EXPERIMENTAL INVESTIGATION OF THE EFFECT OF WATER SPRAY COOLING ON THE ENERGY PERFORMANCE OF A PV MODULE WITH FINNED HEAT SINK

2023
MASTER THESIS
MECHANICAL ENGINEERING DEPARTMENT

Omar Rashid Ismael ISMAEL

Thesis Advisor
Assoc. Prof. Dr. Selcuk SELIMLI

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF WATER SPRAY COOLING ON THE ENERGY PERFORMANCE OF A PV MODULE WITH FINNED HEAT SINK

Omar Rashid Ismael ISMAEL

Thesis Advisor
Assoc. Prof. Dr. Selcuk SELIMLI

T.C.
Karabuk University
Institute of Graduate Programs
Department of Mechanical Engineering
Prepared as
Master Thesis

KARABUK
June 2023

I certify that in my opinion the thesis submitted by Omar Rashid Ismael ISMAEL titled "EXPERIMENTAL INVESTIGATION OF THE EFFECT OF WATER SPRAY COOLING ON THE ENERGY PERFORMANCE OF A PV MODULE WITH FINNED HEAT SINK" is fully adequate in scope and quality as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Selcuk SELIMLI ....
Thesis Advisor, Department of Energy Systems Engineering

This thesis is accepted by the examining committee with a unanimous vote in the Department of Mechanical Engineering as a Master of Science thesis. June 20, 2023

Examining Committee Members (Institutions)		Signature
Chairman	: Prof. Dr. Kamil ARSLAN (KBU)	....
Member	: Prof. Dr. Mustafa AKTAS (GU)	....
Member	: Assoc. Prof. Dr. Selcuk SELIMLI (KBU)	....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Prof. Dr. Muslum KUZU ....
Director of the Institute of Graduate Programs

“I declare that all the information within this thesis has been gathered and presented by academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well.”

Omar Rashid Ismael ISMAEL

ABSTRACT

M. Sc. Thesis

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF WATER SPRAY COOLING ON THE ENERGY PERFORMANCE OF A PV MODULE WITH FINNED HEAT SINK

Omar Rashid Ismael ISMAEL

Karabuk University
Institute of Graduate Programs
Mechanical Engineering Department

Thesis Advisor:
Assoc. Prof. Dr. Selcuk SELIMLI
June 2023, 89 pages

The spread of renewable energy systems in the world and the increasing demand for them, which preserves the environment and reduces carbon emissions and gases harmful to the ozone layer, motivated the subject of this study. Increase in temperature of the solar panel is one of the most important negative effects on its energy efficiency. In this thesis, two monocrystalline solar panels were cooled with aluminum fins installed on the back of them, and the cooling effect of one is enhanced by water spraying to minimize the temperature effect on the performance. The values obtained with the panel, which is called PV1, without any cooling attachment were taken as reference to evaluate the cooling effect. As a result of the experimental study conducted in Karabuk, the temperature reductions of the PV2 and PV3 panels were determined as 11% and 24%, respectively. While the electrical power production of PV1 was 30.26 W, PV2 and PV3 panels electrical power generations reached 31.63 W and 33.63 W, respectively. The efficiency of the PV2 and PV3 panels increased by 13% and 14%, respectively, compared to the PV1.

Key Words : Water spray cooling, PV module, Solar energy, Heat sink.
Science Code : 91408

ÖZET

Yüksek Lisans Tezi

SU PÜSKÜRTMELİ SOĞUTMANIN KANATLI ISI EMİCİLİ BİR PV MODÜLÜNÜN ENERJİ PERFORMANSI ÜZERİNDEKİ ETKİSİNİN DENEYSEL OLARAK İNCELENMESİ

Omar Rashid Ismael ISMAEL

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makine Mühendisliği Anabilim Dalı

Tez Danışmanı:
Doç. Dr. Selçuk SELİMLİ
Haziran 2023, 89 sayfa

Dünyada yenilenebilir enerji sistemlerinin yaygınlaşması ve çevreyi koruyan, karbon salınımını ve ozon tabakasına zararlı gazları azaltan bu sistemlere olan talebin artması bu çalışmanın konusunu motive etmiştir. Güneş panelinin sıcaklığının artması enerji verimliliği üzerindeki en önemli olumsuz etkilerden biridir. Bu tezde, iki adet monokristal güneş paneli, arkasına takılan alüminyum kanatçıklar ile soğutulmuş ve birinin soğutma etkisi, sıcaklığın performans üzerindeki etkisini en aza indirgemek için su püskürtme ile artırılmıştır. Soğutma etkisinin değerlendirilmesi için herhangi bir soğutma eklentisi olmayan PV1 olarak adlandırılan panel ile elde edilen değerler referans alınmıştır. Karabük'te yapılan deneysel çalışma sonucunda PV2 ve PV3 panellerinin sıcaklık düşüşleri sırasıyla %11 ve %24 olarak belirlenmiştir. PV1'in elektrik enerjisi üretimi 30,26 W olurken, PV2 ve PV3 panellerinin elektrik üretimi sırasıyla 31,63 W ve 33,63 W'a ulaştı. PV2 ve PV3 panellerinin verimliliği, PV1'e kıyasla sırasıyla %13 ve %14 arttı.

Anahtar Kelimeler : Su püskürtmeli soğutma, PV modülü, Güneş enerjisi, Soğutucu.

Bilim Kodu : 91408

ACKNOWLEDGMENT

Praise be to God, and prayers and peace be upon my master Muhammad, may God bless him and grant him peace. I would like to thank my supervisor **Assoc. Prof. Dr. Selcuk SELIMLI** for his great help and assistance in overcoming many difficulties that I faced. I would like to thank my teachers at the Faculty of Engineering, Karabuk University, especially the head of the Department of Mechanical Engineering, **Prof. Dr. Kamil ARSLAN**, and all my professors in the bachelor’s and master’s degrees. I would like to thank my father and mother and pray to God that they perpetuate them for me. I would like to thank my wife, children, and sisters. I would like to thank my aunt who supported me a lot and encouraged me to study. I pray for her speedy recovery, and I would like to thank Mr. Ahmed Al-Hariri, Mr. Othman Jassem Al-Nasseri, and everyone who helped me complete this research.

CONTENTS

Page

APROVAL ii

ABSTRACT iv

ÖZET vi

ACKNOWLEDGMENT viii

CONTENTS ix

LIST OF FIGURES xii

LIST OF TABLES xiv

SYMBOLS AND ABBREVIATIONS xv

PART 1 16

INTRODUCTION 16

- 1.1. A BRIEF HISTORY OF ENERGY 18
- 1.2. ANNUAL ENERGY CONSUMPTION AROUND THE WORLD 20
- 1.3. CLASSIFICATION OF ENERGY SOURCE 20
- 1.4. FOSSIL FUELS 27
- 1.5. RENEWABLE ENERGY 28
- 1.6. RENEWABLE ENERGY RESOURCES 29
- 1.7. SOLAR ENERGY 29
- 1.8. SOLAR ENERGY ADVANTAGES 31
  - 1.8.1. Renewable and Clean 31
  - 1.8.2. Without Pollution 31
  - 1.8.3. Low Maintenance Costs 32
  - 1.8.4. Reduced Cost of Paying Electricity Bills 32
  - 1.8.5. Many Possible Applications 32
  - 1.8.6. Solar Boards Can Raise Your House Price 33
  - 1.8.7. Best Solving For Far Places 33
- 1.9. SOLAR CELLS AND FACTORS AFFECTING THEIR EFFICIENCY 33

Page

1.10. CONVERTING SUNLIGHT INTO ENERGY 37
1.11. HOW PHOTOVOLTAIC CELLS WORK 38
1.12. HISTORY OF THE DISCOVERY OF ELECTRICITY FROM LIGHT 39
1.13. PHOTOCELL CLASSIFICATION 39
1.14. PHOTOVOLTAİCS SYSTEM (PV) 40
1.15 SORTS OF PV SYSTEMS 41
    1.15.1 The System Is Connected To The National Network Or On Grid Or Utility Interface (UI) 42
    1.15.2. Independent System or Off-Grid System 43
1.16. The basic components of a solar energy systemS 44
1.17. THE MAIN TYPES OF PHOTOVOLTAIC PANELS 44
    1.17.1. Crystalline Technology System 45
    1.17.2. Multi-Crystalline Silicon System 47
    1.17.3. Thin Film Technology System 47
1.18. solar panels cooling technics 49
    1.18.1. Cooling By Air 50
    1.18.2. Cooling By Liquid 51

PART 2 53
LITERATURE REVIEW 53

PART 3 63
THEORETICAL BASE OF STUDY 63

PART 4 66
METHODOLOGY 66
    4.1. CONFIGURATION AND EXPERIMENTAL MEASURING PROCEDURE. 66

PART 5 70
RESULTS AND DISCUSSION 70

Page

PART 6 78
CONCLUSION 78

PART 7 79
SUMMARY 79

REFERENCES 80
RESUME 89

LIST OF FIGURES

Page

Figure 1.1. Renewable power generation. 17

Figure 1.2. World annual energy share of fuels. 18

Figure 1.3. Global energy consumption. 20

Figure 1.4. Classification and consumption of energy in the world. 21

Figure 1.5. Renewable energy resources. 29

Figure 1.6. The number of units added from solar energy in the world, 2009-2019. 31

Figure 1.7. Sectional view of a solar cell. 34

Figure 1.8. The effect of temperature increase on photovoltaic cells. 36

Figure 1.9. Photovoltaic energy conversions. 38

Figure 1.10. The structure of an inorganic solar cell. 40

Figure 1.11. PV systems types. 42

Figure 1.12. Grid-connected PV system. 43

Figure 1.13. Simple schematic of stand-alone solar with battery storage. 43

Figure 1.14. The different components of a PV system. 44

Figure 1.15. The main types of photovoltaic panels. 45

Figure 1.16. Monocrystalline silicon cell. 46

Figure 1.17. Poly-Crystalline Silicon system. 46

Figure 1.18. Thin film solar cell. 47

Figure 1.19. Models of solar modules. 48

Figure 1.20. Solar panels refrigeration technics. 50

Figure 1.21. Cooling by air with heat sink. 51

Figure 1.22. Cooling by water spray. 52

Figure 4.1. Experiment photography. 68

Figure 5.1. Ambient temperature and solar radiation. 70

Figure 5.2. Backside of panel’s temperature. 71

Figure 5.3. Current curves. 72

Figure 5.4. Voltage curves. 73

Figure 5.5. Electric power curves. 74

Figure 5.6. Electric efficiency. 75

Page

Figure 5.7. Exergy efficiencies. 76

Figure 5.8. Irreversibility. 76

LIST OF TABLES

Page

Table 1. 1. Conversion efficiency of cell. 45

Table 4. 1. Characteristics of used solar panels 67

Table 4. 2. Technical properties for measuring devices and experiment equipment . 69

SYMBOLS AND ABBREVIATIONS

$A_{PV.area}$: PV surface area
PV : Photovoltaic panel
ΔE : Energy difference
$\dot{E}_{electrical}$: Electrical energy
E_{in} : Inlet energy
E_{out} : Outlet energy
$\eta_{electrical}$: Electrical efficiency
η_{ex} : Exergy efficiency
$\dot{E}_{solar}$: Solar power
$\Delta \dot{E}x$: Exergy difference
$\dot{E}x_{destroyed}$: Exergy destruction
$\dot{E}x_{electrical}$: Electrical exergy
$\dot{E}x_{inlet}$: Inlet exergy
$\dot{E}x_{outlet}$: Outlet exergy
$\dot{E}x_{solar}$: Solar exergy
I : Current
S : Solar radiation
$T_{environment}$: Ambient temperature
T_{sun} : Sun temperature
$T_{surface}$: PV surface temperature
V : Voltage

PART 1

INTRODUCTION

The whole world seeks to raise the usage of energy in general due to the increasing industrialization processes and the increase in population. One of the most widespread types of fuel is fossil fuels like natural gas and oil, which are main energy sources, and higher than 80% of its production shall be from the energy consumed by fossil fuels for part of the developed countries, and this will happen in 2035 [1]. Alternative, renewable and clean energy sources similar solar energy, wind energy, earth energy and thermal energy will be an ideal solution to reduce dependence on traditional energy sources, which lead to a rapid transition to global warming and gas emissions harmful to the ozone layer and the environment [2]. Mankind has historically relied on a specific energy source. The quest for a more efficient alternative source starts as a result of evolving requirements and industrial requirements that differ in terms of efficiency and cost. Coal started to replace firewood similar a source of heat and electricity at the ending of the eighteenth century. Coal was a significant and necessary energy source for manufacturing and heating at the time, especially after the invention of the steam engine. However, as industry developed, it became necessary to find a source of energy that was safer, more affordable, and cleaner. Fortunately, oil and gas were discovered and for many years served as the main energy sources. due to the effectiveness of gas and oil as well as their value as a source of energy Due to the effectiveness of gas and oil, coal is now one of the energy sources rather than the primary one it once was. It is also a good root of energy and a significant economic supplier. The hunt for a more affordable, secure, and effective energy source has not halted. The focus in recent years has been in renewable energy origins involving the wind, solar, geothermal, tidal, and nuclear energy because they are risk-free, ecologically benign, and cost-effective when compared to fossil fuels. Despite the worsening status of the world economy brought on by COVID-19, the utilization of sustainable energy sources in the power industry only rose in 2020. Figure 1.1 shows the 505 TWh it measured.[3]. The average annual percentage growth since 2010 is 20% lower than this. About a third of the growth in renewable electricity output for 2020 was due to PV and wind power, with hydropower contributing for another 25% and biofuels for the remainder. The ratio of renewable energy output in overall electricity output grew to a record gain of two percentage points in 2020 thanks to record additions of photovoltaic and wind power as well as the fall in demand for electricity whereas the financial crisis struck in 2008. The output of power from renewable sources reached its greatest level ever in the same year, with a production rate of 28.6%. Power production in 2020 was not particularly ambitious. And in order to fast achieve the level of zero emissions by 2050, there will be a rise in the deployment of renewable technology in the future years. [4].

