for the creation of colored or transparent organic PV devices utilizing a variety of absorbers. Although a lab efficiency of 11.1 percent has been established, module efficiency remains much lower. Major problems include not being able to move charge carriers and energized electron-hole pairs well, not being able to stay stable over time in the sunlight, and having very low-efficiency limits. [60]

3.4.9 Dye-Sensitized Solar Cells (DSSCs)

Among all the nanomaterial-based sun cells choices, solar cells with dye sensitivity (DSSCs) are one of the most established and comprehended solar cell technologies. Photons are

collected by a photosensitizer absorbed in a DSSC onto a tiny semiconductor Nan crystalline layer deposited within the anode. DSSCs employ photo-electrochemical liquid electrolytes cells) to move to an electrode serving as a counter, creating an electric flow. Other PV methods use their solid-state semiconductors form to transport electrons to generate photoelectric effects. The use of small amounts of inexpensive and easily accessible materials manufactured by known methods, easy Deposition on flexible modules, assembly, and compatibility with printing methods multiple the integration of substrates with a wide variety of surfaces are all advantages of DSSCs. Long-term stability under solar irradiation and high temperatures, low absorption coefficients, and low voltages in open circuits owing because of interfacial recombination are all major concerns with DSSC technology. All of these obstacles raise the issue of whether they will be able to compete with standard solar cell technology. [60]

3.4.10 Quantum Dot Solar Cells (QDSC)

A quantum dot solar cell is intended to absorb incoming sunlight photons for photovoltaic effect by employing small particles called quantum dots (a few nanometers in size). Quantum dots (QDs) are semiconductor particles with a diameter of a few nanometers with optical and electrical characteristics that are quite different from bulk material (figure). The frequency of light emitted by a quantum dot may be precisely controlled by modifying its size, shape, and substance. Quantum dots of various sizes and kinds produce light at various frequencies, which may be altered exactly as needed. Quantum dots are artificial atoms with properties similar to actual atoms or molecules, such as singularity, bound structure, and discrete electronic states. Quantum dots are made using a variety of processes, including chemical ablation, electrochemical carbonization, laser ablation, microwave irradiation, and hydrothermal/solvothermal treatment. Dye-sensitized solar cells are thought to be the source of quantum dot solar cells. Because of their versatile optical and electrical properties, QDs such as CdS, CdSe, PbS, and InAs are used as photosensitizers instead of organic dyes. These include 1) a tunable band gap that is dependent on QD size; 2) a larger extinction coefficient; 3) higher stability toward water and oxygen, and 4) multiple exciting generations (MEG) with single-photon absorption. [55]

3.4.11 Colloidal Quantum Dot Photovoltaic (QDPV)

A Nanocrystal is a quantum dot. Made of a semiconductor substance that is so tiny that the principles based on quantum theory must be applied. Because they have a band gap and optical and electrical characteristics that might be controlled easily by changing the nanoparticles' size, they are employed as the photovoltaic substance that absorbs light in solar cells. This makes it simple to build them to absorb various sections of the sun's spectrum, allowing for effective near-infrared photon harvesting. QDPVs are solar cells that employ solution-processed Nanocrystals and may be integrated into a variety of solar cells. Their preparation techniques and operating principles, as well as the benefits and drawbacks of various QDPV device topologies, are explained in Ref. They offer the potential for facile manufacturing and air-stable operations, with a reported lab efficiency of 9.2 percent. Lack of knowledge about the chemistry of the QD surface, low voltages in open circuits, as well as limited mobility of charge carriers are all big problems. [60]

3.4.12 Perovskite Solar Cells

PSCs are based on metal halide perovskites (MHPs), such as methylammonium or formamidinium lead iodide, and are a developing, innovative photovoltaics (PV) technology (MAPbI3 or FAPbI3, respectively). Numerous MHPs have numerous desirable properties for a PV absorber, including a direct band gap with a high absorption coefficient, a long carrier lifespan and diffusion length, a low defect density, and simple composition and band gap adjustment. MHPs were originally used as a sensitizer in a dye cell that used a liquid hole-conducting electrolyte in 2009. The demonstration of 10%-efficient PSCs based on a solid-state hole conductor in 2012 sparked a wave of PSC research. A single-junction PSC's performance has surged to a verified 25.2 percent after nearly a decade of study. The efficiency improvement for PSCs spanning from lab cells (0.1 to 1 cm2) to mini-modules (>10 cm2) is summarized in Figure 9. Surprisingly, the majority of high-efficiency PSCs are now manufactured by solution processing, making PSCs appealing as potentially high-performance and low-cost PV technology. To scale up PSCs, several deposition techniques have been devised, resulting in the recent presentation of an 802-cm2 perovskite solar module with a validated 16.1 percent efficiency. The performance of this module is gradually approaching

that of existing thin-film PV technology (e.g., Cadet and CIGS). PSC stability has also improved dramatically in recent years as a result of numerous attempts to enhance perovskite absorbers and device architectures, as well as encapsulation techniques. As a result, PSCs offer a variety of options for terawatt-scale energy output [61].

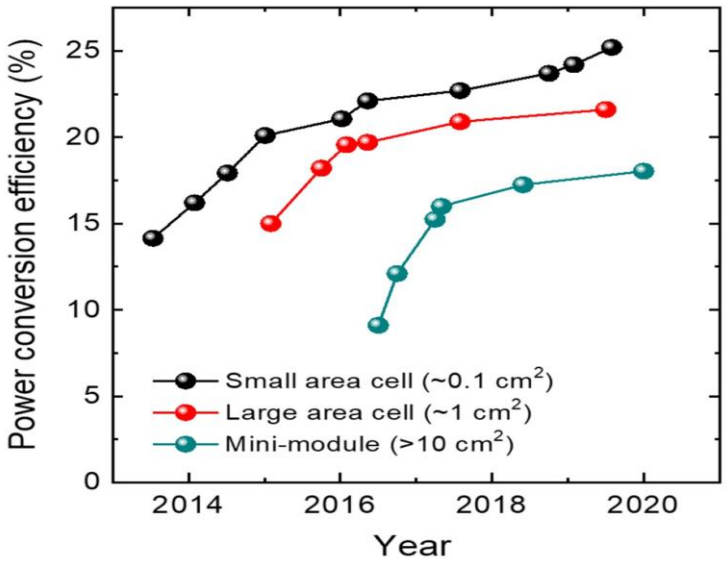


Figure 3. 16: The efficiency improvement for PSCs spanning from lab cells

A PV cell is a large-area PN diode that is illuminated by sunshine. The band gap energy of the semiconductor material Egg is a determining factor for the amount of electricity produced by a PV cell. Egg for multi-crystalline silicon is typically 1.12 eV at 25 °C. The needed energy level for the proper functioning of a PV cell, i.e., the PV cell begins to create a flow of electrons across the PN diode, is defined as the band gap energy. Lower band gap semiconductors benefit from a wider radiation spectrum but produce lower voltages. Multi-junction solar cells have been created to harvest solar energy from a broader range to fully use the available solar spectrum. When compared to single-junction solar cells, multi-junction solar cells have better module efficiencies and output voltages. For example, Inga/Gas/Inga As has a module efficiency of 37.9 percent, which is significantly higher than the efficiency of a mono-crystalline silicon PV cell, and an open circuit voltage of 3.605 V. [53]

Table 3.1: Performance of commercial solar PV technologies

PV technology		Module Efficiency (%)	Record lab efficiency (%)	Record commercial efficiency (%)	Area/kW (m^2/kW)	Lifetime (Years)
c-Si	Mono-c-Si	13-19	24.7	22	7	25
	Multi-c-Si	11-15	-	20.3	8	25
TF	a-Si	4-8	10.4	7.1	15	25
	a-Si/µc-Si	7-9	13.2	10	12	25
	CI[G]S	7-12	20.3	12.1	10	25
	CdTe	10-11	16.5	11.2	10	25

3.5 CHARGE CONTROLLER FOR SOLAR

A Solar Charge Controller (also known as a Solar Regulator) regulates the charge and discharge processes in a solar power system. The charge controller's primary function is to regulate the charge current going from the photovoltaic cells to the batteries, ensuring that the current is not too high to prevent the battery pack from overcharging.

The charge controller uses both MPPT and PWM energy control techniques to manage the current going from the solar panel to the battery. PWM costs less and has a conversion rate of 75%, but MPPT costs more but can increase the conversion rate by up to 99%, which is a big difference.

3.5.1 Mppt

Maximum Power Point (MPPT) is a term that refers to the maximum amount of energy that may be The process of monitoring and regulating the output energy from the solar panels to the batteries is known as tracking. The MPPT continually tracks the maximum power (P=U*I) and controls the output voltage accordingly so that the system may always charge batteries with the maximum power.

3.5.2 Pwm

PWM stands for Pulse Width Modulation and is a method for changing the voltage and frequency of the output energy from the solar cell to charge the battery by modifying the width of the pulse under specified restrictions. The PWM charge controller functions as an electric switch between the solar panel and the battery packs [62].

3.6 TECHNOLOGIES FOR SOLAR BATTERIES

3.6.1 Lead Acid

For decades, Lead-acid deep-cycle batteries have been utilized when it comes to off-grid applications and renewable energy across the world. Lead-acid deep-cycle batteries are much less expensive, unlike lithium-ion batteries. Gel variants of valve-regulated lead-acid (VRLA) batteries are available. Battery life is influenced by a variety of variables, including original design and continuous maintenance, making it impossible to predict when the batteries will need to be replaced. Because these batteries contain no free acid, they may be put not upside down but in any other posture. The utilization of solar energy might be in difficult-reachable or isolated locations, and the capacity to affix batteries and allow them to run for long periods being without upkeep advantageous. Because lead-acid batteries are dangerous, proper disposal is critical. Batteries may be recycled by returning them to a battery merchant, an automobile repair facility, a battery manufacturer, or other approved collection sites.

3.6.2 lithium-Ion

The most prevalent storage method is lithium-ion batteries, which are more costly than lead-acid batteries System for managing batteries is required to control the intensity and heat of every cell to avoid overcharging or draining. Lithium-ion batteries may cut the price of ancillary equipment such as charge-control devices, balancing their increased initial cost and decreasing the total cost of ownership. The most significant advantage of Due to its excellent charge and discharge efficiency is that lithium-ion is ideal for solar energy. Allow for increased vigor harvesting. Also, lithium-ion batteries have a lower capacity loss. While they are not in use, which is advantageous in solar setups where energy is only utilized on occasion. Batteries made of lithium-ion are often softer and also compared to lead-acid batteries, more self-sufficient, making them potentially simpler to install and replace. They may be fixed on the wall and used both inside and outdoors. They don't need to be refilled or maintained since they're solid. Organic or inorganic cells may be used in lithium-ion batteries. Toxins are not present in organic-based batteries. It's far more difficult to get rid of inorganic-based cells. Because the ion of inorganic lithium is hazardous, it must be properly gotten rid of.

3.6.3 Flow Batteries

The usage of flow batteries for long-term storage is increasing. In most traditional flow batteries, two electrolyte solutions are used: one with a cathode that is negatively charged and the other anode which is positively charged. A membrane separates two of the cathode and anode compartments because the battery will short if they come into contact. Need to be replaced. Lithium-ion batteries' membranes break down with time, which is a common occurrence. In flow batteries, however, the interchange of negatively and positively charged fluids provides electrical current without deterioration, resulting in longer cycle life and faster reaction times. In long-term storage applications, flow batteries often outperform lithium-ion batteries. This is because the electrolyte materials may be reused or sold, and they can endure for decades with no care. The membrane of a flow battery degrades slowly over time, enabling them to survive far longer than previous technologies. Flow batteries are also low-maintenance. The creators of flow batteries claim that the Technology does cycle constraints and that batteries may be fully energized and drained without affecting their lifetime. Flow batteries are less reactive and simple to dispose of, with little danger of fire, depending on the chemistry. Flow batteries can often recycle the electrolyte, which brings down the leveled cost of storage.

3.6.4 Cadmium-Nickel

NiCad batteries, often known as nickel-cadmium batteries, have been available since the early 1900s. Even though they lack the in comparison to other technologies' energy density (power), they offer extended living and dependability without the need for complicated management systems. In comparison to other technologies, nickel-cadmium is quite affordable. Gases from NiCad batteries are vented to enable them to escape. They used to need some irrigation, but current designs enable the gases to mix again to generate water, thus eliminating the need for maintenance. These batteries are useful for off-grid applications in hostile areas because of this, as well as their capacity to withstand high temperatures. They've been employed in megawatt-scale installations for storage. NiCad batteries are tough and have a long cycle life. Some vendors claim that their products will last around 20 years. Cadmium is a dangerous substance. In reality, Europe has placed restrictions on the use of NiCad batteries. Before the

battery may be disposed of, toxic elements must be removed. However, NiCad batteries may be recycled. The cadmium in the batteries may be removed and reused. Nickel may be reclaimed and utilized in the production of stainless steel [63].

4. FISHING BOAT PROPERTIES

4.1 FISHING BOAT TYPES

4.1.1 Gaspe Boat

The Gaspe boat, an earlier sailing design, is an example of a motorized fishing boat created purely by minor adjustments. This ship is used on the English coast, or the northernmost point of the Gaspe Peninsula in Quebec, Canada. The standard size is around 35 ft (10.7 m) long, between 9 and 10 ft (2.75 to 3.05 m) wide, and has a draft of 3 j feet (1.07 m). Although the hulls are roughly constructed and lack a smooth finish, they are sturdy and long-lasting. Either lapstrake (clench) or caravel is used for the planking, with the former seeming to be more common. The boats are propelled by a one-or two-cylinder heavy-duty gasoline engine made in Nova Scotia, and they have a straightforward schooner rig jib, a loose-footed foresail, and a booming mainsail of the gaff kind. Most are manually started, have make-and-break ignition, and have a speed range of 5 to 7 knots. The boats typically only spend two or three days at sea and are safe in this region despite being vulnerable to strong gales. They are ideally suited for beaching since they often operate out of secluded coves or harbors. Gaspe boats are suitable for their task and inexpensive to run. To achieve better speed under power, the run might be extended as a design upgrade. Another benefit would be a more powerful, lighter engine. Given the high cost of gasoline, it seems preferable to keep the sailing rig for the time being. With these modifications, the Gaspe boat would be ideal for fishing in remote areas such as northern Labrador. Coast [64], [65].

Figure 4.1: Gaspe Boat

4.1.2 Bedi Boats

The majority of the current motorized fishing boats in West Pakistan evolved from native sailing boats (Beda and Hoar). They are quite seaworthy and well adapted to the local conditions. Fishing boats in West Pakistan up until quite recently were mostly Beda and Hoar-style sailing boats, which were used mostly for gill net fishing. In addition to these sailing boats that have been turned into motor boats, there are now a lot of new motorized fishing boats that are used for both gill net and trawl fishing [66].