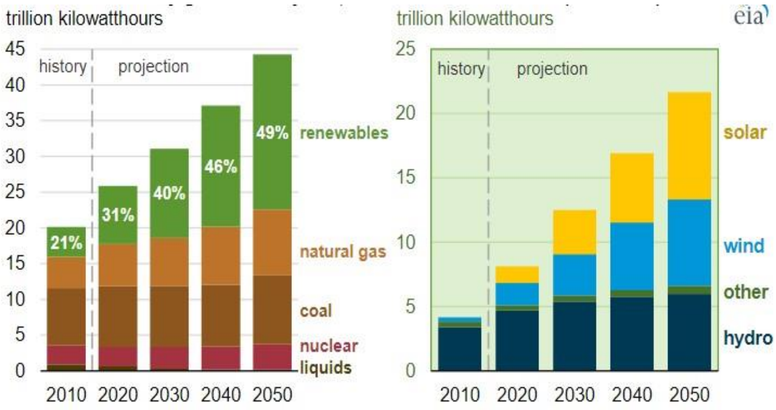


Figure 1.1. Renewable power generation [5].

Fossil fuels, mostly coal, are today's most significant global sources of energy due to the rise in global demand for energy. They have a contaminate effect on an environment because of the emission it produces and the high fields of carbon they produce in comparison to renewable energy sources. These sources were also thought to be a contributing factor in climate change, which is characterized by rising sea levels due to global calefactory and acidic rain from burning coal and fossil fuels. As a result, focus is now on renewable energy sources. Because it is safe, eco-friendly, sustainable, and clean, renewable energies have become essential for each world and the climate. Tidal, solar, wind, geothermal, biomass, hydraulic, etc. are a few examples. wind, geothermal, solar, and hydropower have been evaluated to account for 28.6% of the world's total energy market's production, according to Figure 1.2, which depicts the sources of the world's electricity.

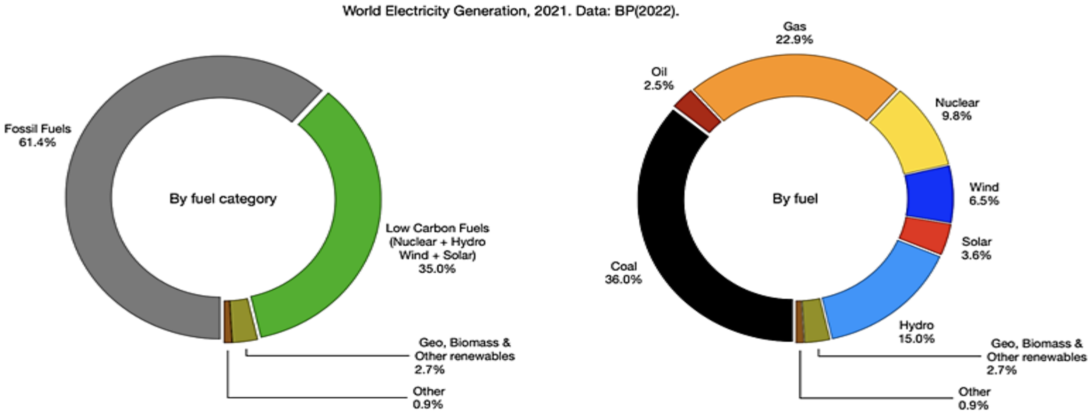


Figure 1.2. World yearly energy portion of fuels [6].

According to the survey, Turkey's rates of solar and wind energy production have been increasing. Data that can be verified demonstrates Turkey's advantage in renewable energy from 2014 and shows that this year, solar energy making amounted to 17 GWh, and that number climbed to 28,289 GWh in 2017. Additionally, it got to 112.65 GWh in 2020 [3]. The goal of all industrialized nations, including Turkey, is to switch to 100% renewable energy roots for all needs. But getting rid of the fuel that is currently being used in many industries, on the ground, and in the air constitutes a significant problem. Despite this, most legislators, with the exception of those involved in the heating, cooling, and transportation sectors, persist on promoting the idea of energy generation using renewable energy. [7].

1.1. A BRIEF HISTORY OF ENERGY

The series of shifts in the use of different fuels can be considered the main idea of history, as Buñuel and Frisoz point out that The word "energy transition" has become popular seventies of the last century when policymakers and researchers in research centre’s abolished the catastrophic energy crisis [8]. The German sociologist Werner Sombart, Der Moderne Kapitalismus. Between the years 1927 and 1902 of the German Historical School, where he showed how the continent of Europe in the sixteenth century faced limits to the growth of trees, which led to the depletion of forests in the aforementioned continent and the decrease in the general stock of the continent of wood due to the new industries that eliminate wood, including the glass industry.[9]. As an alternative to suffocating industry, solar energy provided new and innovative means to reduce the use of coal, as the world began producing and industrializing coal and unleashing new energies for steam, electricity, and chemistry, and opening the way for Europe to advance the industry with an unprecedented force in history [9]. At the beginning of the 20th century, long before the term “energy transfer” login to political books, the chemical changes that formed from adding energy to a substance, like molecular disintegration, were mentioned [10]. In some special cases, the moving in was used to characterization the change from one type of fuel to other, with recognition of the interchangeability of forces [11]. But the usage of the word transition to explain the shift in the prevailing and vital pillar in the world became clear for the first time in the developmental and demographic literature in the fifties of the last century in North America. And as a judicial political order, we found the term the most influential, and after three decades, in America, US President Jimmy Carter said in 1977 in a televised speech, “There has been a shift in the way public use energy twice in the past hundreds of years” from wood to charcoal and then from charcoal to charcoal. Oil is the thing that produces a shortage in supply and prompted a third change to renewable energies [12]. Historians discuss the shifts between fuels for all historical periods are mere ideas and research has shown the accumulation and continuity of technologies and fuels over time [13]. Moreover, energy historians have shown how they considered energy to be conditional rather than date specific. Now, with climate change and the new environmental determinism in part of the circles, those who oversimplify the dynamics of energy transition and over-diagnose them as determinants of climate consider a similar danger, as in the words of geographer Mike Holme. Such as grab energy of the matrix of interdependence that represents human life [11].

1.2. ANNUAL ENERGY CONSUMPTION AROUND THE WORLD

Energy consumption in the world has increased by a third, and this consumption has increased since the year 2000 only, and the increase will likely continue in the coming future. The global need for energy increased by 2.9% in the year 2018, according to the business-as-usual scenario, and when we reach the year 2040, global consuming Will become 740 million Terajoules, which is equal to an extra increase of 30% from 2000 to 2040. This will result in an expansion of the ratio to 77% in global energy consumption. During the years from 1980 to 2050, global energy use can increase approximately three times from 300 to 900 terajoules, and as in Figure 1.3 [14].

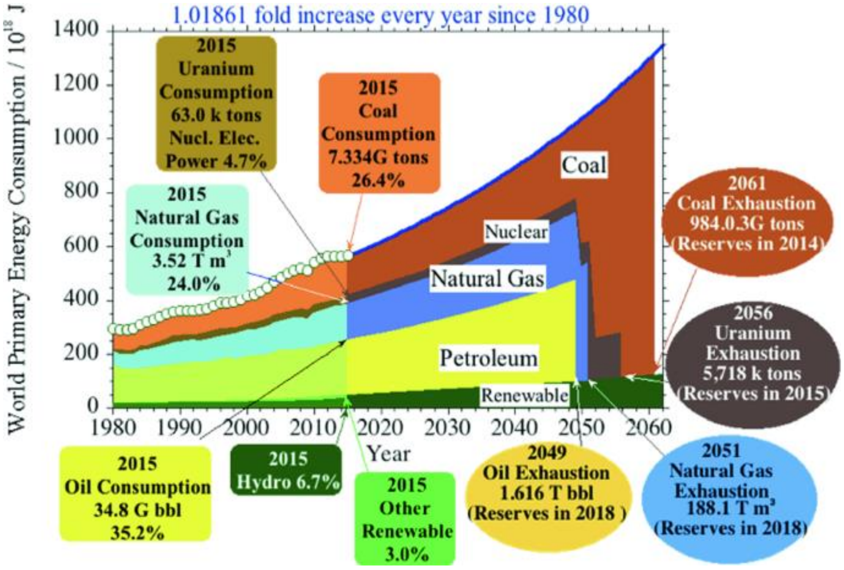


Figure 1.3. Global energy consumption [15].

1.3. CLASSIFICATION OF ENERGY SOURCE

There are several kinds of energy some of these fossil and others renewable energy [16]:

1. Petroleum.
2. Coal.
3. Natural gas.

4. Hydroelectricity.
5. Nuclear electricity.
6. Geothermal.
7. Wind.
8. Biomass.
9. Solar.

as in fig 1.4 we can see the classification of fuel source energy in the world.

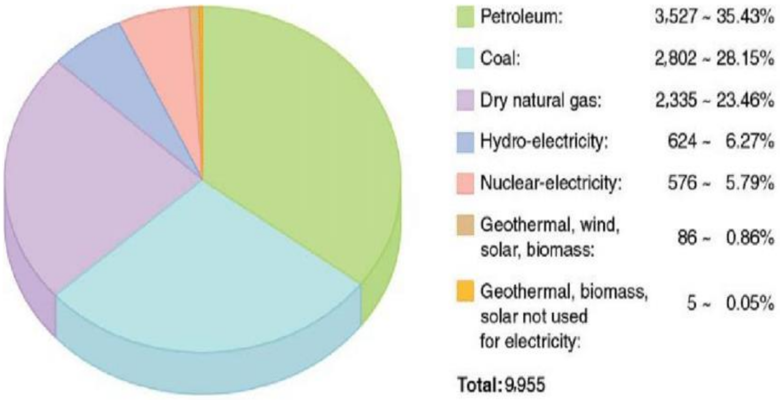


Figure 1.4. Classification of source of energy in the world [17].

1.3.1. PETROLEUM

Crude oil or called petroleum fossil fuel is known as a mixture of hydrocarbon materials that originated of the remains of dead plants and animals that lived millions of years ago in the marine environment, and up millions of years these remains of plants and animals were flooded and covered with silt, rocks and sand, then heat and pressure transformed them into these Layers to petroleum or crude oil, and the meaning of the word petroleum is oil from the ground or shale oil. We can find hydrocarbons and crude oil in its liquid state or in its gaseous state in reservoirs or basins under the ground and inside sedimentary rocks in small areas or near the surface of the earth in tar sands. As for petroleum products, they are products made from crude oil or hydrocarbons that are available in natural gas. Petroleum products can be developed from natural gas, biomass, and coal. After the crude oil is extracted from the ground, it is transferred to the oil refineries, where different materials are separated from the crude oil and converted into useful petroleum products that can be used, such as diesel fuel, gasoline, jet fuel, asphalt, lubricating oils, and some other petrochemical materials[18].