BEDI BOATS are large boats with an overhanging stem, stern timber, and a relatively good beam. The hull has a complete midship section, a transom stern, a sharp entrance, and a firm bilge. The sheer line is 35 to 70 feet long and nearly straight (10.7 to 21.3 m.). The sail area ranges from 350 to 1,500 square feet (32.5 to 140 square meters), with a registered tonnage of 20 to 45. On larger boats, up to four sails may occasionally be hoisted, but this is not the norm. The boats include a sizable number of inboard fittings, including loose decks to transport a single, heavy wooden box for fresh fish and ice; a small hold for cured fish; and a freshwater tank with room for cured fish, nets, and cooking equipment. The deck is open, and when tacking, sandbags carrying ballast are always placed on the windward side of the deck. All of these seaworthy fishing vessels are constructed in Karachi by regional craftspeople without the aid of

blueprints or drawings.[67]

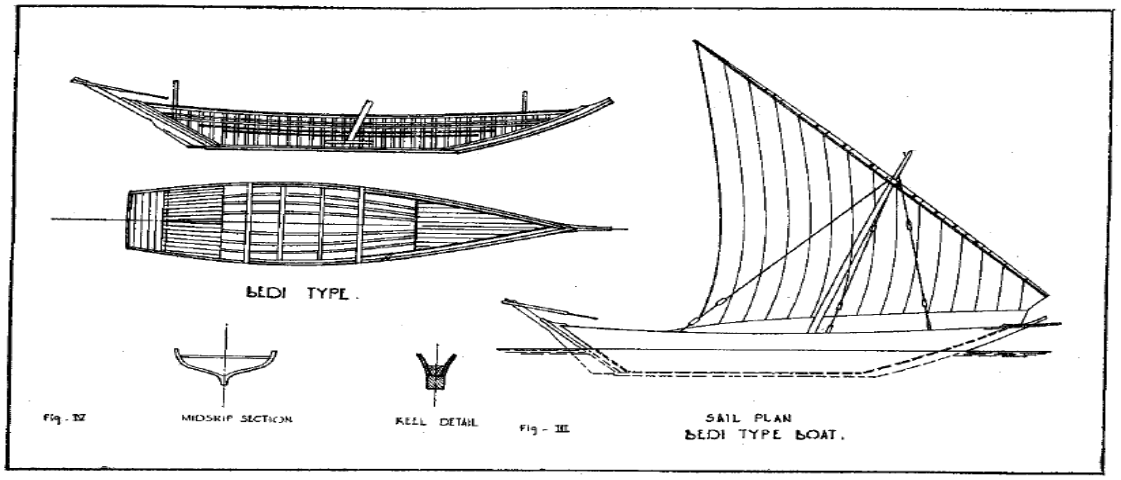


Figure 4.2: Beda Boat

4.1.3 Dugout Fishing Boat

Traditional dugout canoes originated in Kerala, but they are also used in Gujarat, Maharashtra, along the coast of Karnataka, and Tamil Nadu. By scooping up a long tree stem, the hull is created. The part of the keel is thicker than the sides. The sails and paddles help the boat move forward. Instead of a rudder, a paddle is employed. The size could change. The largest ditch measures around 10.5 x 1.0 x 0.75 m and can hold 3.5 tons. The boat's 10 to 15 crew members operate the boat seine. The biggest dugout's nickname is ODOMS. The smaller dugout has dimensions of 7.2 x 0.9 x 0.6 m and a displacement of 2 tons. 5-8 crews are in use on the boat. The boats are frequently referred to as "Thrones. The smallest dugout has an LOA of 7.0–8.0 and is referred to as BEPUTHONI in the local language. Gill nets and lines are operated from small and medium-sized dugouts [68].

Figure 4.3: Dugout fishing boat

4.2 FISHING GEARS

4.2.1 Purse Seine

One of the most efficient fishing techniques currently in use is purse seining, which is a significant fishery around the world. Figure 111 illustrates the gear's operating concept. The operation begins by setting up one end of the seine and then moves on to completely encircle the school of fish until it returns to its starting place. The bottom of the seine is then pursed, effectively sealing it off to prevent fish from escaping. The dragging of the net begins before the fish is carried aboard the vessel. There is certain equipment that must be in place while purse seines are being deployed. First, a particular kind of power block needs to be placed to

haul the seine nowadays; ships frequently employ the so-called Triplex-system. This technique will help the seine be hauled safely and efficiently and will also get the seine ready for the subsequent haul. The fish are then transferred from the ocean to the boat using a fish pump [68].

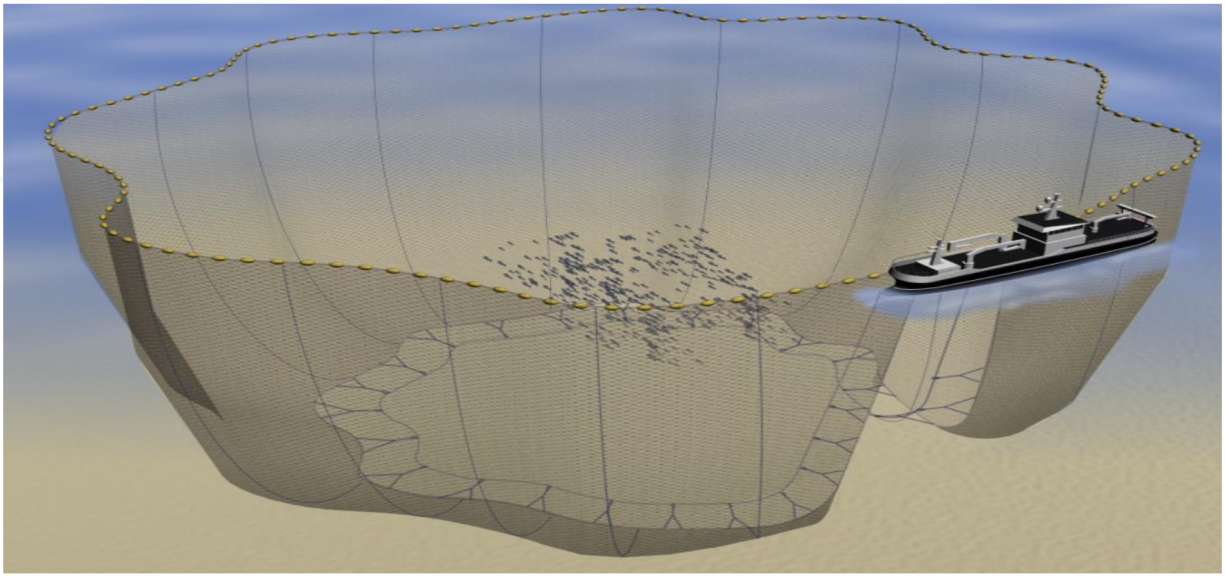


Figure 4.4: Illustration of the layout of a purse seine

4.2.2 Trawl

We divide the category of trawlers into two sub-groups, primarily pelagic trawlers, and white fish trawlers. Trawls are perhaps the most adaptable fishing equipment. The working principle is relatively straightforward, with a cone-shaped bag being trawled through the water by a vessel. These trawls vary in terms of size, area requirement, and species they are designed to catch.

4.2.2.1 Pelagic trawl

The pelagic trawl, with a total area of up to 40.000 m2 at the trawl entrance, is by far the largest fishing equipment now in use. Figure 222 below shows an illustration of a typical pelagic trawl. A vessel tows a pelagic trawl, which is distributed horizontally by a set of trawl doors in the middle of the ocean. A panel above, a panel below, and two side panels make up the square-shaped trawl. A pelagic trawl's size makes it particularly effective, similar to the purse seine. Because they mostly catch the same kind of fish, these two gears are often used

together. Since a pelagic trawl may work at greater depths than a purse seine, it is also employed to catch blue whiting in addition to mackerel and herring. When both methods are utilized, the hauling procedure is essentially identical to that for the purse seine: the trawl is dragged at the side of the boat using a triplex system, and the fish is then pumped onboard. Then, the trawl bag is set up for the next trip by being put on the net drum.

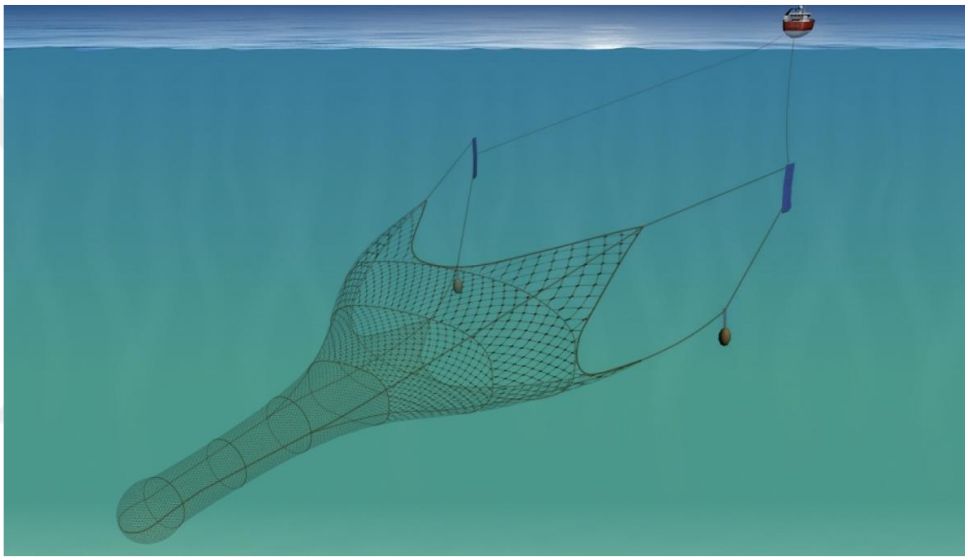


Figure 4.5: An illustration of a pelagic trawl's layout

4.2.2.2 Demurral Trawl

The deferral trawl is towed along the ocean floor and is also known as a bottom trawl or a white fish trawl. As a result, the trawl's design differs significantly from that of a pelagic trawl. The deferral trawl has two net panels—one on top and one at the bottom—and is opened by two trawl doors attached to the sweeps on either side and by floaters attached to the headline. Steel bobbins on the bottom net panel are used to keep the trawl pointing downward, while the ground gear is used to keep it raised off the ocean floor. today Demurral trawls are primarily employed onboard stern trawlers, which means that the trawl is dragged and deployed from the stern of the boat. The whole trawl is hoisted onto the ship and then immediately dumped into the processing facilities. Many winches are required to do this.

Atlantic cod, haddock, seethe, and Atlantic halibut are the most common species captured with a deferral trawl.

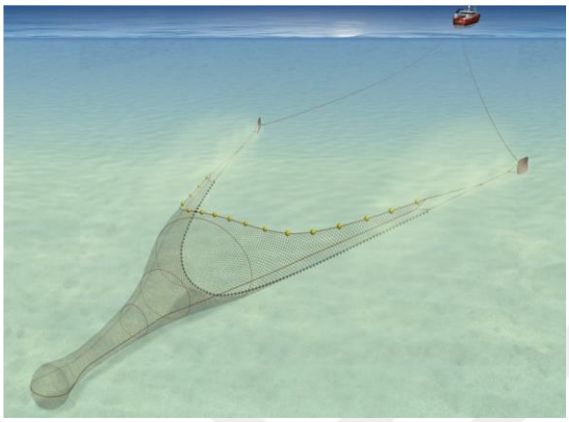


Figure 4.6: An illustration of a deferral trawl's setup showing the hauling procedure on the right and otter boards on the left

4.2.2.3 Shrimp trawl

Many of the white fish trawlers utilize shrimp trawls as part of their combined operations because they have permission to participate in the shrimp fishery as well. The size of these trawls is quite tiny, and the mesh of the net is extremely fine. Many boats with shrimp quotas may construct a boiler in their factory to keep high-quality shrimp. Non-boiled shrimp are marketed as "industrial shrimp." In these situations, the shrimp are immediately frozen after being loaded onto the ship. The shrimp trawl works the same way as a regular deferral trawl, which makes it a good choice for operations that use both kinds of trawls.

4.2.3 Scottish Seine

The Scottish seine, which may best be described as a hybrid of a purse seine and a trawl, is the most extensively utilized deferral seine. The gear is arranged in Figure 2.15 and has a trawl-like appearance. To better capture the fish inside the trawl bag, the Scottish seine includes sizable wings on either side of the trawl opening. Similar to how a purse seine is deployed, the vessel will first shoot one of the buoys and the starboard arm (rope) to encircle the area where

the target fish is present before setting the port arm and the seine. The towing of the equipment starts when the ship has reached its starting point and lasts for roughly 30–45 minutes. The catch is frequently pushed onboard the vessel once the ropes are collected using winches. The Atlantic cod, seethe, haddock, and Atlantic halibut are the main targets of the Scottish seine, which is mostly utilized for the same species as the deferral trawl. Other gear types can only be used in conjunction with this gear. However, new combinations may be appropriate in the future because of their resemblance to both trawls and purse seines.

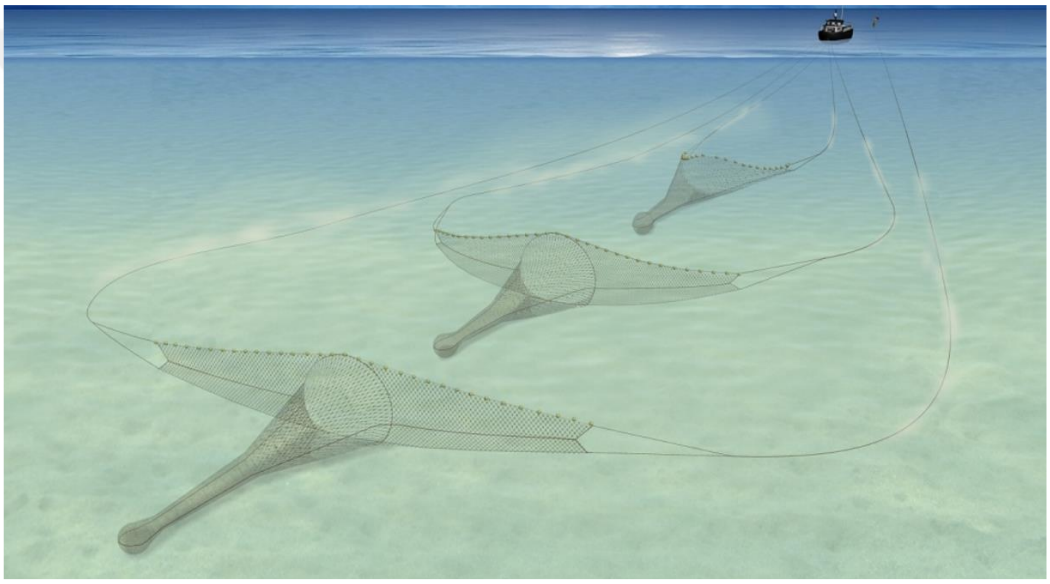


Figure 4.7: An illustration of a Scottish seine's design and the hauling procedure

4.2.4 Nets

As evidenced, using nets for fishing is more common in the coastal fleet than it is among the ocean-going fishing fleet. Because the deployment of the gear is relatively comparable. The deployment of a net involves employing buoys and weights in an area where fish are moving. By adjusting the mesh size, thread thickness, and thread color, the nets can be tailored to fit the fish that are being caught. Regarding the quality of the fish, it is crucial to take the soaking period of the net—that is, the amount of time the net spends in the water—into consideration. Fish can start to decay if the soaking period is too long because the quality is already poorer than with the use of other gear, and the fish can injure themselves more trying to escape the

net. Most species can be caught with nets, which are almost primarily utilized on seethe for ocean-going fishing.

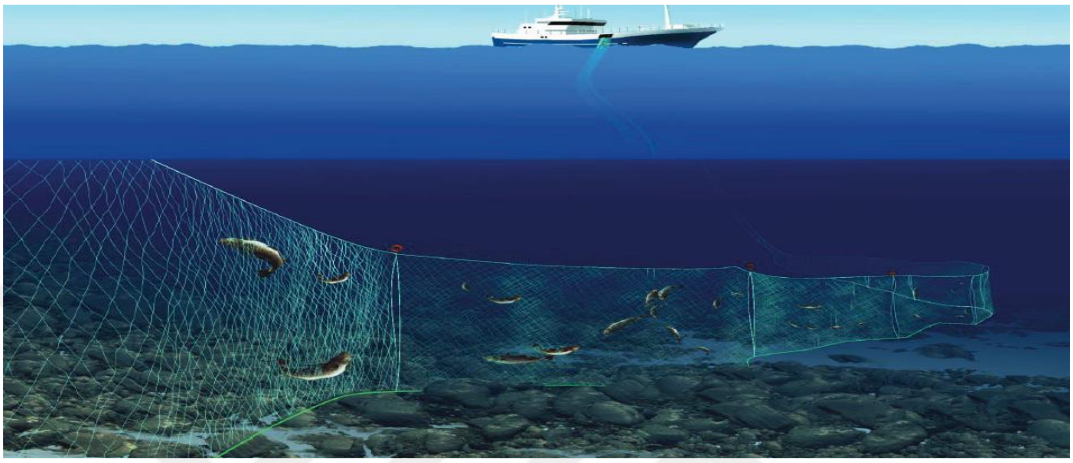


Figure 4. 8: An illustration of how a net operates

4.3 HOW A FISHING VESSEL IS OPERATED

As seen in Figure 4.9, a fishing vessel's operation is a continual activity. The vessel will begin and end this cycle in the same operational mode, whether it is a port facility or at sea, as it represents a single journey. The vessel will start getting ready for its journey here, supposing its starting location is at a port facility. This entails filling up the fuel tanks, checking that the water tanks and supplies are well supplied, and making sure that the equipment needed for the next voyage is on board. When the boat is prepared, it will set sail toward a fishing spot selected based on the fishery it will be pursuing The amount of time spent sailing is greatly influenced by the direction the ship is traveling in and the weather at the time. The captain will start fishing once they get to the designated fishing location. This can be accomplished using echo sounders, sonar, data from other vessels, or other technologies, depending on the species being pursued. The crew on deck will set out the fishing gear once they have discovered a school of fish. The fishing operations will continue till the vessel's capacity is achieved. The size of the vessel, the efficiency of the type of gear being used, and the abundance of fish in the area will all affect how quickly a vessel may fill. If the skipper is dissatisfied with the amount of fish being caught, the boat will relocate and cruise to different places in search of more fish. The ship will proceed to the closest port facility for unloading with a fully loaded

cargo hold. Fish landing sites are what these port facilities are known as, and a particular vessel will frequently use a few of these chosen ports. The cycle is completed when the ship arrives at the landing location, when the fish is unloaded, and preparations are made for the next voyage. [67]

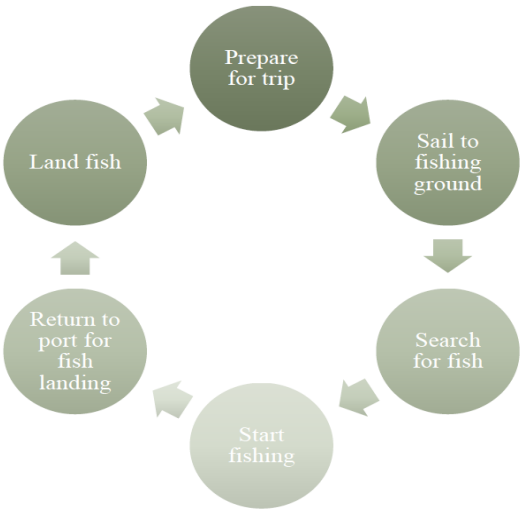


Figure 4.9: the cycle of a typical fishing boat's operation.

5. USING SOLAR ENERGY TO PROPEL FISHING BOATS

5.1 DIMENSION AND LOAD LINES OF THE HULL

This chapter begins with definitions of length, draught, and width expressions used in different scenarios, Definitions of load lines are then provided. Define what portion of the hull is underwater. Lengths when estimating the hull's water resistance, the overall length of the ship (LOA) is usually ignored. The Measurement of the waterline LWL as well as the alleged distance between perpendiculars. LPP is the deciding element. Figure 5.1 depicts the dimensions in question.

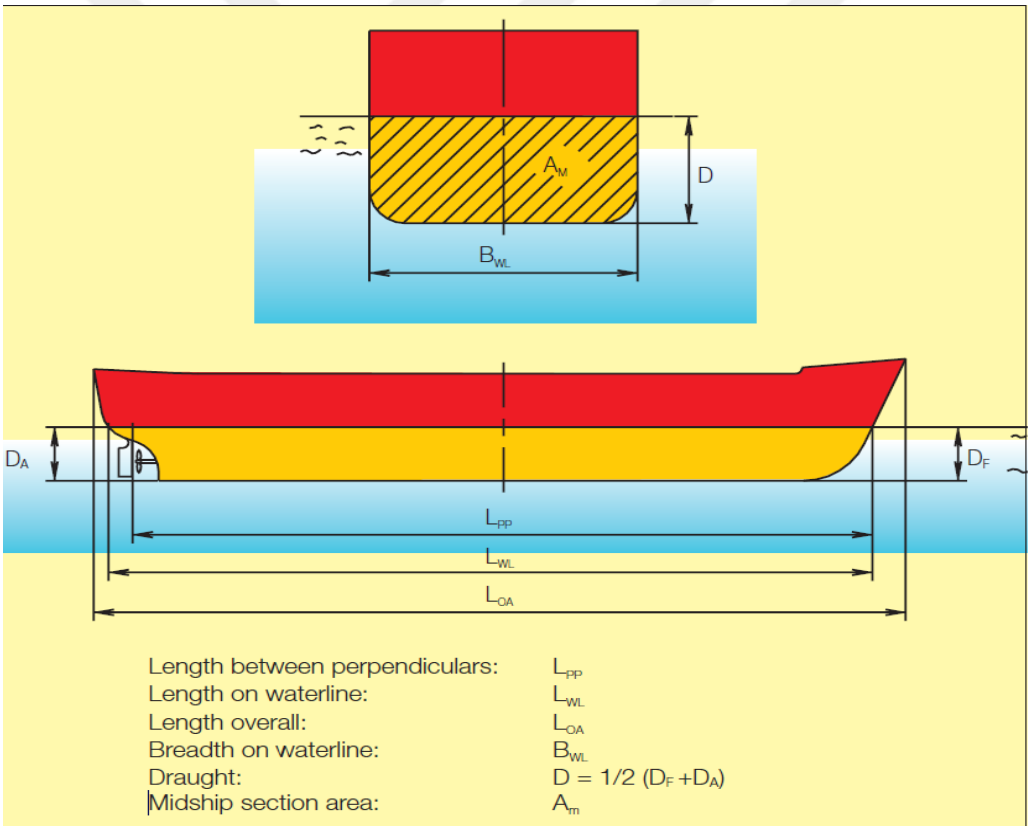


Figure 5.1: Hull dimensions

The distance between perpendiculars is the distance between the forefront perpendicular, which is generally a vertical line along the junction of the stem and the water's edge, and the

rearmost perpendicular, which is usually stock for the rudder. This distance is often a little shorter than the depth of the water, so it is usually written as

$$L_{pp}=0.96\text{-}0.98 \times L_{WL} \quad (5.1)$$

5.1.1 Draught

The vertical separation between the waterline and the hull's tip that is longest in the water is defined as the ship's draught, which is commonly abbreviated T in literature (see Figs. and). When the ship is laden, i.e., with no trim, the foremost TF draft, and the most severe drafts TA are usually the same, the space between the keel and the summer load line is known as the "scantling draught." The breath of a without any cargo but enough using ballast water assures the ship's stability is known as ballast draught. The "design draught" is usually the draught that happens most often between the scantling and the ballast draught.

5.1.2 Breadth

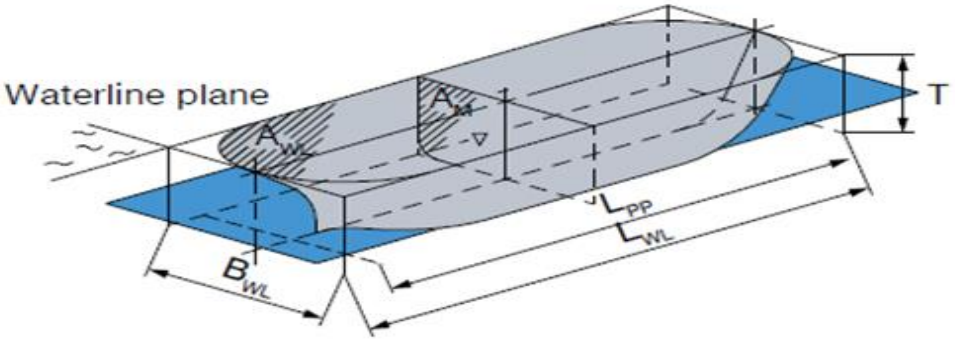
The hull's widest breadth on the waterline BWL, as shown in Figure 5.2, is another crucial consideration.

5.1.3 Depth

The depth, indicated by the letter D, is the distance between the keel and the underside of a ship's deck. The molded depth is the measurement taken from the freeboard deck to the keel from the side of the ship.

5.1.4 Lines of Loading

The load line indicator (also called using a Plimsoll line once its creator) is painted halfway down the ship's side (see Figure 5.3). The load line mark's lines and letters, which comply with IMO and local authority freeboard requirements, show the maximum draught to which the ship may be laden. "Freeboard" means the minimum distance between the ship's lowest watertight deck and the waterline or the load line when the ship is fully loaded.



Volume of displacement : ∇

Waterline area : A_{WL}

Block coefficient, L_{WL} based : $C_{B,WL} = \dfrac{\nabla}{L_{WL} \times B_{WL} \times T}$

Midship section coefficient : $C_M = \dfrac{A_M}{B_{WL} \times T}$

Longitudinal prismatic coefficient : $C_P = \dfrac{\nabla}{A_M \times L_{WL}}$

Waterplane area coefficient : $C_{WL} = \dfrac{A_{WL}}{L_{WL} \times B_{WL}}$

Figure 5.2: Hull coefficients

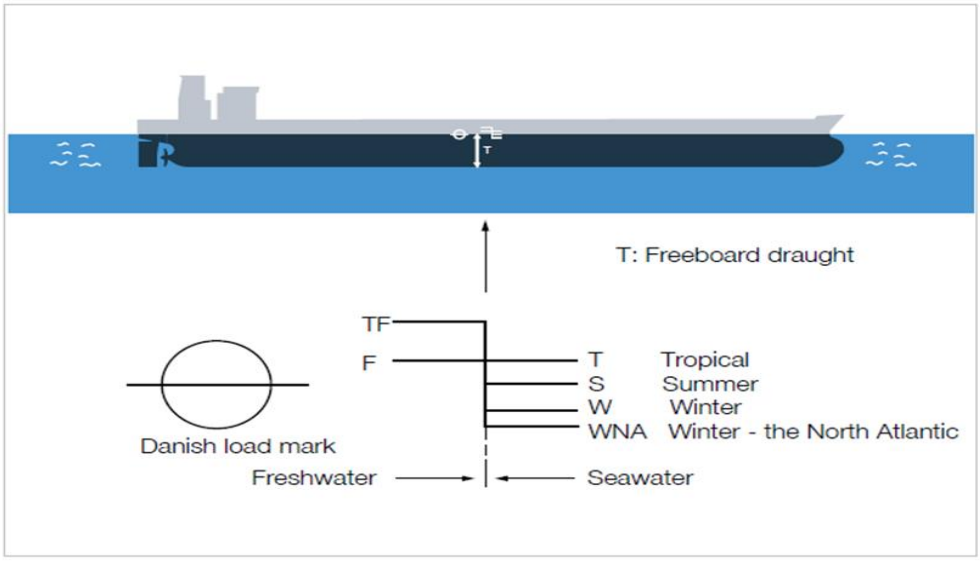


Figure 5.3: Load lines

There are load lines when sailing in freshwater and saltwater, for example, that account for considering the variation in water mass density and the associated variation when buoyant as a function of salinity. There are further classifications for tropical circumstances as well as summer and winter sailing. Because of the likelihood of adverse weather, the freeboard draught in the winter is smaller than that in the summer, according to international freeboard guidelines. As a result, in tropical conditions, a lower freeboard may be permitted.

5.2 SIZE DETERMINING FACTORS

5.2.1 Displacement, Deadweight, and Lightweight

When a ship is suspended at a random water line while laden, its displacement equals the appropriate mass of water displaced by the ship, and the overall weight of an appropriate laden ship, generally in seawater with 1.025 t/m3 mass density, is, therefore, equal to displacement. The ship's displacement is made up of its lightweight and deadweight, with the latter equaling the ship's capacity for loading, which includes bunkers and related materials required for propulsion. The discrepancy between the ship's actual displacements and lightest, all expressed for tons, is the deadweight at any given moment.

Displacing a light body = deadweight

The term "ton" has not necessarily refer to that same unit of measurement. That is also English slang (1,016 kg), sometimes known as the "long ton," in addition to the metric ton (1,000 kg). A "short ton" weighs about 907 kg. Deadweight tons (data) are calculated using the ship’s loading capacity, which includes the source, lubrication oil, and other items necessary for the ship’s function. It frequently serves as a size indicator speaking of the ships while loading capacity is laden to the summer load line, or its meager draught. Deadweight tons may additionally relate to the ship's carrying capacity in the design sketch, which shall be noted if this is the case. The weight of a ship in a light state, i.e., without any cargo, is referred to as its lightweight. The term "lightweight tonnage" (let) is seldom used to describe a ship's size.

The rule-of-thumb connection involving the ship's deadweight lightweight tonnage and tonnage (summer freeboard/scantling draught) is shown in Table 1.01. The term "payload"

refers to the most weight that can be put on a ship, minus the fuel and supplies that are needed to move the ship forward.

5.2.2 Gross and Net Tonnage

Without getting into great depth, it's worth noting that metrics like Net tonnage and dimensionless gross tonnage (get) (not) are computed using the volume of the ship and a multiplier set as published in the International Convention on Ship Tonnage Measurement. Gross weight refers to the whole enclosed space of the ship, while net tonnage solely refers to the cargo compartments. These measures are often used to support IMO regulatory requirements. It is important to distinguish between gross and net tonnage and pre-convention. Terminology of Net register tons (net) and gross register tons (get), which refer to 2.83 to 100 English cubic feet m3, respectively.

5.3 SHIP RESISTANCE

The amount of RT, the ship's hull resistance, is important as the amount of power necessary to move the ship and, as a result, for the quantity of fuel used. In the next section, we'll talk about the physical events that cause the different parts of complete calm water resistance, as well called source obstructions, and what they add to the complete opposition.

Resistance components

The speed, displacement, and hull type of a ship all have an impact on its calm water resistance. The total resistance RT is made up of several source-resistances R, which are separated into three categories:

a. Frictional opposition, RF

b. Continuing resistance, RR

c. Resistance to air, RA

The degree of lingering resistance characterizes the energy that the ship wastes in creating Viscous pressure resistance; waves and eddies are related to and are dependent on the hull lines. Frictional resistance is determined by the wetted surface of the ship, whereas residual

resistance is determined by the hull lines. Frictional resistance has the greatest impact (70-90 percent) on slow-moving ships like tankers and bulkers, but it can account for as little as half of overall resistance on fast-moving ships like Panama container carriers. However, for ships with big superstructures, like container ships carrying containers piled on the deck, air resistance accounts for roughly 2% of the overall resistance and a substantial rise up to about 10% for ships carrying enormous superstructures. When wind resistance is taken into account, the statistics may rise.