1.3.2. COAL

The formation of coal takes millions of years, and coal is black sedimentary rocks or black, brown combustible consisting of high proportions or quantities of hydrocarbons and carbon. Millions of cinquefoils in swamps and forests. Where layers of rocks and dirt covered these plants, and with the help of heat and pressure, these plants turned into charcoal. There are four main types of coal, which are subbituminous coal, anthracite, lignite, and bitumen, and each of them contains different amounts of carbon and the amount of thermal energy that can be produced from burning coal. The rank of coal deposits depends on the amount of heat and pressure that plants have been exposed to over time[18].

1.3.3. NATURAL GAS

As for natural gas, it is also one of the sources of non-renewable energy and among the types of fossil fuels, as it consists of a lot of various compounds, but methane is the largest component of it, and it is a compound in which a carbon atom is linked with four hydrogen atoms, and natural gas also contains small quantities of natural gas liquids They are hydrocarbon vapor liquids and water vapor. Natural vapor is used to make materials and chemicals, as well as fuel. Millions of years ago, or hundreds of millions of years ago, the residue of animal’s plants and plants accumulated in layers on the surface of the earth and in the floors of the ocean with sand, calcium carbonate, and silt. To turn it into oil, i.e., petroleum, and some of it turned into natural gas. In many places, natural gas is collected in large cracks and large spaces under rocks and underground. This type is known as traditional natural gas. In other places, natural gas is found in small pores inside sandstone or oil shale and some sedimentary rocks. This type is known as shale gas or unconventional natural gas. There is natural gas with crude oil also in some places. This type is known as associated natural gas. There are also deposits of gas. It is natural on land

and in the depths of the seas and oceans away from the shore, and it can be found in coal deposits and is known as coal bed methane. The process of finding natural gas begins with scientists who study the formation of the earth, where they identify the types and forms of geological formations on which natural gas deposits are likely to exist. Geologists usually use seismic surveys in the ocean and on land in order to find the right place to drill oil and natural gas wells, and at other times a small number of explosives is used to create sound waves to know the geological nature under the ocean floor. And if these results of the surveys show that it is possible to have natural gas in this area, then an exploration well is drilled and verified. And if the results of the test well are good and the place has a good amount of natural gas, which makes a good profit, other wells are drilled for production, and natural gas wells are drilled horizontally or vertically in places where natural gas is located, and the gas flow is generally through the wells to the surface easily[18].

1.3.4. HYDRO-ELECTRICITY

Since water is the source of hydroelectric power, hydroelectric power abilities are typically built on close to a water source. The quantity of energy that is accessible in moving water depends on the volume of the water flow and the elevation change, also known as head or fall. A hydropower plant can effect more energy the better the head and the large the water stream. In hydropower plants, water go via a pipe called a penstock, pressing against and rotating turbine fins to drive a generator and create energy. Traditional hydroelectric devices consist of: run-of-the- stream systems, in which a turbine is pressed against by the force of the river's stream. weir in the water class may be present at the facilities to direct water stream to a hydro turbine. Systems that store water in reservoirs built by damming rivers and streams, then release it via hydro turbines like needed to produce energy. Lots of hydropower plants in the US have dams and storage reservoirs. Water is pay from a water source over to a storage container at higher elevation in paid-storage hydropower plants, a form of hydroelectric container system. Hydro turbines below the upper reservoir are powered by the water that is released from it. Typically, water is pumped into storage during periods of low energy demand and production price, or when wholesale power cost is few, and then released to produce electricity during periods of high electricity demand. In general, paid- store hydroelectric systems utilize more electricity to pay water to the top tank for storage than the stored water itself can generate. In light of this, pay-storage equipment have net negative equals for power generation.[18].

1.3.5. NUCLEAR ELECTRICITY

The minuscule combinations of the molecules that combinations gases, liquids, and solids are known atoms. Protons, neutrons, and electrons are the three bits that make up an atom. Protons and neutrons concoct the nucleus (or core) of an atom, which is belted as electrons. Electrons have a passive electrical charge, while proton has a positive charge. There is no electrical price on a neutron. The connections keeping the nucleus together include enormous energy. These links can be broken, while shall release the nuclear energy. Nuclear division can break the bonds, and an outcome energy can be utilised to make (generate) electricity. Atoms split apart via nuclear fission, that releases energy. Nuclear division is used by most nuclear power plants, and uranium atoms are normally used on nuclear power plants. the neutron splits a uranium atom while it interacts with it via nuclear fission, liberation a significant quantity of energy on the form of hight heat and radiation. When a uranium atom parts, additional neutrons are too released. The process saves repeating again like these neutrons save crashing into more uranium atoms. Nuclear chain actions are what this process is called as. In nuclear power ingrain reactors, this action is regulated to make the desired quantity of heat. Nuclear fusibility, in which atoms combine or fuse to form a hight atom, is another process this can release nuclear energy. Energy on the sun and stars happen from fusion. Research into utilize nuclear fusion as a root of energy for making heat and power is even ongoing, though it is unclear calamite this technology will be trading feasible due to the problems of managing fusion process. The fuel this nuclear power plants greatest frequently use of nuclear fission is uranium. until though uranium is a normal metal found in rocks all up the world, it is consideration as a non-renewable energy source. Cause the atoms of a particular kind of uranium, known as U-235, are simple to disconnect, nuclear power plants utilize it as fuel. U-235 is a very rare isotope of uranium, while being about 100 times higher frequent than silver[18].

1.3.6. GEOTHERMAL

Heat from the earth is called as geothermal energy. The Greek utterance geo (earth) and theme (heat) are the radix of the term geothermal. Due to the continuing production of heat deep in the ground, geothermal energy is a renewable energy origin. Geothermal energy is utilized by people to make power, heat structure, and take baths.

Geothermal energy is made by the slow dissolution of radioactive particles in the planet's core, a process that action in all rocks. Geothermal energy is built deep with the earth. There are four main sheets or portions of the earth: A solid iron inside core that is almost 1,500 kilometres in ocean a 1,500-mile-thick outside core of hot, molten rock known as magma. An 1,800-mile-thick mantle of rock and magma surrounds the outside core. a solid stone crust between 15 and 35 miles thick that overlay the continents and ocean floors, and between 3 and 5 miles thick elsewhere. Scientists have found that an interior core of the planet is about 10,800 degrees Fahrenheit (°F) hotter than the sun's surface. Near the boundary between the mantle crust and core, the temperature in the mantle ranges from about 392°F to about 7,230°F. Magma that is underground take heat via rocks and water. The warmest stones and water are those are placed deeper underground. The tectonic plates that make up the earth's crust are divided into parts. Near the borders of these plates, magma is near the earth's surface and can travel through plate gaps to the surface. The location of volcanoes. Lava is the name for magma that has reached the earth's surface.[18].

1.3.7. WIND

The uneven heating of the earth's face by the sun is what makes wind. The various kinds of land and water that make up the earth's face cause it to absorb the sun's heat at different rates. The daily wind cycle is single illustration of this inequitable heating. Air over land warms up more quickly via the day than air up water. Wind is produced when warm air up land expands and increase and then rushes in to change it with heavier, cooler air. Due to air cools more quickly up land than it does up sea, the winds change at night. Like how the land with the equator is hotter than the land at the North Pole and South Pole, so are the atmospheric winds that circle the planet. Generating electricity with wind energy. Today, electricity is base produced via wind energy. Some still function on ranches and farms in the United States where water-pumping windmills were previously widely used to provide water for cattle.[18].

1.3.8. BIOMASS

Renewable organic material from animals and plants is called as biomass. Biomass is a popular fuel in some nations, particularly for cooking and heating in underdeveloped nations. In some industrialized nations, the utilize of biomass fuels for electricity transportation and production is increasing to decrease carbon dioxide emissions from burning fossil fuels. Solar chemical energy is saved in biomass. Biomass is made by plants via photosynthesis. Direct combustion of biomass for heating is also an option, like are different processes that turn it into sustainable gaseous fuels and liquid. Energy from biomass sources cantina Firewood, wood chips, and wood pellets are examples of wood waste. Lumber and furniture mills so produce wood. black liquor, trash, and sawdust from pulp and paper mills. Corn, soybeans, sugar cane, switchgrass, woody plants, agricultural, algae, and food processing leftovers from agriculture are utilized primarily to create biofuels. Paper, cotton, and wool goods as well as food, wood and yard, wastes contain biological equipment in municipal solid waste. To making biogas or renewable natural gas, utilize human and animal waste. Various procedures, like the following, are utilized to turn biomass into energy: Using thermochemistry, fuels can be made that are solid, gaseous, and liquid. Liquid fuels are output chemically. Liquid and gaseous fuels are output by biological conversion. The generality popular technique for transforming biomass into useable energy is direct burning. To heating structures and water, providing operations heat for industry, and create power in steam turbines, each biomass can be burned directly. Gasification and Pyrolysis are second examples of biomass conversion by thermochemistry. together thermal decomposition make include heating biomass feedstock materials to peak temperatures in sealed, pressure tanks called as gasifiers. The key variance between them are the conversion operations temperatures and how much oxygen is present. Pyrolysis is the operations of heating organic molecules to (800-900) *F* (400–500 °C) in a nearly oxygen-free environment. Fuels contained charcoal, bio-oil, methane, sustainable diesel, and hydrogen are produced via the pyrolysis of biomass. To make renewable diesel, renewable jet fuel, and renewable gasoline, bio-oil (make by fast pyrolysis) is processed with hydrogen at peak temperatures and pressures in the presence of a catalyst. To make synthesis gas, also called as syngas, organic materials should be heated to temperatures between (1,400-1,700) °F. Controlled amounts of free oxygen and steam are so injected in the vessel via gasification. Syngas is a fuel that can be utilized for gas turbines that supply electricity, heating, and diesel engines. The hydrogen can then be burned or used in fuel cells after being processed to separate it from the fluid. The Fischer-Tropsch process can be utilized to further process the syngas to make liquid fuels. Vegetable oils, animal fats, and greases are transformed chemically in FAME, which are utilized to make biodiesel, via the transesterification process. Anaerobic digestion makes sustainable natural gas from biomass, and fermentation turns biomass in ethanol. cars run on ethanol as fuel. Anaerobic digesters at sewage processing facilities, dairy and animal work, and other places produce renewable natural gas, often called as biogas or biomethane. Landfills for solid waste are another location where it can form and be collected. Natural gas from renewable sources can be utilized in the same roads as natural gas from fossil fuels. Researchers are examining roads to improve these processes and make new strategies for changing and utilizing more biomass for energy [18].

1.4. FOSSIL FUELS

There are great pressures on the possibility of development and expansion of industry on the ground, and the most important of these pressures is the increase people and expansion of economic events, as well as the expansion of demand for clean water, energy, housing, and Environmental pollution formed from use of resources. The expansion of the need for these riches is supported not only by the increase in peoples but also by the need to raise the level of living of the population. Generally, this improvement in the level of living requests an expansion in the use of energy for everyone. These two things result a doubling of the increase in the need for resources and the output of dangerous contaminates. The energy used in fixed applications and means of transportation is all from fossil fuels, as it is produced

Burning this fuel leads to massive growth in the economy, expansion of production, and an increase in the standard of living per capita in most regions of the world during the past century, but it is not continuous. Burning fossil fuels results in health problems, environmental pollution, and deterioration. These resources are of limited quantities and are non-renewable for most countries, which do not have quantities of them. The long-term need and demand for fossil fuels will not be provided by this fuel Sustainable and renewable can be an alternative, but it is far from the competition with fossil fuels in terms of production capacity and cost. There are harmful emissions to the environment, humans, all creatures, and our planet with a negative impact on us outcome from burn of fossil fuels. In 1995, the total emissions of all countries of the world were 22.19 billion metric tons of Carbon dioxide gas, 852 million metric tons of carbon monoxide, 99.27 million metric tons of nitrogen oxides, and 141.9 million metric tons of sulphur dioxide [19]. These values will rise every year, and this increase will fast with the expansion and increase of countries with growth economies and some countries with big people like China and India. The amounts of carbon dioxide will be around 370 parts per million in the atmosphere now, at their maximum standard in 420,000 years. Carbon dioxide now is 18% more than the amount it was in 1960 and is estimated to be 31% more than the amount it was at the beginning of the industrial revolution in Europe in 1750 [20]. Historical studies have shown that there is a very strong relationship between air temperature and levels of carbon dioxide gas in the climate, which is called the phenomenon of global warming, which is the increase in temperature, and the results and effects of this phenomenon so far are not known even if there are expectations and scenarios that indicate It leads to dire consequences. Among these injurious effects on the climate and living creatures beings are the loss of biodiversity, the increase in sea level, the spread of drought, the increase in diseases, the change in weather patterns, the frequency of floods, changes in the quantities of fresh water, and the abundance of extreme weather phenomena [21].