As a consequence, when water is being halted by a body, the body will respond to the water's dynamic pressure on the body's surface, causing the body to experience a dynamic force. By using dimensionless resistance coefficients C, this relationship is utilized to calculate or measure the ship's hull's source resistances R. As a result, C is connected to reference force which is described as the power exerted over a surface equivalent to the wetted area of the hull AS by the dynamic pressure of water at the ship's speed V. The wetted area also includes the rudder surface. The following two essential relationships are used to provide generic data for resistance calculations:

$$\text{Reference force: } K = \tfrac{1}{2} \times \rho \times V2 \times AS \tag{5.2}$$

$$\text{Source resistances: } R = C \times K \tag{5.3}$$

Approaches have been devised for estimating all of the essential resistance coefficients C and, therefore, the corresponding source-resistances R at a quick project without the testing phase, based on numerous tank experiments and using the assistance of applicable dimensionless hull characteristics. In practice replica of the ship is tested in a tank for towing to confirm and improve the rough estimate of the resistance of the ship, which is important for the initial sizing.

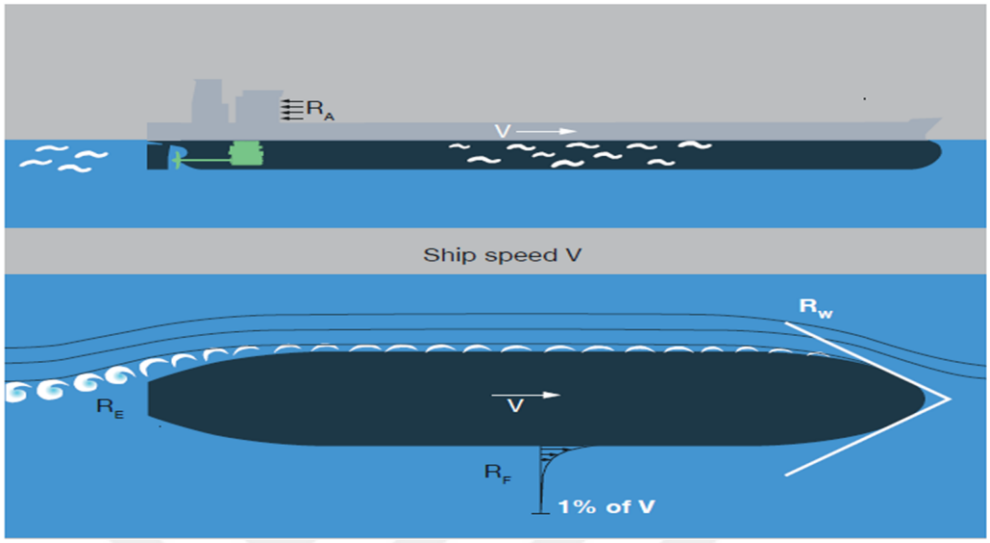


Figure 5.4: Components of resistance on a ship

5.3.1 Frictional Resistance, FR

The resistance to friction Two impacts are accounted for by RF: the Flat-plate friction with identical to the hull's length and area equal to the wetted surface of the hull, AS. Second, the frictional resistance induced by the ship's hull's curvature is in contrast to a flat plate, as seen in Figure 1.05. amount of frictional resistance grows as the hull fouls, i.e., as algae, sea grass, and barnacles develop on it.

$$R_F = C_F \times K \tag{5.4}$$

Mumford's formula may be used to estimate the wetted surface area. This formula can predict it to within 15% accuracy.

$$A_s = 1.025 \times L_{PP} \times (C_B \times B + 1.7 \times T) = 1.025 \times (\frac{\nabla}{T} + 1.7 \times L_{PP} \times T) \tag{5.5}$$

5.3.2 Residual Resistance, RR

Resistance to waves and viscosity pressure resistance are two types of residual resistance. Additional frictional resistance owing to the ship's hull curvature is sometimes included in the residual resistance. The energy expended by the building of the ship's propulsion, waves over

water, is referred to as wave-producing resistance, and it generally accounts for the majority of the residual resistance, depending on the ship's speed. The viscous pressure resistance is often a minor component of the overall resistance. The increasing thickness of the boundary layer along the ship's side causes separation losses in the boundary layer. As a consequence of the higher boundary layer thickness, the strain on the rear of the vessel is lower than in front, causing resistance. The formation of when the flow diverges from the hull surface, eddies forms a unique aspect of pressure viscous resistance that causes losses due to separation, also known as eddy resistance. Eddie is made when the boundary layer breaks apart, and there are sudden changes in the shape of the back half of the ship.

$$R_R = C_R \times K \tag{5.6}$$

At low ship speeds, residual resistance is usually negligible, but it may be considered at higher speeds. As a consequence, the total resistance increases by as much as the cube of the speed, if not more. As a result, for fast ships, the needed fuel and power are related. Consumption might be inversely correlated with the speed of the fourth power, Pike V4, or perhaps more.

5.3.3 Air Resistance, AR

Air resistance is related to the square of the ship's speed and the cross-sectional area of the ship above the waterline in calm weather. It's vital to differentiate involving air resistance and air resistance; the wind; refers to the resistance a ship faces while traveling through the air without any wind. Similar to the previous resistances, air resistance may be stated as RA = CA KA. The resistance may be represented as: Using a CA and a drag coefficient a ship's area above the water line Air, the resistance can be expressed as:

$$R_A = {}^{1}\!/_{2} \times \rho_{air} \times C_A \times A_{air} \times V^2 \tag{5.7}$$

Depending on the design of the superstructure, the coefficient of drag may be predicted at about CA 0.9, but the area where the wind acts above the waterline must be computed since the area varies with prevailing winds [69]–[71].

5.4 INFANTRY BOAT POWER CALCULATION

In the thesis research, the service speed for infantry boats was established to be 6 knots, which was used as a reference [71] [72] [73]. In the same experiments, it was established how much power the boat required for whatever speed value was in the pulling tests done at various speeds. As a result, the effective power values the empty and loaded boat at the service speed Vg=6 knots are as Ahe effective power values of the empty and loaded boat at the service speed Vg=6 knots are as follows:

EHP=2.78 HP for (LWL=WL 3.5)

EHP=3.74 HP for (LWL=WL 5.0)

As indicated in Table.5.1 for LWL=WL 3.5 and Table.5.2 for LWL=WL 5.0, these values, both loaded and unloaded, have a 10% safety rate for obsessions when compared to the effective horsepower (EHP) value determined from model trials. Attained by adding

Table 5.1: Ship power E.H.P values for LWL=WL 3.5

V(knots)	$EHP_{(experimental)}$	$EHP_{(correction)}$
1.246	0.02508	0.0272371
1.533	0.04461	0.053966
1.913	0.07717	0.093412
2.314	0.11975	0.144958
2.477	0.14038	0.169884
2.896	0.20664	0.249986
3.006	0.22829	0.276243
3.272	0.29103	0.35211
3.368	0.31794	0.38469
4.103	0.59518	0.720192
4.522	0.81731	0.988933
4.937	1.08917	1.317932
5.281	1.23801	1.497980
5.675	1.80991	2.189979
5.934	2.17767	2.635017
6.176	2.61933	3.169353
6.346	3.02232	3.656983
6.456	3.33359	4.033656
6.541	3.60653	4.363865
6.925	5.27622	6.384202
7.063	6.07434	7.350024
7.162	6.70367	8.111477
7.361	8.06836	9.762764
7.457	8.76503	10.605650

Table 5.2: Ship power, (E.H.P) values for LWL=WL 5.0

V(knots)	EHP(experimental)	EHP (correction)
1.409	0.06025	0.07290
1.757	0.09322	0.11280
2.027	0.12309	0.14894
2.307	0.15955	0.19306
2.605	0.20770	0.25132
2.772	0.24078	0.29134
3.031	0.30430	0.36820
3.624	0.52227	0.63159
4.043	0.74825	0.90538
4.383	0.98043	1.18632
4.677	1.21062	1.46485
4.976	1.50987	1.82694
5.256	1.83563	2.22111
5.548	2.24260	2.71355
5.817	2.70262	3.27017
5.966	3.00914	3.64106
6.186	3.55260	4.29865
6.499	5.39218	6.52454
6.690	5.39218	6.52454
6.847	6.18347	7.48200
7.060	7.42777	8.98760
7.191	8.25871	9.99303

5.5 INFANTRY BOAT ENGINE AND MOTOR SIZING

From the previous studies, as shown below, the type and capacity of the internal combustion engine were then determined. Also, the type, capacity, and electrical specifications of the

electric motor were taken in proportion to the size of the boat. A solar system will be designed based on this data to generate sufficient power to propel the infantry boat.

The maximum ship's effective power will be EHP = 3.74 HP when considering the ship's effective power necessary in response to the service speed of both waterlines. The diesel engines listed below were chosen based on characteristics such as environmental circumstances, robustness, quietness, and trouble-freeness, and they will deliver the required power.

a. Brand: Hats Diesel
b. Engine Type and Model: 1D41C
c. Engine power: HP=4.5 HP
d. Engine speed: v =1800 rpm

An electric motor with a power similar to that of the diesel engine chosen in the preceding section will be chosen to achieve the effective horsepower of the same propeller. The major criteria for an electric motor to function on an infantry boat are high take-off torque, the ability to vary the speed, the ability to change rotation direction, and the ability to be inexpensive and quick. One of its characteristics, As a result, it has been agreed that the propulsion system's electric motor will be DC (Direct Current). Following the study, the Bell Marine 5.0 engine was chosen, which has the same power as a diesel engine but uses less current than other electric engines. [72]

a. DESCRIPTION Drive Master 5A
b. MOTOR SIZE 180-8
c. NOMINAL kW 4 kw
d. INTERMITTENT kW 5 kw
e. BATTERY DC 48 V
f. MOTOR rpm 1500 rpm
g. Current (A) 105 A
h. Productivity 90%
i. Rated Torque (Nm) 18 Nm

j. Maximum Current (A) 175 A

k. Maximum Torque (Nm) 31 Nm

l. Weight of Engine and Mounting Bracket (kg) 25kg

Figure 5.5: electrical motor

$Energy\ demand{=}Load(kW){*}Time(hr)$ [72]

5.6 PV SYSTEM DESIGN

To fulfill the load profile is the boat that the design is intended to prepare; each element in a stand-alone solar energy system must have a certain capacity (in terms of voltage and current). This procedure is known as PV system design.

5.6.1 Elements That Influence PV System Design

Despite the various benefits that have previously been mentioned, it is crucial to realize that the significant upfront investment costs of PV power systems continue to be a significant

barrier to their usage. So, during the design process, many different parameters are often taken into account to lower the total cost of the system, as explained below:

5.6.1.1 A manageable Load Profile

When calculating the necessary average energy consumption in watt-hours per day, energy conservation guidelines must be properly followed. This is often assessed by making a list of all the loads and the daily use hours that correspond to them. A certain load must not be used during the hours when it is prohibited.

5.6.1.2 Location of PV power system installation

The geographical position of the installation location is crucial since it affects the array orientation, tilt angle, and the average number of hours of sunlight received daily. Additionally, no shadows of any kind should be present at the installation location during the solar day.

Solar panels, a metal frame, batteries, an inverter, cables, meters, a charge controller, and circuit breakers make up the stand-alone PV solar system used on boats and ships. At the job site, these parts are joined to one another. The battery is packaged in a robust, portable, and corrosion-resistant cover to safeguard it from inclement weather. This system can be used as an alternative energy source and can be counted on to provide clean, safe, and consistent energy in many situations.

5.6.2 The Description of Case Study Site

Knowing the daily solar radiation values for the location and the required quantity of energy is the first stage in developing and sizing the standalone PV system. The procedure of supplying meteorological data (solar radiation and temperature) to the system location (Hamitköy, Turkey) to acquire the optimal design for the solar system is one of the essential components of the design. Table 1 shows the average daily solar radiation values for the city of Hamitkoy. The city gets a lot of sunlight, especially in the summer.[75]

Table 5.3: Average monthly Solar Radiation, wind velocity, and temperature

Describe	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	unit
Horizontal global	2.42	3.05	4.17	5.83	7.15	7.92	7.70	7.01	5.27	3.67	2.74	2.30	4.95	$kWh/m^2/day$
Ambient Temper.	9.1	10.2	13.1	16.1	20.7	25.1	28.5	28.2	24.0	19.2	14.2	10.5	18.2	°C
Wind Velocity	3.0	2.9	2.7	2.6	2.5	2.7	2.8	2.6	2.6	2.3	2.3	2.7	2.6	m/s

5.6.3 Calculating the Required Boat Load

How powerful a PV system has to be installed will depend on the electrical demand of a particular boat. To make the shipload profile, you list each application along with its power rating and the number of hours it runs. This gives you the overall average energy demand in watt-hours for all ship applications.

Table 5.4: Daily Load Profile

S/N	Appliance	Quantity	Power Rating (Watt)	Hours of use per Day	Energy per Day
1	Electric motor	1	5000	4	20000 w

5.6.4 Calculating the PV Array's Size

A connected group of solar modules is called a photovoltaic array. The electricity that one module can provide is seldom sufficient to supply a residential building's energy needs; thus, the modules are connected to create an array. The individual strings are then joined in parallel to enable the system to generate additional current as needed. Typically, the modules in solar

panel arrays initially sequence of connections to get the necessary voltage. Before the PV array's exact size is calculated, the following details need to be established:

The system's DC voltage (DC),

the average daily hours of sunlight at the installation location (Tosh), and

The watt-hours of daily average energy use (Ed)

The daily average energy demand (Red), which is determined by dividing the daily average energy needs by the product of the efficiency of all the system components as indicated in the equation, is the first step in sizing the array.

$$\text{Red} = \frac{\text{Ed}}{\eta b\, \eta i\, \eta c} \tag{5.8}$$

Where

ηb = battery efficiency

ηi = inverter efficiency

ηc = charge controller efficiency

The average peak power (Pave, peak) is then calculated by dividing the site's average daily energy demand by its average daily sun exposure (Tosh), as shown in the equation.

$$P_{ave,peak} = \frac{\text{Erd}}{\text{Tsh}} \tag{5.9}$$

The average peak power of the system is then divided by the dc voltage of the system, as shown in the equation, to provide the total DC (ID).

$$I_{dc} = \frac{\text{Pave,peak}}{\text{Vdc}} \tag{5.10}$$

The system DC voltage is then divided by each module's rated voltage (Vim), as shown in the equation, to get the number of modules in series (NM).

$$N_{sm} = \frac{Vdc}{Vrm} \tag{5.21}$$

Next, using the equation, we can calculate the number of parallel module strings (NM) by dividing the system's total DC by the rated current of one module (Irma).

$$N_{pm} = \frac{Idc}{Irm} \tag{5.32}$$

Finally, the total number of modules (NM) that make up the array is calculated by dividing the number of parallel modules by the number of series modules, as shown in the equation. This yields the necessary array size.

$$N_{tm} = N_{sm} \times N_{pm} \tag{5.43}$$

5.6.5 Calculating the Battery Bank's Size

Deep-cycle batteries are the preferred type of battery for solar PV electricity systems because of their unique architecture, which allows them to be quickly recharged again for years even after being depleted to low energy levels. The battery has to be big enough to hold enough power to run all the loads throughout the night on overcast, rainy, and dusty days.

Calculating the estimated energy storage (East) needed is the first step in sizing the battery. East is equal to the product of the daily average energy needs and the number of autonomy days (Daunt), as shown in the equation.

$$E_{est} = E \times D_{aut} \tag{5.54}$$

The predicted energy storage afterward is separated by the maximum permitted discharge depth (Disc), according to the equation, to get a secure energy repository (Safe).

$$E_{safe} = \frac{Eest}{Ddisch} \tag{5.65}$$

As shown in the equation, the safe energy storage is then divided by the rated DC voltage of one battery (Vibe), yielding the total capacity of the battery system in ampere-hours (CT).

$$C_{tb}=\frac{E\ safe}{V\ b} \tag{5.76}$$

The number of batteries overall (Nab) may once be calculated by division of the ampere-hour and the battery bank's capacity as a whole by the ampere-hour power of one of the chosen batteries (Cob), as shown in the equation.

$$N_{tb}=\frac{C\ tb}{C\ b} \tag{5.87}$$

When dividing the system's DC voltage by a battery's rated DC voltage, as shown in the equation, it is now possible to calculate the number of batteries in series (Nab).

$$N_{sb}=\frac{\mathrm{Vdc}}{\mathrm{Vb}} \tag{5.98}$$

Now, divide the sum by the number of batteries connected in series. as shown in the equation, we can find the number of parallel battery strings (Nab).

$$N_{pb}=\frac{\mathrm{Nb}}{\mathrm{Nsb}} \tag{5.109}$$

Finally, the size of the battery bank is entirely established and consists of Nab Npb batteries since the number of batteries in series (Nab) and the number of parallel battery strings (Npb) are now known.

5.6.6 Calculating the Charge Controller's Capacity

The solar charge controller is typically sized such that it can carry out its duty of controlling current. A decent capability of the charge controller handles both currents in the array and the overall current load, and it has to be built the same as both the PV panel's and the battery bank's voltages.

It is common practice to size the charge controller such that it can resist the sum of the array's total short circuit current (Isc = Isc x Npm) plus a certain safe factor (Safe). To allow for

acceptable system growth, the safety factor is required. The equation provides the required charge controller current (Icc).

$$I_{cc} = I_{sc} \times N_{pm} \times F_{safe} \quad (5.20)$$

Where I_s = the short circuit current of the selected module

5.6.7 Calculating The Inverter's Capacity

When an AC power output is required, In the PV power system, an inverter is utilized. The input rating of the inverter and the battery bank's nominal voltage must be the same. and should never be less than the combined power of the various loads. In reality, the total power of all concurrently operating loads plus three times the total power of all inductive loads with significant surge currents is regarded to constitute the inverter's capacity. To allow for realistic system growth, the resulting afterward increased by a factor of 1.25 to increase its capacity by 25%. As a result, the following equation is used to compute the inverter power [76].

$$P_{inv} = 1.25(P_{sum} + 3P_{ind}) \quad (5.21)$$

Where P_{ine} = Power of the inverter

P_{sum}= Power of all loads running simultaneously

P_{ind}= Power of all inductive loads with large surge currents

6. SAMPLE DESIGN

First of all, the main elements of the system to be used in the solar electric drive system, the advantages of this system compared to the diesel engine driven system, and the solar system that paves the way for the use of electric drive systems in the many entire sectors, the preliminary design of the solar electric propulsion system will be made by referring to the calculations made in the previous studies.

6.1 INTRODUCTION

The first things to be determined when starting the design of the sea vehicles are the mission profile, the waters to be operated, the route to be followed, the speed value to be reached, etc., information. Based on all this information, the mobility capability of that boat is revealed. This mobility is determined by the propulsion systems.

The propulsion system should be able to produce sufficient electricity to enable the means to fulfill its expected duties and responsibilities during the entire time it will spend on the cruise without any external support with the equipment it has. In addition, low operating costs and efficient operation are other important features expected from the drive system. In the broadest sense, these features change based on what kind of energy source is used to power the propulsion system. Some substances, such as oil, natural gas, and coal, are widely used as energy sources in the transportation sector. Of these, the most commonly used as a power source is diesel fuel, produced from petroleum. Innovative, highly efficient applications that can reduce investment or operating costs and increase maintenance times are important in the sector where diesel fuel has been at the forefront for many years. Electric solar watercraft can provide a valuable solution to this energy paradigm of today. In solar electric propulsion systems, the propeller that provides the propulsion power to the ship is driven by an electric motor, not an internal combustion engine, and the electrical energy needed by this electric motor is provided by solar energy, not by diesel generators.

6.2 BOAT DIMENSION

In particular, at the Köyceiz lake, which is at the confluence of the Aegean and Mediterranean seas, fishermen employ infantry-type fishing boats for both fishing and sightseeing trips for

millions of domestic and international visitors. In this manner, these boats have evolved into the local community's primary source of income in that area. These boats range in length from 7 to 12 meters and are built of wood. They were built by skilled boat builders in their shipyards over a period of hundreds of years without the use of any scientific or mathematical techniques, eventually taking on their current shape. When examining their hydrodynamic shapes, it is evident that this sort of fishing boat's current, highly efficient design was made possible by the experiences of boat builders who defined it after many trials and mistakes. The model test results from the previous investigations were used for the subsequent computations in this research. By using geometrical similarity principles, the values for a 10-meter-long army-type fishing boat were derived using the needed values from the previous thesis investigations and utilized as a starting point. Then, assuming a service speed of 6 knots, a concept design study for a diesel engine propulsion system for 10-meter-long army-type shipping boats was created. Previous research covers the diesel engine, reduction gear, and propeller options are covered in previous research. [72]

Table 6.1: Fishing boat specification

Boat Type	infantry-type fishing (parade)
Boat materials	wood
Boat length	10m
Boat beam	2.8 m
Boat depth	1.150 m
Service speed	6 knots

Figure 6.1: Infantry Type Fishing Boat

6.3 SOLAR PANEL

The top solar panel and cell producer in the world have long been recognized as Sun Power. The world's most efficient solar panels are still made by Sun power, which is now known as Maxton Solar Technologies. Sun power also has the best performance warranty, with a minimum guaranteed rated output of 92 percent after 25 years. More economical performance as the pioneer in solar technology, Sun Power Corporation has a long history of producing solar energy systems. This is a huge claim, but it's difficult to refute it given that they now manufacture the Maxton 3, the most effective home solar panel on the market with the lowest degradation and greatest performance guarantee. Sun Power panels are among the most costly in the world, yet excellent performance comes at a high price, as it does with most things. The acclaimed Maxton series panels are among the highest-performing panels in the world, while Sun Power's more affordable Performance series provides a wide selection of

panels for home, business, and utility-scale solar systems, The Maxton 3 is the new star product in the Sun Power lineup, and it comes in sizes from 370 to 400W for residential installations. Its new 104-cell format increases power output and outperforms the competition with a staggering 22.8 percent maximum efficiency, making it the most effective solar panel in the world. In this study, the solar panel (SPR-MAX3-400) was considered to be the panel approved for the design of the solar system, which will be installed on the deck of the boat to provide it with sufficient energy to carry out its tasks. The following are some of the most important characteristics of the solar panel adopted in the study.

Table 6.2: Electrical properties of the solar panel

Electrical properties	
Nominal Power (Prom)	400 W
Power Tolerance	+5/0%
Panel Efficiency	22.6%
Rated Voltage (Vamp)	65.8 V
Rated Current (Imps)	6.08 A
Open-Circuit Voltage (Vic)	75.6 V
Short-Circuit Current (Sic)	6.58 A
Max. System Voltage	1000 V IEC
Maximum Series Fuse	15 A
Power Temp Coif.	—0.29% / °C
Voltage Temp Coif.	—176.8 mV /°C
Current Temp Coif.	2.9 mA / °C

Table 6.3: Operating conditions of the solar panel

Operating conditions	
Temperature	—40° C to +85° C
Impact Resistance	25 mm diameter hail at 23 m/s
Solar Cells	104 Mon crystalline Maxton Gen III
Tempered Glass	High-transmission tempered anti-reflective
Junction Box	IP-65, Stable (MC4), 3 bypass diodes
Weight	19 kg
Design Load	Wind: 2660 Pa, 274 kg/m^7 front & back Snow: 4000 Pa, 408 kg/m^2 front
Max. Load 10	Wind: 4000 Pa, 408 kg/m^2 front & back Snow: 6000 Pa, 611 kg/m^2 front
Frame	Class 1 black anodized (highest AAMA rating)

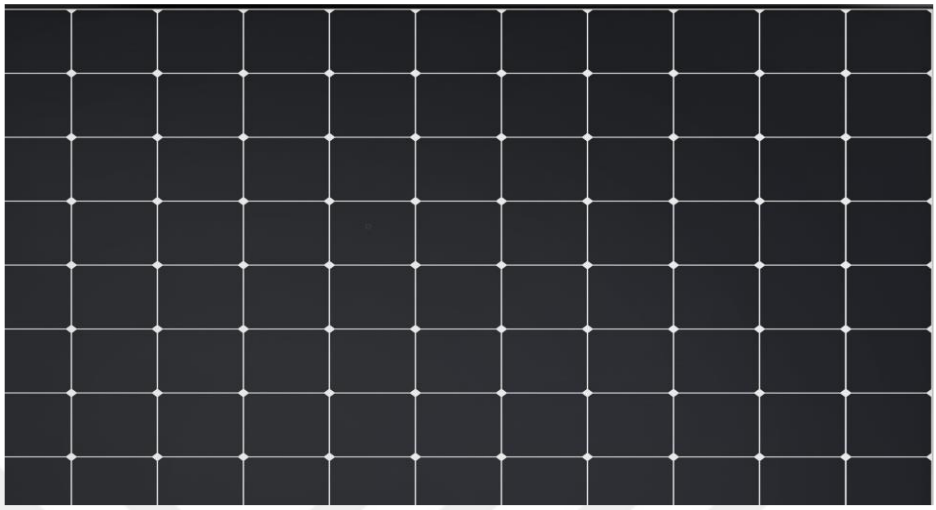


Figure 6.2: Solar panel (SPR-MAX3-400)

The selected solar panels will be placed on the roof of the boat as shown in the figure below and the tilt angle is about 15 degrees to get the highest amount of sunlight directed towards the boat shown in the figure below, a boat that uses solar panels as well

Figure 6.3: Solar boat with a roof made of solar panels

6.4 BATTERY

Lithium-ion battery modules were taken into account in this investigation. The lithium battery has the following advantages: it is lighter, provides more charge cycles (+5000), doesn't self-discharge, and may be discharged completely. The carbon lead battery is hefty and occupies a lot of space. The lead/calcium battery is the most popular and least priced battery, although it self-discharges quickly, has a limit of 300 charging cycles, and can only be depleted up to 50%. Therefore, it is advised to use lithium batteries in the system. The lithium battery makes up for its greater initial cost with a substantially longer lifetime. It is the best option for an electric motor in a boat since it absorbs excess energy while charging and gives energy when RE sources are inadequate to meet load needs. The battery bank will provide extra power in bad weather when there is no sun if the PV solar energy output is not enough to drive the ship's engine.

Table 6.4: Characteristics and dimensions of the battery

	Whole battery (module)	Per element
Nominal voltage	48.1 V	3.7 V/cell
Capacity at C10	120 Ah	60.00 Ah/cell
Internal resistance @ref. temp.	9.75 mΩ	1.50 mΩ/cell
Reference temperature	20 °C	20.0 °C
Columbic efficiency	96 %	96 %
Charge Cut-off voltage	54.6 V	4.2 V/cell
Discharge Cut-off voltage	39 V	3.0 V/cell
Maximum charging current	212 A	106 A/string
Maximum discharging current	212 A	106 A/string
Minimum charging current	10 °C	10 °C
Minimum discharging current	-10 °C	-10 °C

Dimensions			
Width	depth	high	Weight
245 mm	385 mm	285 mm	39 kg
Base cell			
Kokum SLP120216216			

Figure 6.4: Battery module

6.5 CHARGE CONTROLLER

MPPT stands for maximum power point tracking. Controller feature that extracts the most power possible from the PV module in some circumstances by controlling current and voltage. solar energy, outside temperature, and the temperature of solar cells all affect maximum power. The Morningstar TriStar MPPT solar controller with Tri-Star Technology is a cutting-edge maximum power point tracking (MPPT) battery charger for off-grid solar (PV) systems with PV array max power (Pump) up to 4.2 kW. When compared to other MPPT controllers, the controller has the highest peak efficiency in the industry at 99 percent and significantly lower power loss. Advanced battery compatibility for the newest Lithium, Nickel Cadmium, and Lead Acid battery types is made possible by detailed battery programming choices. With very quick sweeping of the whole I-V curve, the TriStar MPPT's intelligent tracking algorithm optimizes the energy collection from the PV by quickly locating the solar array peak power point. This device is the first PV controller available with up to 200 days of data recording and onboard Ethernet for a fully web-enabled interface, this device is the first PV controller available [77].

Table 6.5: Charge controller Technical Specifications

Technical Specifications		
Maximum Battery Current		45 amps
Nominal Maximum Output Power* 12 Volt 24 Volt 48 Volt		 600 Watts 1200 Watts 2400 Watts
Max Recommended Solar PV Input*		130% of Nominal Max Output Power -1
Peak Efficiency		99%
Nominal System Voltage		12, 24, or 48 volts DC
Maximum PV Open Circuit Voltage**		150 volts DC
Battery Operating Voltage Range		8-72 volts DC
Maximum Self-consumption		2.7 Watts
Transient Surge Protection		4500 Watts/port
Battery Charging		
Charging Algorithm		4-stage
Charging Stages		Bulk, Absorption, Float, Equalize
Temperature Compensation:	Coefficient Range Set Points	-5mV/°C/cell (25° ref) -30°C to +80°C Absorption, Float, Equalize, HVD
Remote Temperature Sensor (RTS)		Included

Table 6.6: Charge controller properties

Electronic Protections	
Solar	**Overload, Short Circuit, High Voltage**
Battery	**High Voltage**
High Temperature	
Lightning &Transient Surges	
Reverse Current at Night	
Mechanical	
Dimensions	**29.1 x 13.0 x 14.2 cm** **11.4 x 5.1 x 5.6 in**
Weight	**4.2 kg / 9.2 lbs**
Maximum Wire Size	**35 mm^2 / 2 AWG**
Conduit Knockouts	**M20;1, 1, 1 1/4 in**
Enclosure	**Type 1 (indoor and vented) IP 20**

7. SIMULATION

7.1 SIMULATION

Pvsyst7 is used for system simulation.

In contrast to sizing tools, simulation tools require the user to define the kind and size of each component. The program then offers a thorough study of the system's behavior. The input meteorological data and user-set simulation settings have a significant impact on Posit simulation accuracy. Pvsyst software is utilized in this study for modeling, analysis, and optimization. The program simulates PV, converters, and batteries with various sizes to fit the needs using load demand and solar energy data. The mechanism for fishing boats in this research was modeled. Pre-feasibility, sizing, and simulation assistance for PV systems are integrated by Pvsyst. After defining the location and loads, the user chooses the different parts from a product database. The program then figures out the sizes of each part on its own.