1.5. RENEWABLE ENERGY

Renewable sources of energy are defined as sources that can renew and can provide energy for all uses and for an indefinite or endless time. Among the types of this energy are wind, solar, tidal, geothermal, waves, water, biomass, and others., and consist of [22]:

1. Geothermal energy.
2. Wind energy.
3. Solar energy.

1.6. RENEWABLE ENERGY RESOURCES

One of most gains of renewable and unfinished Energy References is that they don't give out while used in power obstetrics. Renewable energy sources can be comprised in the following Figure 1.5:

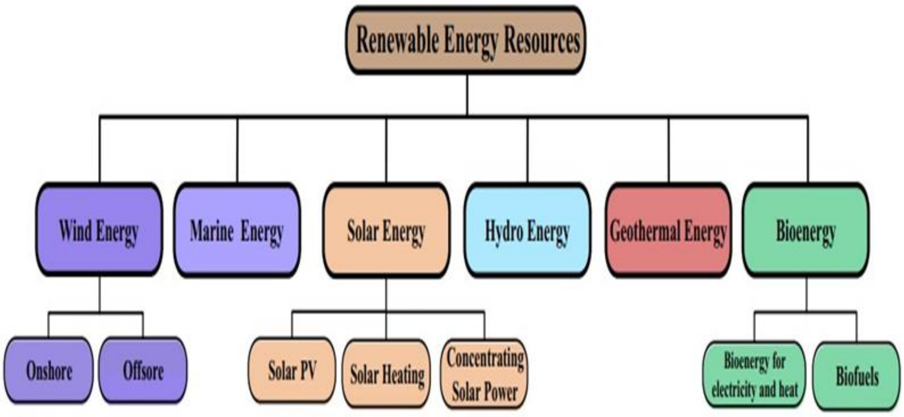


Figure 1.5. Renewable energy sources [23].

1.7. SOLAR ENERGY

Solar ray energy is the best important sources of our expected energy. It is one of the renewable energies that will reduce reliance on traditional types of energy like fossil fuels, uranium, etc. In addition, the energy of solar radiation is omnipresent, as no political cartel can manipulate and assert its hegemony over it. The sun's energy is called a free resource and does not cause any environmental pollution associated with the use of this energy which makes their great doubts about the use of fossil and nuclear fuels in the future. Solar energy is more suitable for small-scale decentralized applications and can be used on a larger scale. In some developing countries, a mediator is needed on a larger scale. Solar energy is provided, and it is a major alternative to energy in far places where there is no power at all. It is simply adaptable to needs and locations. In some locations, it is not always possible to rely on fossil fuels because of the distance and transportation that bring fuel to the user, knowing that solar energy has not developed much despite its great attraction, and one of the reasons for this problem is the inconstant and change nature of solar energy. Solar radiation, but sometimes during the middle of the day solar radiation reaches very high numbers, but at night it decreases to zero. Weather, such as dust, fog, and clouds, may adversely affect the amount of radiation that reaches Earth. The reason requires expensive equipment, we must use capacitors to convert solar radiation energy into mechanical energy, and we also need a storage method for this energy, such as batteries, which are also very expensive. One of the best characteristics of solar energy systems is that it has a high initial cost and a low cost for operation and maintenance over time and their income is free once the installation, connection, and operation are completed, and thus this energy is formed with a high initial cost and a low operating cost relative to the traditional energy systems, which distinguished traditional fossil fuels and caused the uneconomical energy solar. This balance has begun to change rapidly in the past five years, with increasing importance given to solar energy resources. The industrialized countries and the international community began to be increasingly concerned about their dependence on available and low-cost fossil fuels, mostly imported or coming from other countries or foreign sources, as people began to realize the lack and limitations of fossil fuels and its reserves, especially shortly and the decline in its production [21]. Some suggested that the final solution to the problems of the nation's growing energy needs, the very high cost of nuclear fuel, and pollution problems led to a reduction in its use on a large scale. Public dissatisfaction with the increasing cost of non-renewable and conventional energy resulted in a reconsideration of the sums we spend on energy, and for this reason, it has been solar energy was the one with the most interest and turned to it faster to be a future alternative to traditional energy and possessed economic attractiveness to people and is not harmful to the environment [24]. As we can see in figure 1.6, the amount of units compiled in the world increased from 2009 to 2019 [25].

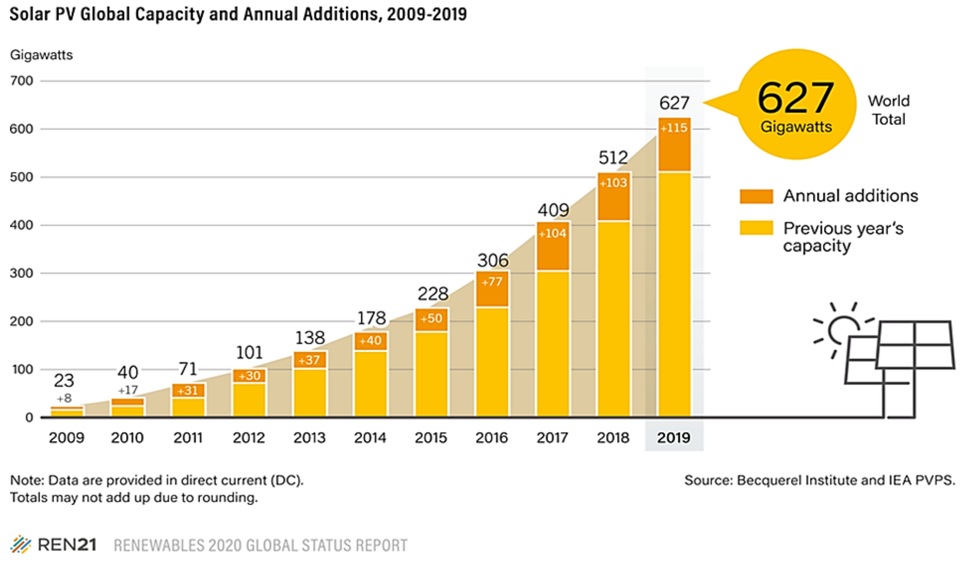


Figure 1.6. The amount of units compiled from solar energy in the world, 2009-2019 [26].

1.8. SOLAR ENERGY ADVANTAGES

Here we must point out and show the benefits of solar energy, which are:

1.8.1. Renewable and Clean

The best positive and important benefits of using the energy of solar radiation is that it is renewable and clean, and thus we make sure that it will not be regulated in any way, it is present daily, and that the sunrise and sunset are foregone and constant, which makes solar energy highly reliable and continues as God wills, even in days Those that contain clouds will be present, but with a lower density [27].

1.8.2. Without Pollution

The fact that solar is an immaculate energy, as it is not producing any deleterious waste and is environmentally friendly and does not cause any pollution to it in any way when compared with other energy sources such as fuel and fossils, as carbon emissions are at low levels released from sunlight, which is a great benefit to the environment. The sun is a massive and sustainable resource for generating electricity with no greenhouse emissions and no toxic pollution [27].

1.8.3. Low Maintenance Costs

Solar energy and the panels used to generate electricity do not require much maintenance and often need to be kept immaculate and free of trash and dust to operate efficiently. And most of the companies that produce the panels give a guarantee of about 10 years, meaning that the panels do not break down easily. As for the inverter, you have to take care of it and perhaps replace it after five or ten years [27].

1.8.4. Reduced Cost of Paying Electricity Bills

Most of the lighting of the houses is sufficient for its operation by solar energy, and it is also available to use solar in other things in the house such as heating, cooking, etc. This assists us in remission the price of the bills that we pay, which are high and exorbitant, and when we use solar energy, we can control the use of electricity and energy. solar boards are a free source of energy. As for the cost of installing solar panels, they are somewhat expensive, but when you complete their installation, you will not pay money or pay very little money for cleaning. If you use energy that depends on regular electricity, you must pay a lot of additional amounts to pay your bills every month. Electricity [27].

1.8.5. Many Possible Applications

Regardless of the use of energy for any household purposes and lighting, the energy of the sun is very important in many fields. We can supply villages and communities with energy, as well as small cities. Among the benefits of solar energy, it can be used in several areas such as cars, spacecraft, and aircraft, and it can also be relied upon in places In which there is no national electricity network, such as distilling water on the continent of Africa, and in space, such as satellites [27].

1.8.6. Solar Boards Can Raise Your House Price

Among the benefits of solar panels, the value of your house increases in the event of selling it or renting it if you put solar panels on it. You can also add the price of inauguration of the panels to the cost of the house. Thus, you will not lose the price of installing the panels if you calculate it within the value of the house in the event of selling it, and this is one of the reasons that prevent us from installing solar panels Because it increases the cost of building a house [27].

1.8.7. Best Solving for Far Places

The best largest and widest sources of energy is solar energy in places far from cities and villages that do not connect cables supplying electric energy or operating it is very expensive. It continues, but it is better than its absence in such places, and it is a reality that exists in some remote areas, so the sun's energy is the best and best solution for them [27].

1.9. SOLAR CELLS AND FACTORS AFFECTING THEIR EFFICIENCY

When the generation of electrical energy of light arose, this the opening of relying on solar cells to generate electricity [28], and the solar cell is the last part that is affected or responds to the light falling on it and turns it into electrical energy where the solar radiation activates the electrons in the cells to make electricity and affects the efficiency of a cell two main things:

1. Transformation efficiency inside the cells.
2. The Possibility of the cell absorbing photons.

Photovoltaic cells contain silicon and germanium, that considered semiconductors. a solar energy transmission process in a solar cell is clarified in Figure 1.7.

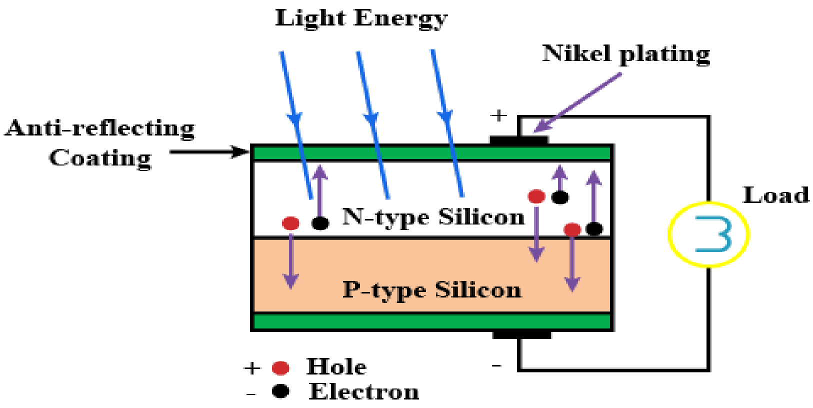


Figure 1.7. Sectional vision of a solar cell [29].

Electricity is generated from the solar cell after the cell converts sunlight, and its function is to capture the largest possible amount of sunlight. This is by eliciting voltage near the tip of the photovoltaic cell whenever the cells are exposed to sunlight. The cells contain semiconducting materials that form the cell and capture the incident light. At this time, the photons of light catalyse the electrons to move them from a place of least energy to a place of higher energy, and by this, we obtain an electric current from the solar cells, and this process is called the photovoltaic effect [30]. Most cells are created of silicon, either one crystal or several crystals, or they are amorphous. Thin slices are treated with thicknesses or layers that do not exceed a few millimetres in thickness and are fixed behind the glass and fixed tightly with a flexible polymer material and collected in frames of solar panels. The factory cells are of two main types:

1. Cells made from silicon wafers or silicon tapes are known as wafers.
2. Cells that are directly deposited in thin films are known as thin membrane cells.

It is possible to connect several panels in a group to form a series of units for some meters. The flat panel is fixed with a certain angle and connected to a device that tracks the sun for the cells to take in the largest amount of sunlight and for the cells to obtain a greater electrical current. As for the panels with thin films, they are placed on the ceiling, or the tiles used in the ceilings or the facade of the building. The solar cell usually contains of very thin sheets of semiconductor materials such as silicon and then deformed with other elements such as boron or phosphorous on its surface. And the benefit of these added elements is considered an activator within the chemical structure of the silicon element. Inside the solar cell, there are two thin layers of dissimilar semiconducting materials. The solar cell consists of: The A layer is a type that consists of semiconductors and phosphorous atoms, which give an overabundant of free electrons with negative electric lading. Type B layer, which contains semiconductors and boron atoms, leads to a shortage of electrons, which gives the positive charge to this layer, and fact that the carriers are near the B-N junction, where they are detached and swept far to the opposite finish of the chip and are on the surface, and they can be compile to the external stopping place of the ornament. It is possible to connect several panels in a group to form a series of units for some meters. The panel is fixed at a certain angle and connected to a device that tracks the sun for the cells to take in the largest amount of sunlight and for the cells to obtain a greater electrical current. As for the panels with thin films, they are placed on the ceiling, or the tiles used in the ceilings or the facade of the building. The solar cell usually contains of very thin sheets of semiconductor materials such as silicon and then deformed with other elements like boron or phosphorous on its surface. And the benefit of these added elements is considered an activator within the chemical structure of the silicon element. Inside the solar cell, there are two thin layers of dissimilar semiconducting materials. The solar cell consists of:

1. The N-layer type consists of semiconductors and phosphorous atoms, which give a huge number of free electrons near negative electric charges.
2. Type P-layer, which contains semiconductors and boron atoms, leads to a shortage of electrons, which gives the positive charge to this layer.

And fact that the carriers are near the P-N junction, where they are unattached and swept away to the opposite finish of the chip and are on the surface, and they can be compile to the external stopping place of the cell [31]. The effective conversion of light emitted from the sun in a current is the measure that determines the solar cell efficiency, expressed as under 30% of the upper power, which is the under solar cell efficiency ideal in situations. lots of sunlight collapse on the cell, where part of it is converted into heat, part of it is mirrored and the other part is sucked by the material constituting the cell, as the standard cell efficiency is 15%, and the diversion efficiency of the cells can stretch 18% for the commercial single crystal cell. Crystallinity is about 14%. The process of converting incident light on cells, i.e., photoelectric diversion, depends on several determinants, which as the intensity of glowing affects the numeral of excited electrons, i.e., the intensity from current. The photoelectric effect can't be below the sill voltage where the value corresponding to a radiation frequency is the frequency function. In the case of a voltage, the limit value corresponding to the amplitude frequency is, and the performance and doing of the cells gradually diminution with the raise in the heat of the cells, as in the Figure 1.8 [31].

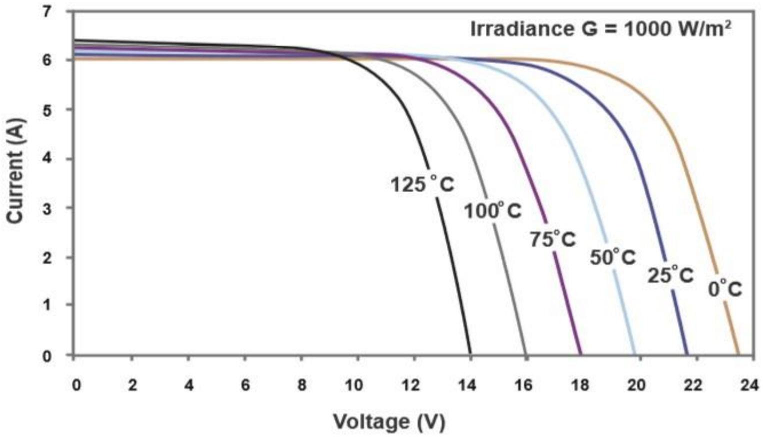


Figure 1.8. The action of temperature growing on photovoltaic cells [32].

In brief, If the cell operates at a radiation rate of (0.8 kW / m^2), then the spectral allocation is 1.5 AM, the temperature of the place is 20°C, and the wind is at a speed of (> 1 m/s), where the normal running temperature of the cell becomes the running temperature of the cell and the electricity produced decreases When the temperature exceeds 25°C.

$$T_c = T_a + [NOCT - 200.8 \times S] \tag{1.1}$$

Where $T_a$and T_c are the ambient temperature and cell temperature one by one in °C and S is the solar radiating in kW/m^2 [28]. Solar radiation that reaches our planet fills the world's need to operate energy. 0.5-0.6 V is the result of a onece solar cell, and this is a small voltage that a few electrical devices operate on. Therefore, some solar cells are connected to growth the voltage. The electrical unit is connected to 12 V battery to enable some units to work. Therefore, the batteries work to fill the deficiency that occurs at night or at night. Non-standard cases or they are charged during the cell reaching the overvoltage stage. To make the process more reliable and better, approximately 33-36 groups of solar cells are parallel connected Solar cells are parallel joint and series to get a high voltage and to get this needed voltage from the voltage and current. The modules are connected alternately in a parallel group and these groups are called modules as shown in Figure 1.9 [28].

1.10. CONVERTING SUNLIGHT INTO ENERGY

Solar energy is transformed into electricity by solar cells, where the sun's heat is estimated at 6000°C, because of the high temperatures and the combustion of it forms hot gases, and because of these gases, different spectrums of sunlight are sent, such as ultraviolet and infrared rays, and the light is waves, as is known by quantum theory as a result of for a certain basic The interaction of material with light, the phenomenon is known as Wave coupled to a non-heavy particle contains energy that is the basis for groups of photons. Photon energy amount (HV) range from 3.5 eV (ultraviolet region) to 0.5 eV (infrared region). The visible area is ordered of 3.0 V (purple) to 1.8 V (red). The Sun's maximum amount are in a yellow area of the visible region at about 2.5 V. The top of the Sun's power take place in the yellow area of the vision area, at about 2.5 eV. At midday and on a pure day, 1000 watts of the sun's energy falls to the ground per meter square (1 kW/m^2) Photovoltaics include light absorbers to some extent. The lower bound for the absorbed energy is known such the band puncture. Where photons with energy below the band puncture pass during the band puncture, Where the absorption of photons that have more energy than the band puncture, in inorganic semiconductor materials or their combinations, daylight can be ingested by the solar cell. Electrons for inorganic semiconductors like silicon have energy that is within a specific energy band known as bands. This band contains energy blanks between them. The parity band is the band in which electron has the highest amount of energy. The case band is defined as the range next to the electrons' potential energy, the one with the minimum power in the conduction band separates an electron from the maximum energy in the band puncture. Where all electrons are at the lowest energy levels that are found in the ingested in the energy case, and the conduction band and valence band are devoid of electrons. Where there is no energy in the dark state the parity and conduction bands. Passive charges are when photons of electrons travel through the band puncture, for this reason, passive charges are present in the conduction band to create a positive charge. From the parity band to a conduction band, the energy of the electron increases to absorb photons the reason is that there is no energy between the conduction band and the parity band. But when electrons get about via the band puncture, passive charges shape at the case band, leaving a plus charge called H^+ and punctures in the parity band. Pairs of positive electrons and negative holes are created due to the sucking of the photon by the semiconductor when absorbing light in photovoltaic cells [33].

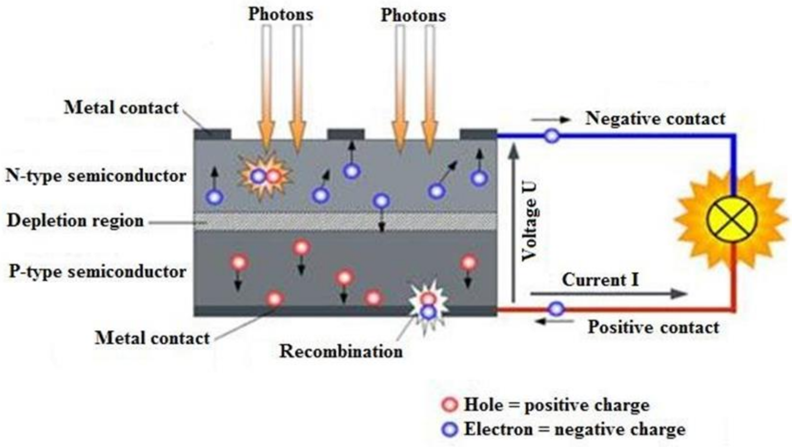


Figure 1.9. Photovoltaic energy conversions [34].

1.11. HOW PHOTOVOLTAIC CELLS WORK

The photovoltaic cell converts the energy in solar radiation into electricity with the help of semiconductor materials cell in the solar modules consists of several cells that include a photovoltaic Nasser. One of its advantages is that it generates electric current in a quiet, reliable way and clean, as the photovoltaic system consists of photovoltaic or solar panels, which are responsible for converting part of the sunlight into electrical energy. It is called the solar cell because the light root is particularly the sun. The origin of the word photovoltaic is two syllables, volt, and photo, from

Greek. The cell consists of two layers or one layer of semiconductors, and when light contact the roof of the cell; an electric domain arises between the strata of the cell and causes the flow of electricity. The density of electrical energy diversion based on density of the radiation that down to the cell, and since silicon is a semiconductor, it is an essential element for the made of a solar cell, and there is silicon in the sand in abundance [35].

1.12. HISTORY OF THE DISCOVERY OF ELECTRICITY FROM LIGHT

Production of electrical energy from sunlight was first find out in a nineteenth century and was not utilized until the twentieth century in the year 1883 when the physicist Edmund Becquerel wrote down the light effect by mistake, and then the research continued until Willoughby Smith discovered the use of selenium as a conductor of light, and then the research continued until Bell Laboratories found Chopin manufactures photovoltaic cells, but their efficiency is low, about 6%. Finally, in 1958, the first photovoltaic cell for space use was made in America, but it was a small number and at a high cost. The development continued in this field and utilization solar cells such a source of electricity in the seventies of the twentieth century until the cells became like this Currently user [36].

1.13. PHOTOCELL CLASSIFICATION

Photovoltaic cells are based mainly on the light falling on them from the sun, which scores in the motion of electrons and apertures. It is also possible to know the variance among the energy of the hole and the electrons prior leaving the solar cell. The energy output is the result of the movement of electrons and gaps, and we can determine and the efficiency in the conversion of the solar cell into electricity using peak power (WP), which is the generation power of the cell with summit hour in lucid weather. Photovoltaic cell is classified in three categories:

1. A cell made of inorganic semiconducting materials is known as an inorganic cell.

2. A cell made of mainly organic semiconductor materials is known as an organic cell.
3. A cell that contains a mixture of semiconducting materials and molecules is known as a photo electrochemical cell.

Where the inorganic cell contains negative electrons that move freely and are known as n-type semiconductors. They also contain holes and are also free to move positively. They are known as semiconductors of type A as shown in figure 1.10 and because there is a permit for the intersection of n to separate the holes and electrons that are generated outcome of the fall of solar radiation on the cell is transmitted to the outside by wires to produce electricity. The good thing about generating electricity from photovoltaic cells is that there are no moving parts and they are silent [33].

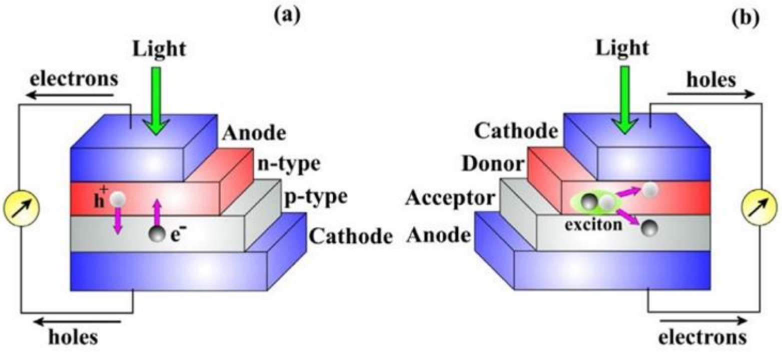


Figure 1.10. The construction of a not organic solar cell [37]

1.14. PHOTOVOLTAİCS SYSTEM (PV)

It is single of the types of systems used in generating electricity and is considered one of the most important and best systems in providing energy and the most efficient and it is not harmful to the environment. Companies are doing research and development to increase cell production and reduce costs in many countries. Society makes the consumer want to electrify the solar panels and perhaps provide his full needs of electric energy. Among the advantages of photovoltaic electricity:

1. Generating electricity with reliability and at a low cost, and it is possible to dispense with the electricity network.