7.2 ORIENTATION

In this study, the tilt angle and azimuth for fixed planes were taken as follows (tilts/azimuths: $15^0/0^0$), then these angles were taken for a whole year These angles were taken so as not to create a sharp edge on the roof of the boat and to make it suitable for receiving the sun's rays falling on it easily.

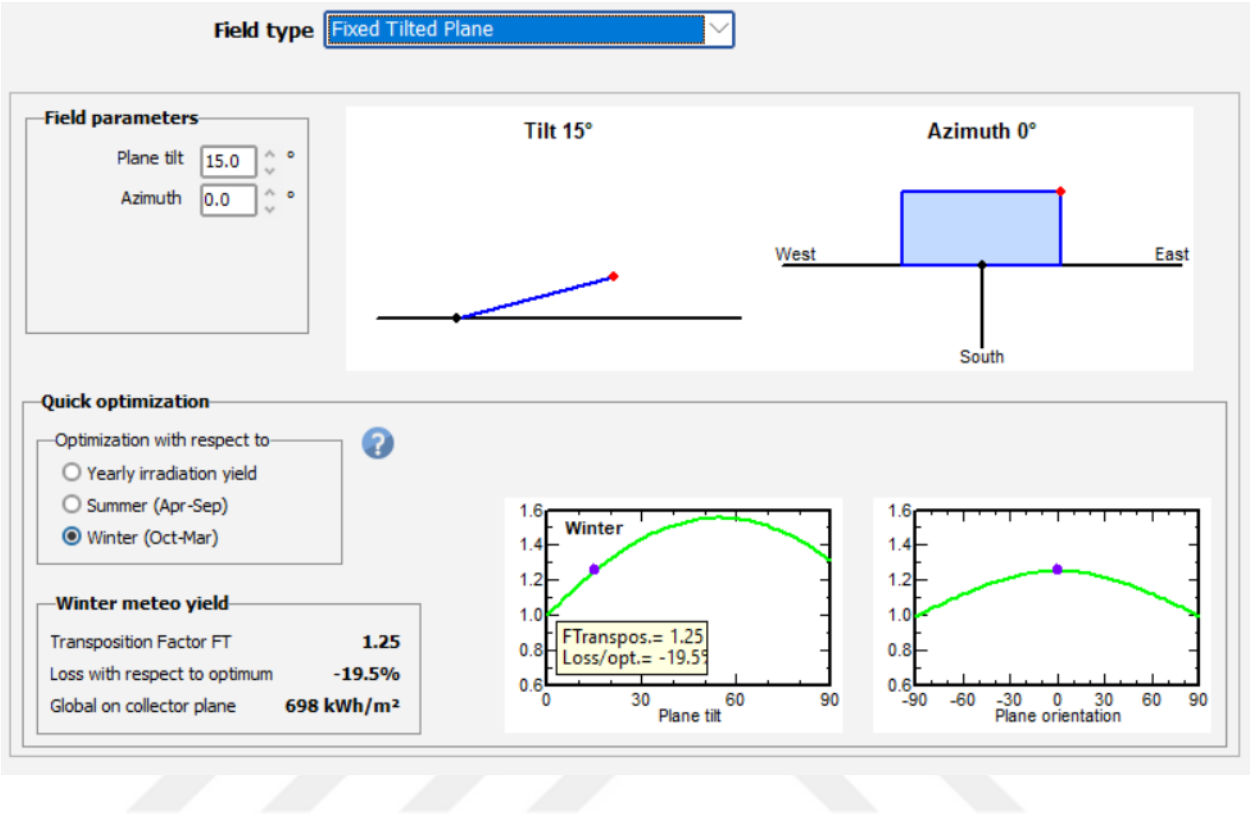


Figure 7.1: Pvsyst system orientation

7.3 LOAD DISTRIBUTION

It was distributed throughout the day for four separate hours, with a break in the afternoon these are the normal working hours during which the solar radiation is at its maximum.

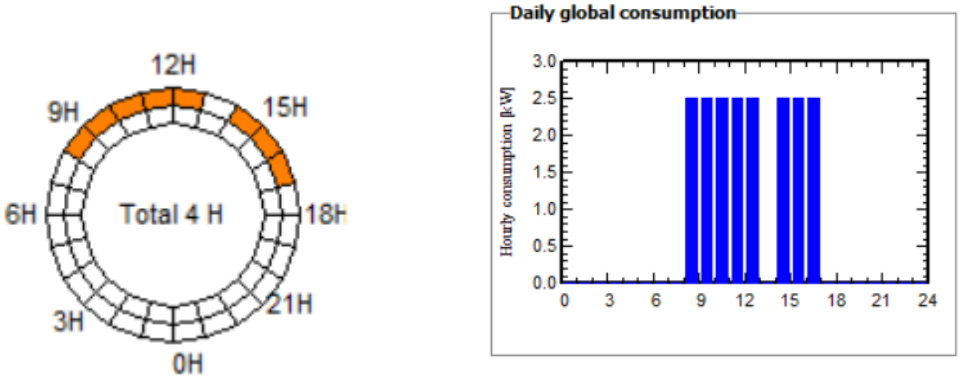


Figure 7.2: Load hour distribution

7.4 PV ARRAY CHARACTERISTICS

The components of the solar system have been carefully selected to efficiently meet the requirements of the solar boat

General parameters

Stand alone system — **Stand alone system with batteries**

PV Field Orientation

Orientation		Sheds configuration	Models used	
Fixed plane		No 3D scene defined	Transposition	Perez
Tilt/Azimuth	15 / 0 °		Diffuse	Perez, Meteonorm
			Circumsolar	separate

User's needs

Daily household consumers
Constant over the year
Average 20.0 kWh/Day

PV Array Characteristics

PV module

Manufacturer	SunPower
Model	SPR-MAX3-400
(Original PVsyst database)	
Unit Nom. Power	400 Wp
Number of PV modules	14 units
Nominal (STC)	5.60 kWp
Modules	14 Strings x 1 In series
At operating cond. (50°C)	
Pmpp	5.23 kWp
U mpp	59 V
I mpp	88 A

Battery

Manufacturer	Kokam
Model	KBM216_2P13S 120Ah
Technology	Lithium-ion, NMC
Nb. of units	4 in parallel
Discharging min. SOC	10.0 %
Stored energy	20.6 kWh
Battery Pack Characteristics	
Voltage	48 V
Nominal Capacity	480 Ah (C10)
Temperature	Fixed 20 °C

Controller

Manufacturer	Morningstar
Model	Tristar TS MPPT 45 - 48V
Nb. units	2 units
Technology	MPPT converter
Temp coeff.	-5.0 mV/°C/Elem.
Converter	
Maxi and EURO efficiencies	98.5 / 97.7 %

Battery Management control

Threshold commands as	SOC calculation
Charging	SOC = 0.96 / 0.80
Discharging	SOC = 0.10 / 0.35

Total PV power

Nominal (STC)	6 kWp
Total	14 modules
Module area	24.7 m²

Figure 7.3: PV array characteristics

7.5 SIMULATION RESULTS

Using the simulation system in the program, we can get a wide range of results in the form of tables or charts

Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	75.1	96.6	506	0.0	119.4	500.6	620.0	0.807
February	85.4	99.1	517	7.7	75.3	484.7	560.0	0.865
March	129.2	142.2	730	133.4	40.1	579.9	620.0	0.935
April	174.9	182.4	928	310.4	0.0	600.0	600.0	1.000
May	221.6	220.6	1098	458.6	0.0	620.0	620.0	1.000
June	237.5	230.1	1127	511.1	0.0	600.0	600.0	1.000
July	238.9	234.0	1132	498.9	0.0	620.0	620.0	1.000
August	217.2	223.9	1085	444.5	0.0	620.0	620.0	1.000
September	157.8	171.4	846	234.2	0.0	600.0	600.0	1.000
October	113.9	131.2	662	55.9	20.0	600.0	620.0	0.968
November	82.1	103.6	531	30.6	103.1	496.9	600.0	0.828
December	71.4	93.3	488	0.0	145.4	474.6	620.0	0.765
Year	1805.0	1928.4	9650	2685.3	503.3	6796.7	7300.0	0.931