2. Easy to install and weather resistant.
3. The operation of many systems and their reliance on solar energy as a source of energy, as well as pocket calculators that work on solar energy.
4. The parts of the photovoltaic system are fixed and immovable, meaning there are no vibrations or friction, meaning there are no parts subject to damage.
5. It is quiet and emissions free.
6. The basic material in the cell industry is silicon, which is environmentally friendly [38].

1.15 SORTS OF PV SYSTEMS

Photovoltaic systems are classified into:

1. Grid-connected photovoltaic system.
2. Independent photovoltaic system.

The photovoltaic systems connected to the grid are also divided into two parts: The system does not include storage systems and Bimodal PV Systems have storage systems. The photovoltaic systems connected to the network can be classified into other classification, which is: Direct connection and two-mode systems. Independent photovoltaic systems can also be classified into: The system does not contain batteries, hybrid, and batteries. These are directly connected systems and the battery system may contain a DC self-regulating system or an AC system over a battery and a load duty controller. crossbred PV systems contain a wind turbine, hydro turbine, fuel cell, diesel generator, or other origins.

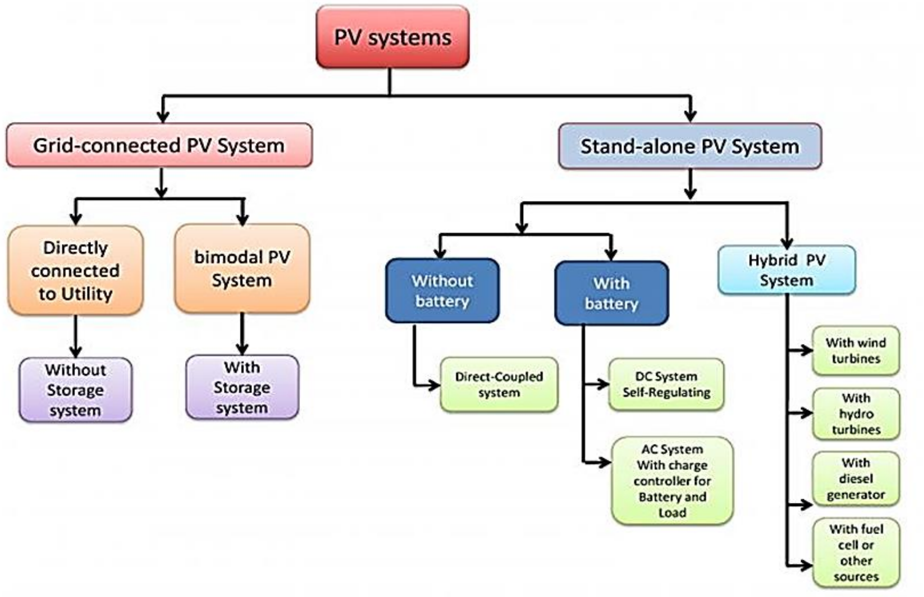


Figure 1.11. PV systems kinds [39].

1.15.1 The System is Connected to The National Network or on Grid or Utility Interface (UI)

It is possible to use this system in places where there are recurrent power outages, where the network helps as an auxiliary factor or backup support. Therefore, photovoltaic systems connected to the grid are relatively simpler. Without that a system, it is tough to compete with the electric current coming from a national net, which is cheap paralleled to the photovoltaic system connected to the net. Such a system is in place to install photovoltaic arrays on roofs or poles. Batteries can be added as a precaution if there are network problems. In this system, single of the most significant units is the power case unit, which converts the continuous current into alternating current, and the electricity that comes from the photovoltaic cells and prior it is distributed to the load passes via the utility network through this unit and it look after the quality in the supply and cooperates to operate this system more efficient, Figure 1.12. When the cost of electricity rises in the middle of the day, these systems save energy in the locations where they are installed. We see this when the price of electrical energy rises, where the photovoltaic systems built-up in homes or corporations are an association part of it. Solar panels installed on buildings have become widespread with the decrease in their prices and become more grown [28].

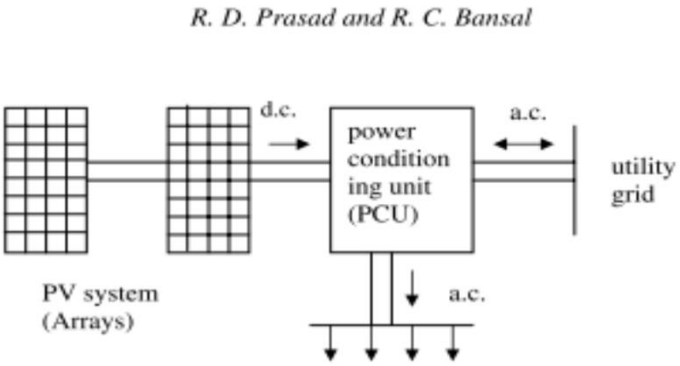


Figure 1.12. Grid- joint PV system [28].

1.15.2. Independent System or Off-Grid System

As for this type, it is needful to consider the value and compare it with the price of contacting to a web or connecting a diesel engine. To guarantee the best quality and the lowest cost, these systems must be designed with great care. Battery checks and maintenance must always be carried out by the users of the system, and they must prepare all their requirements and perform the safe process of the system against the electricity being evaluated. As for the solar systems that are formed independently and that are provided In addition to the control device and control of battery charging where the inverters are one of the most important components, regardless of the battery and the solar panel Figure 1.13 [28].

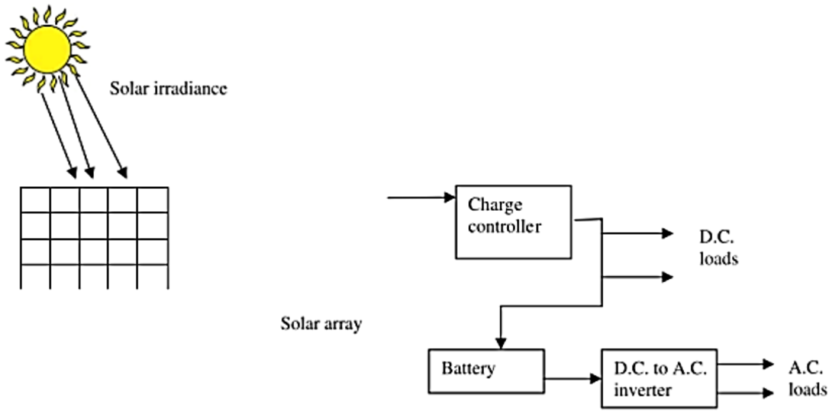


Figure 1.13. Easy solar diagram for a self-contained system with battery stock piling [28].

1.16. THE BASIC COMPONENTS OF THE SOLAR ENERGY SYSTEMS

A solar cell gives a specific value of electrical energy at a constant voltage, and this is not practical for most applications. Because the cell has a specific size, it supplies a limited amount of electricity that does not meet the needs of most devices. To use electricity generated and produced by the solar cell, a certain current or voltage is required. Therefore, several solar panels are connected in a group to provide a greater current. The main and most important part of this system is the solar panel, but many necessary components are required and important for the operating system. This depends on climate the system is independent or linked to the network. This system has several components, the most important of which are: An iron or metal structure that holds the panels and faces the sun energy storage batteries where the battery is also an important part to storage energy for use at darkness or when cloudy climate. A DC-DC converter to convert the changing outgoing power due to climate or any other influence into a fixed voltage that can be utilized to charge batteries. Convert AC to DC for network-connected systems so that the network can be fed into it connecting wires to join the parts of the photovoltaic structure and the load and must be of appropriate thickness to reduce losses of electrical resistance. It is needful to take into computation the devices joint to the system during work if their cargos are AC or DC [30].

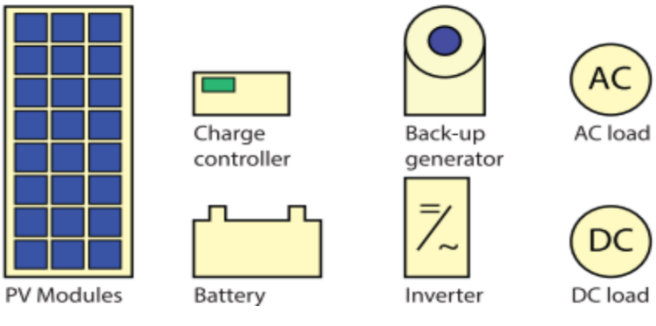


Figure 1.14. The different elements of the PV system [30].

1.17. THE MAIN KINDS OF PHOTOVOLTAIC PANELS

There are options for photovoltaic modules in two different options thin film technology and crystalline technology and its subsections as in Figure 1.15.

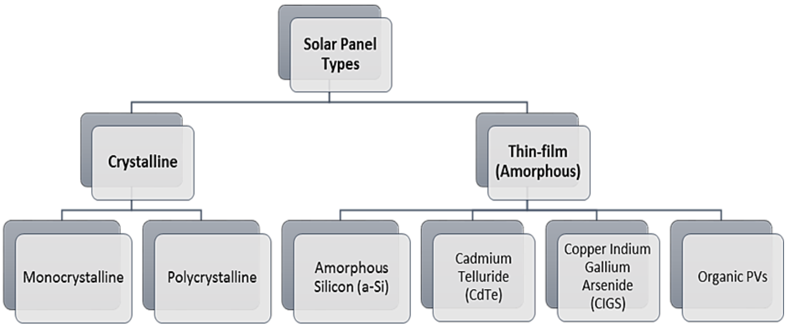


Figure 1.15. The main types of photovoltaic panels [40].

Table 1.1. Conversion efficiency of cell [41].

Module Type	Efficiency Rate	Advantages	Disadvantages
Monocrystalline	20%	• Highest efficiency • Aesthetic • Space efficient • 25+ year lifetime	• Expensive
Polycrystalline	15%	• Low cost • Less waste • 25-year lifespan	• Low efficiency • Aesthetic
Thin-Film	7-10%	• Portable and flexible • Lightweight • Readily available	• Lowest efficiency • No residential application • Short lifespan • Low space efficiency

1.17.1. Crystalline Technology System

Silicon is an element that is available, but not in a large quantity on our planet after oxygen. It is considered the mother of a material used in the manufacture of the solar cell using crystalline silicon technology, which is The main reason for increasing the amount of efficiency solar cell, which is approximately 20% [42].

1.17.1.1. Mono-Crystalline Silicon System

It is single of the techniques that are classified as old. The efficiency varies according to how it is manufactured, in which the high-purity single-crystal silicon cell is made from pieces of rods to thin films. The efficiency of this type of cell reaches 17-18%.

The chemist Zucker Alexei invented the Chucker Alexei method in 1916 and from this method we get a monocrystalline silicon cell. The element of silicon is either type p or kind N, relying on the type of impurities added to cells, such as phosphorous or boron, the thing that participates in the difference in a electrical specifications of the cell despite the efficiency values are different. Depending on the manufacturing method, these additives are very beneficial for high electrical accessibility and the colour of a monocrystalline cell is black, dark, or blue [42].

Figure 1.16. Monocrystalline silicon cell [43].

1.17.1.2. Poly-Crystalline Silicon System

This technology was reached in 1984, and it uses crystalline silicon, and its efficiency does not exceed 15% in laboratories, and currently, its efficiency has reached about 22.3% in the laboratory [44]. With an approximate efficiency of 14-20% [45]. The efficiency of this type is low compared to other technologies, but the cost of producing it is also low. The silicon is poured after melting into a graphite case, and then the cell is in the shape of flakes [46]. The colour of the cells is polycrystalline, depending on the style of treatment, and it is often blue, Figure 1.17.

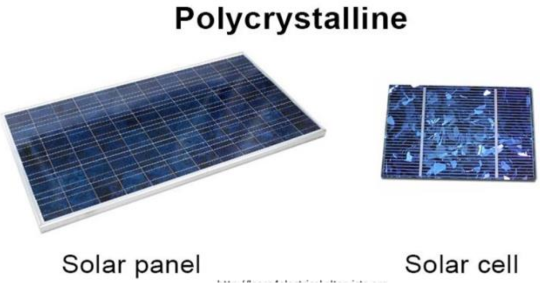


Figure 1.17. Poly-Crystalline Silicon system [43].

1.17.2. Multi-Crystalline Silicon System

This cell is formed by fusion the silicon element and placing it in a module wrapped with a graphite crucible, and then it is divided into bars and then into flakes. This technique is taken of the crystalline silicon technique, but this technology is considered the least efficient and cheaper than the monocrystalline cell. The efficiency of this crystalline silicon cell is approximately 13-14%, and it is possible to produce this cell with higher efficiency of up to 22.3% in a lab environment, thus reaching the efficiency of Its production is a larger scale between 14-20% [42].

1.17.3. Thin Film Technology System

Thin-membrane units few cost a lot of silicon, and as shown in Figure 1.18, their thickness is very small, ranging from 35 to 260 nanometers. These cells are made using fewer materials due to their lower thickness and higher manufacturing efficiency than crystalline silicon. Where the semiconductor material is placed on a coated glass layer or stainless steel or polymer material. With a diversion efficiency of 7-10% due to the lack of efficiency of this type, so it needs large areas to compensate, so the best place to install this type in better under low irradiance conditions. The main materials of this type are indium, gallium, copper, silicon, and cadmium telluride [42].

Figure 1.18. Thin film solar panel [47].

1.17.3.1. Amorphous Silicon Thin Film Technology System

This kind is widely used for sensitive devices, such as calculators, watches, and electronic equipment because this type highly reliable sources of energy. It is one of the non-new techniques where thin-thick silicon cells are deposited by the chemical vapour deposition method from hydrogen gas and silage, crystalline silicon, Nano silicon, and amorphous siliconize produced. Note that the production of this type is inexpensive, but the conversion efficiency in it is lower than in the cell made of silicon, and based on the little amount of the charge transporter that are compiled for photons, the efficiency of these cells is relatively low and is about 14%. Also, the silicon element is considered the most suitable for open circuits that contain high voltage because it has a small section of nan scale silicon [42].

1.17.3.2. Cadmium Telluride Thin Film Technology System

Since cadmium telluride (CdTe), which is a crystalline substance, is a semiconductor, it was considered effective in sucking light. In laboratories, the efficiency of cadmium range 16%, when compared to thin films. (CdTe) is less expensive and simple to deposit. And because cadmium has good physical features, it can work with low levels of light and switch it into electrical energy with higher efficiency than a conventional cell. The disadvantages of cadmium are its lack of availability and pollution is one of its most important determinants [42]. The Figure 1.19 shows a model of solar panels according to the kind of silicon cells, as most cells are made of silicon as shown [35].

Figure 1.19. Models of solar modules.[48]

1.18. SOLAR PANELS COOLING TECHNICS

It is needful to go down the solar panel efficiency and their energy production to increase economic returns. Increasing conversion solar panel efficiency is the most important thing in it and thus increases their production of electricity. The radiation falling on Solar panels contain many variables, which are time, day, longitude, latitude, weather conditions, and the direction of the panels [28]. The efficiency of the panel lowering as the temperature elevation due to the transformation of 50% or lots of light drops on the baseboard, which is useless and harmful heat to the panel. The solar panel efficiency varies and based on type of material the panel is made of. Many researchers have carried out many studies to address this problem, which is considered one of the most important problems in solar panels. They made many attempts to get rid of the excess heat by cooling the panel, including [49]:

1. Air cooling.
2. Water cooling.
3. Cooling through the use of variable phase materials.
4. Cooling by extended surfaces /fins / Heat sink /heat exchanger
5. Nano liquid cooling.
6. Thermoelectric cooling.
7. Cooling by a Heat pipe.
8. Cooling by Micro channel heat exchanger.
9. Spectrum filters cooling (optical beam splitter).
10. Evaporative cooling.
11. Radioactive sky cooling (photonic cooling).
12. Hybrid/multi-concept cooling systems.

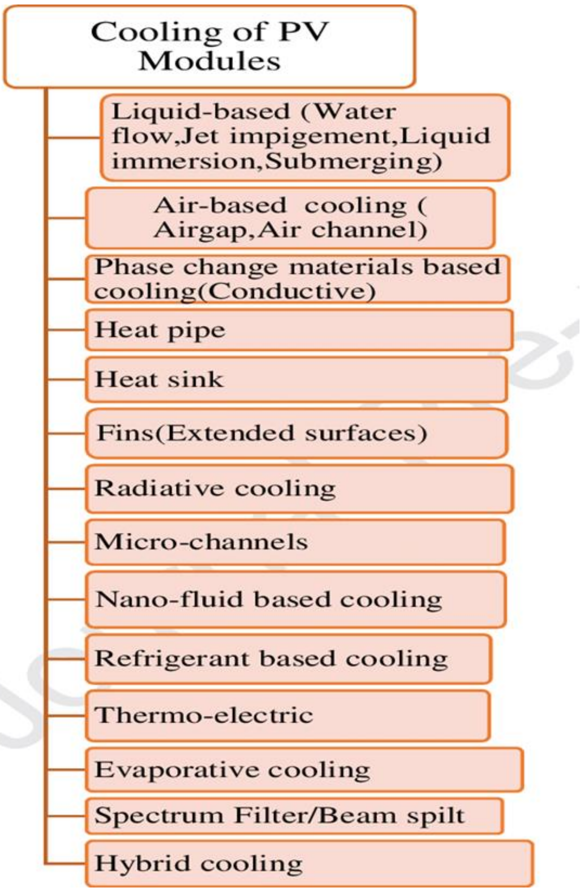


Figure 1.20. Solar panels cooling technics [50].

1.18.1. Cooling By Air

It is one of the common ways to cool the panels. The cooling process is done by air, naturally or short, and because of the simplicity of this method, it is the most widespread sometimes it does not need additional materials, especially if it is cooled naturally and its cost is low, as the heat is removed By convection and air flow over the upper part, where it is more effective than the lower part of the panel, or it may be cooling using fans, i.e. forced or active air cooling, and this type of cooling can be improved if we add fins made of metal materials and a good heat conductor that is fixed under the solar panels [49,50].

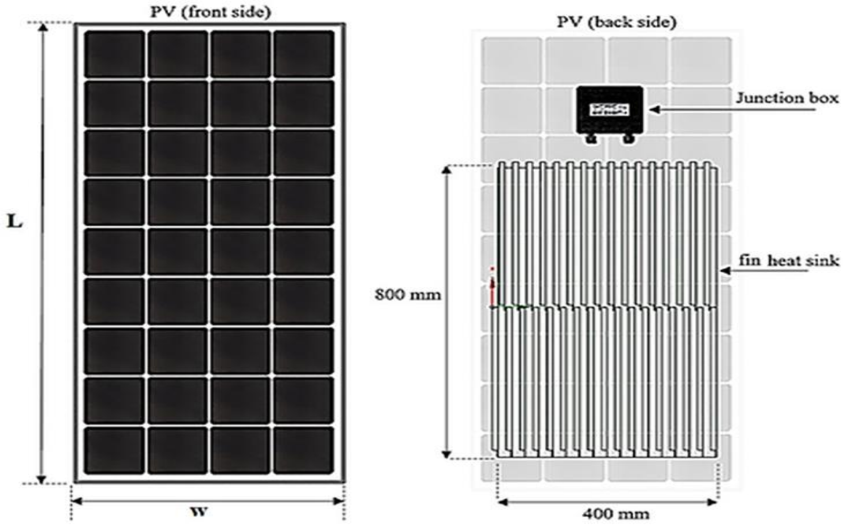


Figure 1.21. Cooling by air with heat sink [53].

1.18.2. Cooling By Liquid

The water must flow permanently through the system when it is used for cooling. It is necessary to use water pumps that operate on a constant current. These pumps supply electricity from solar panels in the active cooling system. There are several methods of active cooling using water, the most prominent of which are in flowing.

1.18.2.1. Circulation and Forced Movement of Water

One of the ways to reduce the heat of the panels is to install metal tubes that conduct heat at the bottom of the panels, and liquids such as water, for example, it is used as a cooling medium for solar panels. The resulting heat can be transferred by the modules resulting from the excess absorption of radiation to the circulating cooler and used for other uses, such as drying some materials or helping to heat water, as in solar heaters [54].

1.18.2.2. Water Immersion Cooling

In this cooling technique, the panels are fixed on the water, and the results are highly efficient, as the water absorbs heat from the panels [55]. The panels can be placed at a depth of 1 cm, thus improving the efficiency by approximately 17.8%, as this method has very little impact on the environment and reduces the rise at high temperatures [56].

1.18.2.3. Cooling By Water Spraying

The water is pumped by the pump, where water is sprayed through the sprayers installed on the solar panel. Water sprays can be installed on the front of the board or the back of it. Previous research has produced good and interesting results, and the efficiency has increased by about 15% in severe weather. But this technology wastes some water, can be used in many ways for cooling and is considered an effective and cost- solving for floating systems [57], as Figure 1.22. Where the outcomes of the experiment's presentation that the uses of water spray is better than not using it the percentage of rise in the efficiency of the panels was 14.6%. This system consists of solar panels, a pump, sprays to spray water, water storage, a tank, and a system Recycle, and using this method smaller than the panel heat to 35°C [58].

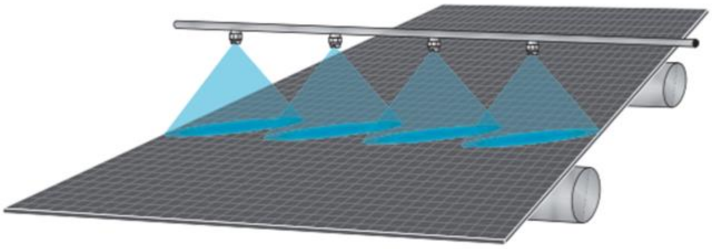


Figure 1.22. Cooling by water spray [59].

PART 2

LITERATURE REVIEW

Solar energy was not very widespread in the past, but now solar energy and all kinds of renewable energies are real and in demand because of the benefits of its magnitude. Researchers' efforts have been intensive and sustained to increase the efficiency of solar panels. We write down some scientific research and literature on the cooling of solar panels and address what the researchers have reached here:

Suherman et al. cooled solar panels passively with pieces of aluminium metal filled with water and heat distractions and reduced the face the heat the solar panel by 11.91% compared to the non-refrigerated panel and gave 6.28% more energy than other method [60].

Hasan et al. Cooling solar panels by water-cooled thermal dispersion increase solar panel efficiency and reduces temperature. The lowest panel temperature was measured mid-day with 16 liters/minute water flow [61].

Sultan et al. cooled the solar panels in two ways, the first being air-cooled by a DC fan behind the panel. Second, use water-cooled pieces of aluminium behind the board and a copper perforated tube for the water to be sprayed on a front face of the panel. The results were preferable to cool it in favour of spraying water with greater efficiency [62].

Ghorpade et al. reduced the temperature of the panels in several ways, namely, by cooling air, water, and phase-changing materials, and they found that the way to reduce heat and to cool both sides of the board is the best, as the efficiency rise by 14.1% and the heat decreased by about 20°C [63].

Ali et al. worked on a comparison between several cooling methods. The first method was spraying water mist on the front side, the second using air fins on the back side, and the third using fans with fins, the first method was 2.5% and the temperature decreased by about 7°C, while the second and third methods decreased the temperature by 3 degrees and the most effective the second method was the fin method [64].

Irwan et al. used a comparison between cooling the panel by a DC water pump and spraying water on both sides of the panel against cooling by DC brushless fans. In the first method, the pump method, the voltage increased by 3.52%, the current by 36.27%, and the energy by 38. 98%, and the temperature drops to 6.36%. As for the fan, it rises as follows in current, voltage, and power, respectively, 29.55%, 3.47%, and 32.23%. As for the temperature, it decreased to 6.1°C [65].

Abdulgafar et al. raise the solar panel efficiency by the method of immersion water in distilled water of varying depths. As the water depth increases, the efficiency increases. The increase was about 11% with a depth of 6 cm [66].

Hussien et al. designed heat exchanger placed on a behind surface of a solar panel through which water passes, and the efficiency increased by about 9.8% with a inflow of 0.2 L/sec, and the heat decreased by about 6°C [67].

Parthiban et al. are doing to raise the efficiency of a solar panel and increase its energy production all ways, integrating and comparing them in terms of energy, voltage, current, and temperature [68].