Figure 7.4: balances and main results

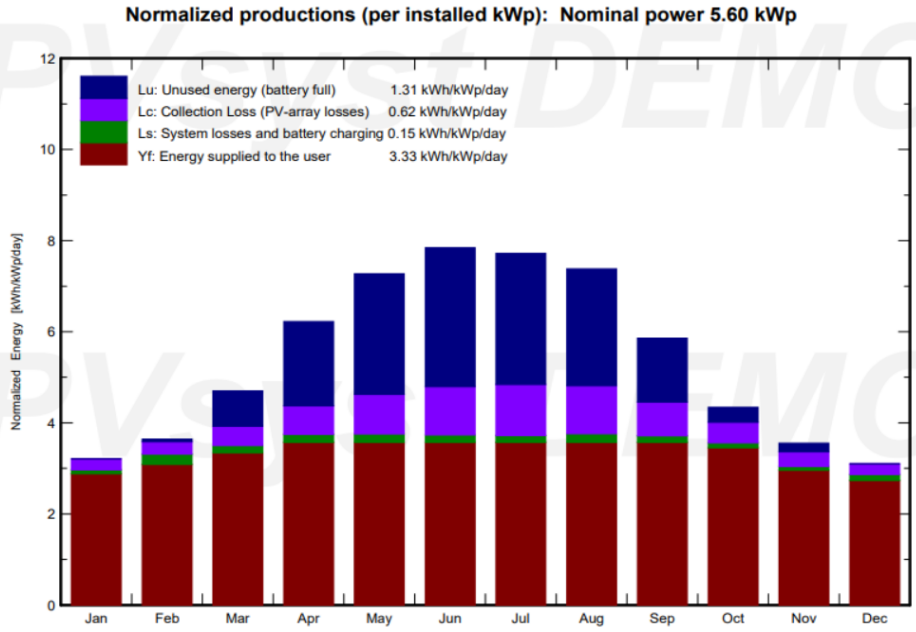


Figure 7.5: Energy chart

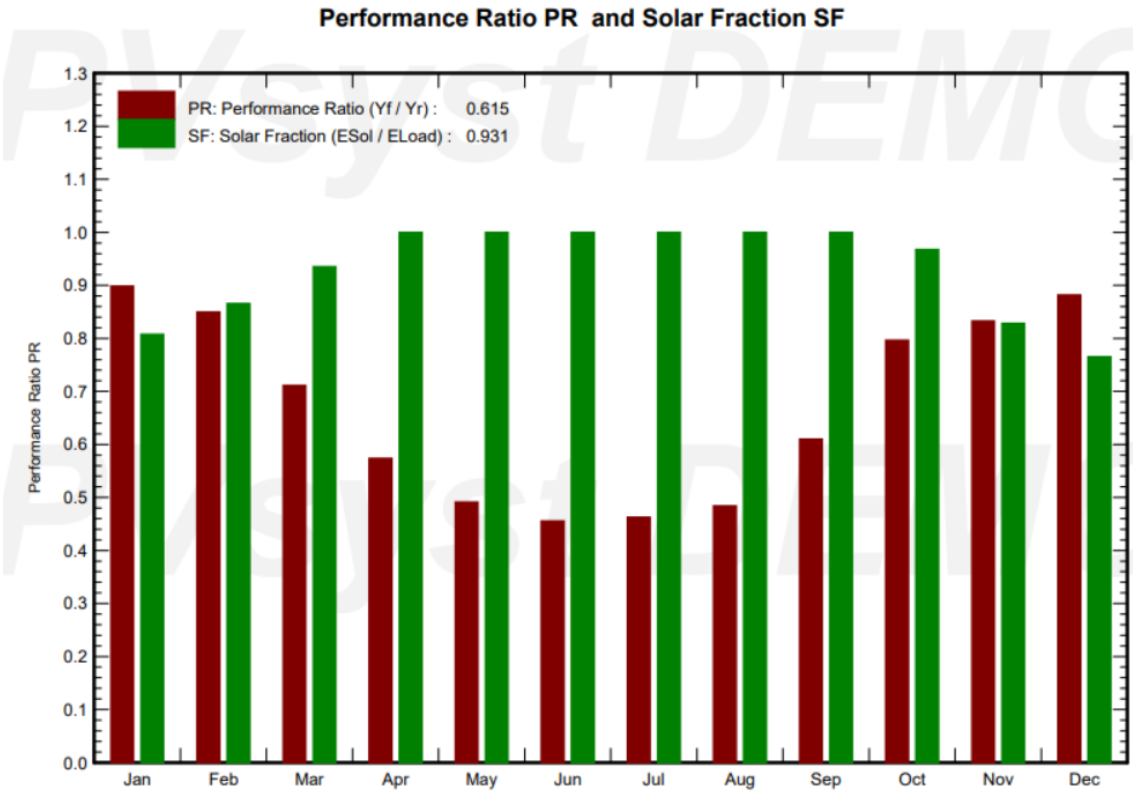


Figure 7.6: Performance ratio

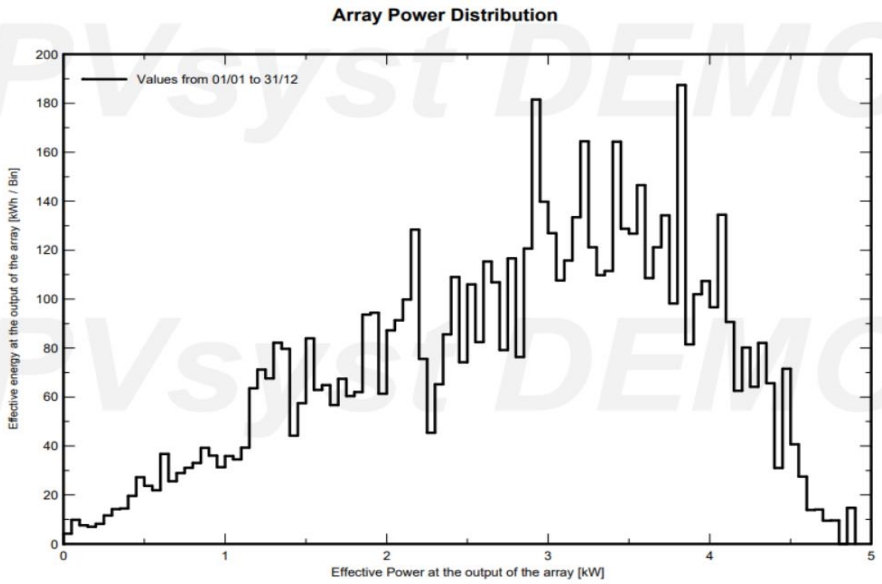


Figure 7.7: Array power distribution

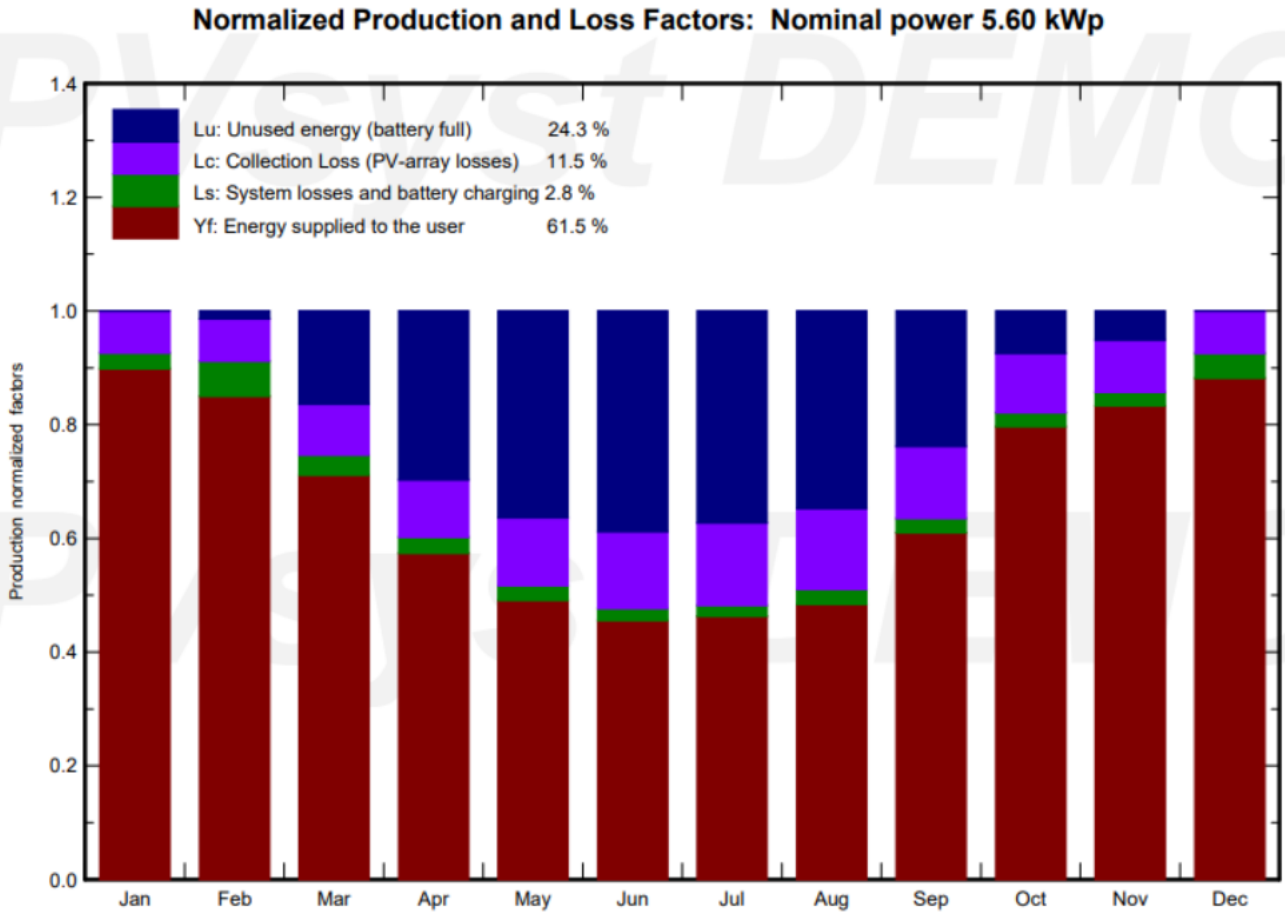


Figure 7.8: Energy chart

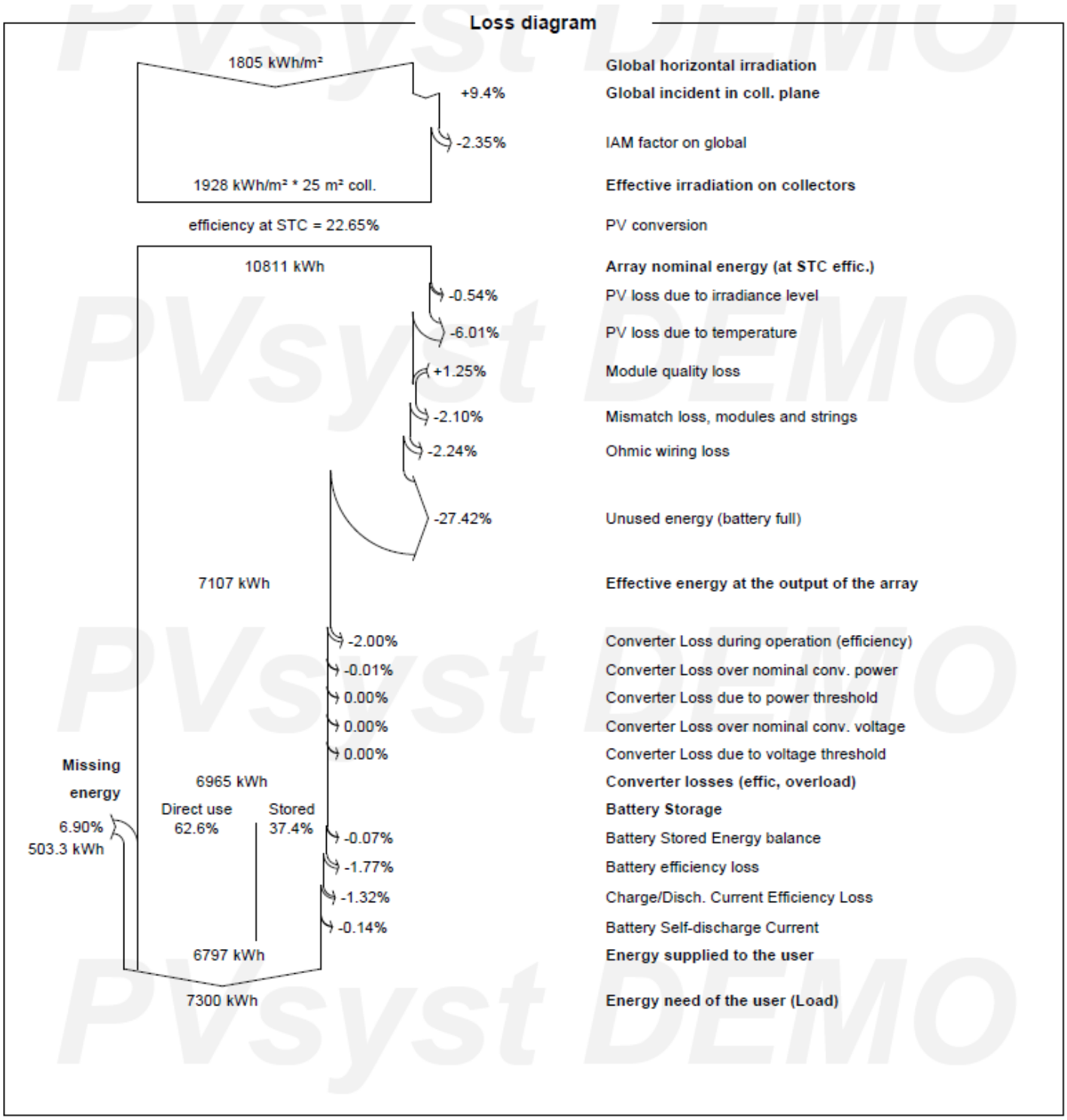


Figure 7.9: Loss diagram

8. RESULT AND CONCLUSION

8.1 PV ARRAY SIZING

Identifying the daily energy demand for the PV array is the first step in sizing it. The amount of energy needed to reach peak power in Bache is then multiplied by the typical daily solar hours. The total DC current is then calculated by dividing the peak power by the chosen system's DC voltage. Lastly, the size of the array can be found by counting how many modules are in parallel and how many are in a row.

Solar Module: (SPR-MAX3-400)

System Voltage (**Vdc**) = 48 V

Average Sun-hours for Köyceiz (**Tsh**) = 5

Daily Average Demand (**Ed**) from Table 1 = 20000 Watt-hours

Battery Efficiency (**ηb**) = 0.96

Inverter Efficiency (**ηi**) = 0.90

Charge Controller Efficiency (**ηc**) = 0.90

Required Daily Energy Demand (Erd)

$$Erd = \frac{Ed}{\eta b\ \eta i\ \eta c} \tag{8.1}$$

$$rd = \frac{20000}{0.96*0.90*0.90} \tag{8.2}$$

$$Erd = 25.720\ kWh.Day^{-1} \tag{8.3}$$

Average Peak Power ($P_{ave,\ peak}$)

$$P_{ave,peak} = \frac{Erd}{Tsh} \quad (8.4)$$

$$P_{ave,peak} = \frac{25.720}{5} \quad (8.5)$$

$$P_{ave,peak} = 5.144 \text{ kw} \quad (8.6)$$

Total DC (I_{dc})

$$I_{dc} = \frac{Pave,peak}{Vdc} \quad (8.7)$$

$$I_{dc} = \frac{5144}{48} = 107 \text{ A} \quad (8.8)$$

Number of Series Modules (N_{sm})

$$N_{sm} = \frac{Vdc}{Vrm} \quad (8.9)$$

$$N_{sm} = \frac{48}{65.8} = 0.73 = 1 \quad (8.10)$$

Number of Parallel Modules (N_{pm})

$$N_{pm} = \frac{Idc}{Irm} \quad (8.11)$$

$$N_{pm} = \frac{107}{6.17} = 17.3 = 18 \quad (8.12)$$

Total Number of Modules (N_{tm})

$$N_{tm} = N_{sm} x N_{pm} \quad (8.13)$$

$$N_{tm} = 18*1=18 \quad (8.14)$$

8.2 SIZE OF BATTERY BANK

The projected energy storage must be established initially to determine the battery bank's size. The needed battery bank's securely storing energy value is, so calculated division of the acquired energy value by the battery's permitted depth of discharge. The capacity of the whole battery bank in amp-hours is now calculated using the parameters of the specific battery to be utilized, and the number of batteries in the bank is calculated after that. Finally, the number of batteries in the bank's parallel and series branches is calculated.

Number of Days of Autonomy (Daunt) = 1 Day

Battery:, Kokum SLP120216216 module C_b=120 Ah, V_b=48 V, D_{disch}=95 %

Estimated Energy Storage (E_{est})

$E_{est} = E_d \times D_{aut}$

$E_{est} = 20000 \times 1 = 20000$ w

Safe Energy Storage (E_{safe})

$$E_{safe} = \frac{Eest}{Ddisch} \quad (8.15)$$

$$E_{safe} = \frac{20000}{0.95} = 21052.6 \text{ w} = 21 \text{ kw} \quad (8.16)$$

Total Capacity of Battery Bank (C_{tb})

$$C_{tb} = \frac{E\ safe}{V\ b} \tag{8.17}$$

$$C_{tb} = \frac{21052.6}{48} = 438 \text{ Ah} \tag{8.18}$$

Total Number of Batteries in Bank (N_{tb})

$$N_{tb} = \frac{C\ tb}{C\ b} \tag{8.19}$$

$$N_{tb} = \frac{438}{120} = 3.65 = 4 \text{ Batteries} \tag{8.20}$$

Number of Batteries in Series (N_{sb})

$$N_{sb} = \frac{Vdc}{Vb} \tag{8.21}$$

$$N_{sb} = \frac{48}{48} = 1 \text{ Battery} \tag{8.22}$$

Number of Batteries in Parallel (N_{pb})

$$N_{pb} = \frac{Nb}{Nsb} \tag{8.23}$$

$$N_{pb} = \frac{4}{1} = 4 \text{ Batteries} \tag{8.24}$$

8.3 CHARGE CONTROLLER

Calculating the needed total current that the controller must sustain is the first step in sizing an appropriate charge controller. Based on how much current is needed, the total number of charge controllers can then be worked out.

Charge Controller: TS-MPPT-45, V_{cc}= 48, I_{cc}= 45 A (dc)

Safety Factor (**Fsafe**) = 1.25

$I_{cc} = I_{sc} \times N_{pm} \times F_{safe}$

$I_{cc} = 6 \times 18 \times 1.25$

I_{cc}= 135 A

Number of Charge Controllers (N_{cc})

$N_{cc} = I_{rcc}/I_{cc} = 135/45 = 3$

8.4 COMPARISON OF THE SOLAR SYSTEM AND THE ENGINE SYSTEM

Here are some basics to compare the two systems in several respects

Table 8.1: comparisonn between solar and egine systems

Description	Engine system	Solar system
the working principle	internal combustion engines	Solar cell
weight	approx. 100 kg	approx. 550 kg
Greenhouse gases GHG	yes	no
Advantage	No need for solar light	No noise, no need to refuel, and no need for regular maintenance

Fuel need	Yes	No
Cost	The capital cost is lower than the solar power system	The capital cost is higher than the engine system
Maintenance need	Yes	No
System components	internal combustion engines	The solar cells, batteries, and charge controller

Through the table above, the comparison between the solar system and the one that operates with internal combustion engines shows that the solar systems do not have an impact on the environment, but they have high capital costs, but the maintenance cost is non-existent and does not need fuel. It is sufficient that there is sunlight in order for the boat to operate.

8.5 CONCLUSION

In this research, information is typically initially provided about the fundamental concepts of ship resistance and propulsion systems to be utilized in calculations, followed by information about the dimensional definitions and coefficients of ships with an emphasis on ship engineering. In particular, the Köyceiz Lake, which is at the confluence of the Aegean and Mediterranean Seas, is utilized by fishermen as a fishing vessel and for touristic trips for millions of domestic and international visitors. This research focuses on diesel-powered fishing boats that operate in this environment. The purpose of this study is to promote the switch from diesel engine propulsion systems, which harm the environment and threaten the survival of species, to solar electric propulsion systems for the boat classes commonly used in the area, and to demonstrate how this change also benefits boat owners financially over time. The model experiment test findings from earlier studies were employed in the study's computations. Starting with the test findings for the 10-meter-long boat, which are also presented in this thesis, the values were estimated using the similarity approach. Then, the 10-meter yacht with a service speed of 6 knots got the solar system it needed.

In the research, a solar electric propulsion system instead of a diesel engine propulsion system has been suggested as a clean power source.

A preliminary design of the electric solar propulsion system was produced for the infantry-type boats that were the subject of the research. This design provided basic information regarding the components and operating scenario of the system. The solar system to supply this electric motor has been defined; the batteries to be used in the solar system have been chosen, and the connection type of these batteries has been defined to meet the battery capacity. An electric motor providing the same power as a diesel engine has also been chosen. The power system, which comprises solar photovoltaic panels and battery storage, was sized using Posit. The boat was initially calculated for length (10 meters), beam width (2.8 meters), and speed (6 knots) to ascertain the total quantity of electrical power required. It was eventually established that a 5kW DC motor would be sufficient to drive the vessel up to 1500 rpm. A solar energy system made up of PV solar plus an It has been suggested to use a battery bank. provide the boat's whole power requirements. The simulation program Posit examines and evaluates the technical optimization of the solar system.

REFERENCES

[1] W. F. Lamb *et al.*, "de la Rue du Can," *S., Chapungu, L., Davis, SJ, Bashmakov, I., Dai, H., Dhakal, S., Tan, X., Geng, Y., Gu, B., and Minx, J.: A review of trends and drivers of greenhouse gas emissions by sector from*, 1990.

[2] A. García-Olivares, J. Solé, and O. Osychenko, "Transportation in a 100% renewable energy system," *Energy Convers Manag*, vol. 158, pp. 266–285, 2018.

[3] M. PAMIK and M. NURAN, "The historical process of the diesel electric propulsion system," *Dokuz Eylül Üniversitesi Denizcilik Fakültesi Dergisi*, vol. 13, no. 2, pp. 299–316, 2021.

[4] E. C. D. Tan and L. Tao, "Economic Analysis of Renewable Fuels for Marine Propulsion," National Renewable Energy Lab.(NREL), Golden, CO (United States), 2019.

[5] L. A. M. Z. F. Rodrigues and J. R. do Amaral, "Social tagging for e-learning: an approach based on the triplet of learners, learning objects and tags," in *International Workshop on Learning Technology for Education in Cloud; Springer: Cham, Switzerland*, 2015.

[6] D. Tamunodukobipi, N. Samson, and A. Sidum, "Design Analysis of a Lightweight Solar Powered System for Recreational Marine Craft," *World Journal of Engineering and Technology*, vol. 6, no. 02, p. 441, 2018.

[7] C. Sharma and A. Jain, "Simulink Based Multi Variable Solar Panel Modeling," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 12, no. 8, pp. 5784–5792, 2014.

[8] C. S. Postiglione, D. A. F. Collier, B. S. Dupczak, M. L. Heldwein, and A. J. Perin, "Propulsion system for an all electric passenger boat employing permanent magnet synchronous motors and modern power electronics," in *2012 Electrical Systems for Aircraft, Railway and Ship Propulsion*, 2012, pp. 1–6.

[9] S. Ahmed, A. Castellazzi, and A. Williams, "Multi-source energy networks for cargo Vessels," *Transactions on environment and electrical engineering*, vol. 1, no. 4, 2016.

[10] W. Obaid, A.-K. Hamid, and C. Ghenai, "Hybrid PEM fuel-cell-diesel-solar power system design with fuzzy battery management system and weather forecasting for electric boats," in *2018 6th International Renewable and Sustainable Energy Conference (IRSEC)*, 2018, pp. 1–7.

[11] M. Daibo, “Toroidal vector-potential transformer,” in *2017 Eleventh International Conference on Sensing Technology (ICST)*, 2017, pp. 1–4.

[12] R. D. Geertsma, R. R. Negenborn, K. Visser, and J. J. Hopman, “Design and control of hybrid power and propulsion systems for smart ships: A review of developments,” *Appl Energy*, vol. 194, pp. 30–54, 2017.

[13] G. C. D. Sousa, D. S. L. Simonetti, and E. E. C. Norena, “Efficiency optimization of a solar boat induction motor drive,” in *Conference Record of the 2000 IEEE Industry Applications Conference. Thirty-Fifth IAS Annual Meeting and World Conference on Industrial Applications of Electrical Energy (Cat. No. 00CH37129)*, 2000, vol. 3, pp. 1424–1430.

[14] H. Liu, Q. Zhang, X. Qi, Y. Han, and F. Lu, “Estimation of PV output power in moving and rocking hybrid energy marine ships,” *Appl Energy*, vol. 204, pp. 362–372, 2017.

[15] R. Leiner, “Solar radiation and water for emission-free marine mobility,” in *2014 IEEE International Energy Conference (ENERGYCON)*, 2014, pp. 1425–1428.

[16] T. Gorter, “Design considerations of a solar racing boat: propeller design parameters as a result of PV system power,” *Energy Procedia*, vol. 75, pp. 1901–1906, 2015.

[17] A. Glykas, G. Papaioannou, and S. Perissakis, “Application and cost–benefit analysis of solar hybrid power installation on merchant marine vessels,” *Ocean Engineering*, vol. 37, no. 7, pp. 592–602, 2010.

[18] C. Ghenai, M. Bettayeb, B. Brdjanin, and A. K. Hamid, “Hybrid solar PV/PEM fuel Cell/Diesel Generator power system for cruise ship: A case study in Stockholm, Sweden,” *Case Studies in Thermal Engineering*, vol. 14, p. 100497, 2019.

[19] N. A. S. Salleh, W. M. W. Muda, and S. S. Abdullah, “Feasibility study of optimization and economic analysis for grid-connected renewable energy electric boat charging station in Kuala Terengganu,” in *2015 IEEE Conference on Energy Conversion (CENCON)*, 2015, pp. 510–515.

[20] K. Mahmud, S. Morsalin, and M. I. Khan, “Design and fabrication of an automated solar boat,” *International Journal of Advanced Science and Technology*, vol. 64, pp. 31–42, 2014.

[21] K. Bradbury, L. Pratson, and D. Patiño-Echeverri, “Economic viability of energy storage systems based on price arbitrage potential in real-time US electricity markets,” *Appl Energy*, vol. 114, pp. 512–519, 2014.

[22] S. Wen *et al.*, “Optimal sizing of hybrid energy storage sub-systems in PV/diesel ship power system using frequency analysis,” *Energy*, vol. 140, pp. 198–208, 2017.

[23] S. Das, P. K. Sadhu, and S. Chakraborty, “Green sailing of solar PV powered country boat using buck-boost chopper,” in *2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT)*, 2016, pp. 1–5.

[24] K. Yigit and B. Acarkan, “A new electrical energy management approach for ships using mixed energy sources to ensure sustainable port cities,” *Sustain Cities Soc*, vol. 40, pp. 126–135, 2018.

[25] A. K. Sharma and D. P. Kothari, “Solar PV potential for passenger ferry boats in India’s National Waterways,” in *2018 2nd International Conference on Inventive Systems and Control (ICISC)*, 2018, pp. 120–130.

[26] A. Nasirudin, R.-M. Chao, and I. K. A. P. Utama, “Solar powered boat design optimization,” *Procedia Eng*, vol. 194, pp. 260–267, 2017.

[27] J. Ling-Chin and A. P. Roskilly, “Investigating the implications of a new-build hybrid power system for Roll-on/Roll-off cargo ships from a sustainability perspective–A life cycle assessment case study,” *Appl Energy*, vol. 181, pp. 416–434, 2016.

[28] N. Fonseca, T. Farias, F. Duarte, G. Gonçalves, and A. Pereira, “The Hidrocat Project–An all electric ship with photovoltaic panels and hydrogen fuel cells,” *World Electric Vehicle Journal*, vol. 3, no. 4, pp. 764–776, 2009.

[29] R. Tang, Z. Wu, and Y. Fang, “Configuration of marine photovoltaic system and its MPPT using model predictive control,” *Solar Energy*, vol. 158, pp. 995–1005, 2017.

[30] R. Tang, “Large-scale photovoltaic system on green ship and its MPPT controlling,” *Solar Energy*, vol. 157, pp. 614–628, 2017.

[31] W. Obaid, A.-K. Hamid, and C. Ghenai, “Hybrid solar/diesel power system design for electric boat with MPPT system,” *International Energy Journal*, vol. 19, no. 1, 2019.

[32] J. Campillo, J. A. Domínguez-Jimenez, and J. Cabrera, “Sustainable boat transportation throughout electrification of propulsion systems: Challenges and opportunities,” in *2019 2nd Latin American conference on intelligent transportation systems (ITS LATAM)*, 2019, pp. 1–6.

[33] B. J. Dilip, D. H. Vilas, A. V. Anil, and P. N. Jaiswal, “So traction boat inland water transportation system,” in *2016 International Conference on Energy Efficient Technologies for Sustainability (ICEETS)*, 2016, pp. 245–249.

[34] S. Babu and J. V. Jain, “On-board solar power for small-scale distant-water fishing vessels,” in *2013 IEEE Global Humanitarian Technology Conference (GHTC)*, 2013, pp. 1–4.

[35] T. B. Soeiro, T. K. Jappe, W. M. dos Santos, D. C. Martins, and M. L. Heldwein, “Propulsion and battery charging systems of an all-electric boat fully constructed with interleaved converters employing interphase transformers and Gallium Nitride (GaN) power FET semiconductors,” in *2014 IEEE Applied Power Electronics Conference and Exposition-APEC 2014*, 2014, pp. 3212–3217.

[36] F. Diab, H. Lan, and S. Ali, “Novel comparison study between the hybrid renewable energy systems on land and on ship,” *Renewable and sustainable energy reviews*, vol. 63, pp. 452–463, 2016.

[37] M. D. Margaritou and E. Tzannatos, “A multi-criteria optimization approach for solar energy and wind power technologies in shipping,” *FME Transactions*, vol. 46, no. 3, pp. 374–380, 2018.

[38] S. Reza, M. Shiblee, M. R. Mawla, J. N. Jein, and M. M. Rahman, “Design and Analysis of Solar PV System for Marine Fishing Trawlers in Bangladesh,” in *2018 4th International Conference on Electrical Engineering and Information & Communication Technology (iCEEiCT)*, 2018, pp. 677–680.

[39] C. P. Leung and K. W. E. Cheng, “Zero emission solar-powered boat development,” in *2017 7th International Conference on Power Electronics Systems and Applications-Smart Mobility, Power Transfer & Security (PESA)*, 2017, pp. 1–6.

[40] J. Hua, Y.-H. Wu, and P.-F. Jin, “Prospects for renewable energy for seaborne transportation—Taiwan example,” *Renew Energy*, vol. 33, no. 5, pp. 1056–1063, 2008.

[41] S. Chakraborty, S. M. S. Ullah, and M. A. Razzak, “Quantifying solar potential on roof surface area of fishing trawlers in Chittagong Region in Bangladesh,” in *2016 IEEE Innovative Smart Grid Technologies-Asia (ISGT-Asia)*, 2016, pp. 833–837.

[42] C. Ghenai, I. Al-Ani, F. Khalifeh, T. Alamaari, and A. K. Hamid, “Design of solar PV/fuel cell/diesel generator energy system for Dubai ferry,” in *2019 Advances in Science and Engineering Technology International Conferences (ASET)*, 2019, pp. 1–5.

[43] P. Joore and A. Wachter, “Frisian solar boat design. A multi-level innovation analysis,” in *2009 34th IEEE Photovoltaic Specialists Conference (PVSC)*, 2009, pp. 2214–2219.

[44] W. Obaid, A.-K. Hamid, and C. Ghenai, “Hybrid Power System Design for Electric Boat with Solar Irradiance Forcasting,” in *2018 6th International Renewable and Sustainable Energy Conference (IRSEC)*, 2018, pp. 1–5.

[45] R.-M. Chao, H.-K. Lin, and C.-H. Wu, “Solar-powered boat design using standalone distributed PV system,” in *2018 IEEE International Conference on Applied System Invention (ICASI)*, 2018, pp. 31–34.

[46] A. A. Khamisani, “Design methodology of off-grid PV solar powered system (A case study of solar powered bus shelter),” *Goolincoln Avenue Charleston, IL: Eastern Illinois University*, 2019.

[47] B. D. Sherman, N. K. McMillan, D. Willinger, and G. Leem, “Sustainable hydrogen production from water using tandem dye-sensitized photoelectrochemical cells,” *Nano Converg*, vol. 8, no. 1, pp. 1–15, 2021.

[48] J. Byrne *et al.*, “World solar energy review: technology, markets and policies,” *Center for Energy and Environmental Policies Report*, 2010.

[49] F. Rahman and W. Xu, *Advances in solar photovoltaic power plants*. Springer, 2016.

[50] W. P. Symington, “Modelling and solar PV contribution to marine electric propulsion,” 2019.

[51] K. H. Solangi, M. R. Islam, R. Saidur, N. A. Rahim, and H. Fayaz, “A review on global solar energy policy,” *Renewable and sustainable energy reviews*, vol. 15, no. 4, pp. 2149–2163, 2011.

[52] M. v Dambhare, B. Butey, and S. v Moharil, “Solar photovoltaic technology: A review of different types of solar cells and its future trends,” in *Journal of Physics: Conference Series*, 2021, vol. 1913, no. 1, p. 012053.

[53] L. M. Fraas, “History of Solar Cell Development,” in *Low-Cost Solar Electric Power*, Springer International Publishing, 2014, pp. 1–12. doi: 10.1007/978-3-319-07530-3_1.

[54] G. M. Reaven, “Pathophysiology of insulin resistance in human disease,” *Physiol Rev*, vol. 75, no. 3, pp. 473–486, 1995.

[55] A. A. Bayod-Rújula, “Solar photovoltaics (PV),” in *Solar Hydrogen Production*, Elsevier, 2019, pp. 237–295.

[56] M. Aghaei, S. Damanafshan, M. Abyari, M. Imamzai, M. H. Pourdadash, and Y. H. M. Thayoob, “An overview of solar cells materials classification,” in *Nat Grad 2013. Proceedings of the II National Graduate Conference*, 2014, pp. 18–19.

[57] S. H. Shah *et al.*, “Potential of microalgal biodiesel production and its sustainability perspectives in Pakistan,” *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 76–92, 2018.

[58] J. Rosales, J. Cozart, R. Charles, and T. Jimogaon, “UCF Solar Powered Beach Buggy Challenge”.

[59] G. M. Wilson *et al.*, “The 2020 photovoltaic technologies roadmap,” *J Phys D Appl Phys*, vol. 53, no. 49, p. 493001, 2020.

[60] M. G. Fikru, G. Gelles, A.-M. Ichim, and J. D. Smith, “Notes on the Economics of Residential Hybrid Energy System,” *Energies (Basel)*, vol. 12, no. 14, p. 2639, 2019.

[61] M. A. Burney, “Fishing boats of West Pakistan,” *IPFC 9 th Proc. Sect. II*, pp. 76–79, 1961.

[62] S. Ali, “From comprehensive health service provision to publisher of scholarly journal: The journey of St. Paul’s Hospital Millennium Medical college towards center of excellence”.

[63] J. F. Hansen and F. Wendt, “History and state of the art in commercial electric ship propulsion, integrated power systems, and future trends,” *Proceedings of the IEEE*, vol. 103, no. 12, pp. 2229–2242, 2015.

[64] P. Wolański, “Detonative propulsion,” *Proceedings of the combustion Institute*, vol. 34, no. 1, pp. 125–158, 2013.

[65] M. A. Burney, “Fishing boats of West Pakistan,” *IPFC 9 th Proc. Sect. II*, pp. 76–79, 1961.

[66] R. Hamlisch, “The influence of social and economic factors on technological development in the fishing sector,” *Fishing Boats of the World (3)*, pp. 33–51, 1967.

[67] “Fishingboatsofth034609Mbp.Pdf.”

[68] S. M. L. Kabir, I. Alam, M. R. Khan, M. S. Hossain, K. S. Rahman, and N. Amin, “Solar powered ferry boat for the rural area of Bangladesh,” in *2016 International Conference on Advances in Electrical, Electronic and Systems Engineering (ICAEES)*, 2016, pp. 38–42.

[69] A. Chacko and T. Hayajneh, “Security and privacy issues with IoT in healthcare,” *EAI Endorsed Trans Pervasive Health Technol*, vol. 4, no. 14, pp. e2–e2, 2018.

[70] H. A. Guda and U. O. Aliyu, “Design of a stand-alone photovoltaic system for a residence in Bauchi,” *International Journal of Engineering and Technology*, vol. 5, no. 1, pp. 34–44, 2015.

[71] “The Fishing Vessel Optimising Design and Functionality Based on Profit Optimisation of Fishery Selection, Routing and Change of Equipment Configuration,” 2020.

[72] S. M. Lutful Kabir, I. Alam, M. Rezwan Khan, M. S. Hossain, K. S. Rahman, and N. Amin, “Solar powered ferry boat for the rural area of Bangladesh,” *2016 International Conference on Advances in Electrical, Electronic and Systems Engineering, ICAEES 2016*, no. May 2018, pp. 38–42, 2017, doi: 10.1109/ICAEES.2016.7888005.