Hassan et al. cooled the solar cells used for poles in an extreme and desert environment using aluminium dispersions, as the temperature go down by 16.4% and the efficiency went up by 13.32% per day [69].

Dwivedi et al. discussed the need to raise the efficiency of solar energy, methods of cooling solar cells, its problems and challenges, and the effect all factors on the panels such as shade, humidity, dust, wind, and the urgent need to cool solar cells [56].

Hasan used rectangular fins with variable cross-sections placed on a back side of a solar panel as a passive method for cooling and increasing the solar panel efficiency, as the temperature decreased by about 5.7°C, and the efficiency rose by about 15.3% [70].

Ibrahim et al. worked on building and designing a system to cool the solar panel, consisting of water sprinklers, fans, and wipers to reduce heat and clean the solar panel, as the energy increased by 34.55% [71].

Mehrotra et al. immersed the solar cells in water as a way to cool them, where the heat of the cell can be controlled between 31 to 39°C, and the power increased dramatically and the efficiency has increased 17.8% at a depth of 1 cm [55].

Yesildal et al searched cold of a solar panel by spraying water with the help of air, and the factors affecting to increase the efficiency were known, such as the levels of spray time the spray flow rate and the outflow average of the air nozzle, [72].

Moharram et al. worked to reduce the water used to cold the solar panel for arid and desert regions, and the time required for spraying was calculated until the heat reached 35°C and the highest temperature that can be reached is 45°C, and a compromise was made between the heat and energy coming out of the panel to reduce the use of water in cooling [58].

Laseinde et al. chose to improve the methods of automatic water spraying to cold the solar panel and increase its ability, as the efficiency of the panels increased by 16.65% [73].

Al-Zaabi et al. compared the water-cooled panel to the non-cooled panel and increased the efficiency of the cooling panel by 15-20%, in addition to a solar thermal mode. Collector on board [74].

Schiro et al., applied the method of cooling solar panels with water on a face of the cell, where a significant improvement in photovoltaic energy was observed [75].

Ceylan, et al. conducted experiments on placing a simple tube on a back face of the panel to serve as a spiral heat exchanger for active cooling, and the efficiency was about 13% compared to uncooled cooling. panel, which was 10% effective [76].

Kabeel et al. designed a water purification system in desert areas with cooling panels and the use of reflectors to raise solar irradiation. The panels were cooled in several ways, including air injection and the water cold, and achieved raise in the energy produced by the solar panels [77].

Elminshawy et al. experimented with the usage of the water-activated system for cold and dust reduction, and the Nano-ceramic panel system to obtain the best products at high temperatures [78].

Bahaidarah et al. developed the cooling of the panel with a heat exchanger on the bottom face of the panel, and also developed a digital model on the Y program to solve equations, and there was good agreement between the two models as the temperature decreased by about 20% and the efficiency raise by 9% [79].

Rajasekar et al. designed a new cooling method by placing a saturated biomaterial filled with coconut seeds with a continual supply of the water on a back surface of the panel, while the front face made a thin layer of water flow over it. Ordinary water was again used with slurry water, and the efficiency increased by about 64%, the temperature of the bowl was 5-8 ° C [80].

Nižetić et al. made water spray to cold system on a face and bottom face of the solar panel, which is a technology that increases efficiency by cooling and removing dust on the front surface. The electric power increased by 16.3% and the temperature decreased from 54 to 24°C [57].

Rajvikram et al made a solar panel cooling system using a phase-changing material with external finned heat sinks, increasing the panel's efficiency and lowering its temperature [81].

Abdo et al, experimented to cool the panels usage activated alumina saturated with brine, where six various concentrations of salinity were used, and the results resulted in a lowering in a temperature by 3-4°C [82].

Ghadikolaei et al. presented a search in the environmental impact of different cold processes of panels on the environment and emissions, and the best results were by using hybrid Nano-material, hybrid phase-change materials, and hybrid water, respectively, more effective and efficient. lower emissions [83].

Lari et al. The effect of cooling panels by Nano-liquid and an uncooled thermal system to counteract the heat load of the building by the EES program and compared, and there was an improvement in electricity by about 11.7% [84].

Peng et al. have studied the effect and effectiveness of solar energy cooling systems and found that the annual output can be increased to 35%, and a total annual energy capacity, inclusive electric power and the water heating, enable to be increased by more than 107%, and the value recovery period is lowering to 12.1 instead of 15 [85].

Castanheira et al. studied, tested, and validated an analytical model in a 20-kW rooftop plant. Experiments produced how the thermal time constants for cooling and stopping water affect the efficiency of photovoltaic cells, and the researcher concluded an increase in annual energy production of 12% [86].

Siahkamari et al. The experiment of cooling solar panels using micro-copper tubes running on cold water placed on the back surface with the use of sheep fat and copper pieces and comparing it with traditional wax. Both cases showed an increase in efficiency, but the higher value was in favour of sheep fat with copper particles [87].

Rajput et al. made a cylindrical fins at the lower side of the solar panels under stagnant air conditions and illumination with a halogen light with a density of 1378.4 W/m^2, the heat was drop to 47.9°C and efficiency was lifted [88].

Abdo et al. demonstrate in a study an importance of cold solar panels together with hydrogel granules of various configurations and multiple layers with fins, and the best result was the use of 3 lines of hydrogel together with fins, while the heat decreased by about 10 degrees, 14%. Efficiency increased by 7.2% [89].

Khanjari et al. devised a simulation system using computational fluid dynamics, and made liquids used for pure water and Nano-liquid cooling with the addition of alumina, efficiency increased and temperature decrease [90].

Irwan et al. designed a simulation of solar panel cooling indoors under different halogen illumination irradiation. The panels are cooled by spraying water from a DC pump pumping water, and the water flows on top face of the panels, reducing panels temperature and enhancing efficiency [91].

Bahaidarah et al. designed the water-cooled crossbred system, and the results offer a 20% lowering in heat and 9% raise in efficiency [92].

Bijjargi et al. a spiral tube on the bottom face of the solar panels as an active heat exchanger for cooling the cells with a parallel set of channels with a manifold flowing to the back surface with phase-changing materials and the thermoelectric internal viscosity of the heat cart about 14% and the efficiency was increased [93].

Rajasekar et al. made laminated and mounted channel back face of the board through which the moist air flows while sprinkling the pot water on the front face of a board at the same time, which increased the efficiency and reduced the heat of the board [94].

Bashir et al. emphasized the importance of cooling the solar cells by making air ducts on the lower side in addition to a flow of water, so the output energy increased and the temperature decreased [95].

Gotmare et al. raise the efficiency of panels by attaching a cold system to the bottom face of the panels and a temperature was lower than the uncooled panel [96].

Elnozahy et al. conducted a study that investigated the automatic cold and face cleaning of a solar cell. The cell cleaning period is controlled by a system. This study outcome in an 11.7% raise the efficiency and a lowering in temperature by 45.5% [97].

Ali et al. got up a study that includes maximizing efficiency of panels in hot environments using experimental method to decrease temperature about 15°C and an boost power approximatelly 14% [98].

Masalha et al. experimented with a cooling duct system with different dimensions hold on the lower face of the cell with porous media under halogen lamps with a density of watts, and the heat lower by 42.17%, and the efficiency raise by 12.9% [99].

Salih et al. designed a system of forced spraying with water with a constant flow to lower the heat of the solar panel, which increases its efficiency, as well as It is possible to use the water resulting from heating the solar cells at home, uses as a water heating system, and the panel efficiency was increased by 7 W [100].

Salameh et al. conducted simulations to raise the efficiency of the cell in a hot climate, and the cooling system contains 11 parallel channels and anchored to the back side of the board and the simulation was done in a three-dimensional numerical model, and the efficiency increased as in many practical results [101].

Manasrah et al. worked on cooling the panels by forced convection in different directions and paths on the bottom surface of the board with the use of DC air fans, Where the results were a 32.8% decrease in heat and an increase in efficiency [102].

Vittorini et al. presented a practical test to cold the panel by adding flippers, where heat is exchanged with the surrounding air. Various models of thermal fins were designed and their effect on heat loss, in addition to the quantity and engineering of the fins, and the effect of all of this on heat loss and increasing the efficiency of the panel [103].

Chandrasekar et al. experimented with a cooling system for solar panels, which is a negative cold system consisting of cotton wick frames with a water-Nano-water cooling system with aluminium oxide and aqueous Nano-liquid with copper oxide. The results were compared with an un cold panel, where the efficiency increased and the heat decreased [104].

Baloch et al. Two numeral and experimental studies were completed and their comparison was done in hot weather. The effectiveness the convergence angle on a thermal property was studied in numerical analysis. In practical experiments, the temperature reached 48.3 and 71.2°C in December and month June, respectively, and by using convergent cooling, the temperature decreased by a Massive to 36.4 and 45.1°C for December and month June respectively, while the efficiency increased by about 35.5%, The efficiency of solar cells to convert light to 36.1% rapprochement to the uncooled panel. As for the simulation, the energy cost for your LEC was lowered by 1.95 kWh / € to 1.57 kWh/€ [105].

Rahimi et al. in this study showed the collection of solar energy and wind energy to produce more electricity, as solar cells were cooled by a conical wind tunnel, and the wind collected from the tunnel worked to cool the solar cells and used it to produce electricity through special turbines, where the total energy increased by about 36%. Modelling was presented on CFD software based on MRF technology [106].

Valeh-E-Sheyda et al. in this study are fulcrum on knowing the effect of the two-phase flux of a hybrid ultra-small cell, as these experiments were carried out in micro-channels of rectangular shape and hydraulic diameter of 0.667 mm, and the velocity of the gas was 27 m/s, where the inflow of the liquid was 0.04. The study of the influence of this two- period cooling on the cell was compared with a single phase, where the results indicate that the resulting energy increased dramatically [107].

Younas et al. concentrated on increasing the efficiency of panels by using simple locally manufactured cooling channels. The experiments showed a temperature decrease of 27.5°C with eradiation of 895 W/m^2 and the efficiency increased by 1.61% [108].

Arshad et al. made a system of mirrors and lenses to strengthen and focus the solar radiation to increase electricity production. The experimental results of a system of panels with inverters with cooling give more energy than cells without inverters and cooling, and the efficiency increased from 32% to 52% [109].

Singh et al. experimented with passive cooling of solar cells using heat sinks with PCM fins (FPCM) and it was examined numerically. The heat generated was used in space heating. It was found that it was possible to reduce heat by 13 K, the sinks enhance cooling by 19 K, electricity increased by 7% to 8%, and efficiency increased. From 13% to 19% [110].

Haidar et al. focused on cooling the solar panels by evaporative cooling, where the heat is absorbed into the panels by the latent heat of evaporation, then the steam condenses on the down face of the solar cell and is uncovered to the ocean, then the water descends with the effect of the force of attraction to a tank. to 14% [51].

Fakouriyan et al. focused on the cooling of solar panels with water in addition to a solar heater, as It is possible to benefit from the water that was heated by the panel to enhance the solar heater, and the efficiency of Generation and production of electric power, thermal energy, and total energy increased to 12.3%, 49.4%, and 61.7%, respectively [111].

Nižetić et al. designed a cold by water spray on both directions of the solar panel to increase its efficiency and reduce the panel temperature. The results were as follows: the electrical energy has risen by about 16.3%, the high efficiency of electricity generation by about 14.1%, and the temperature decreased from 54 to 24°C [57].

Odeh et al. referred to the long-term modelling of cooling the solar panels by pumping water on the front face of a cell. This system is used for washing and contains of a water tank and submersible pump used to cool the board panel as well, as water-cooled solar cells. It was found that there is an raise the efficiency of 15 % approximately [112].

Wongwuttanasatian et al. mention the importance of cooling, especially passive cooling with a finned heat sink with a phase-changing substance such as palm wax, where the efficiency increased from 9.33% to 9.82%, corresponding to an improvement of 5.3%, and the temperature lowered from 57.9°C to 51.8°C and average performance raise by about 4.8% [113].

Jasim et al. Aluminium oxide, which is a Nano fluid, was used to cool the solar panels passing through a copper tube fixed on the bottom face of the cell. The fluid moves by a DC pumping that supplies electricity from an additional panel. The efficiency increased by about 40.17% and 78.27% for the solar collectors, and the cooling was done by 28.94% and 48.54% [35].

Bahaidarah et al. designed the cooling of the impact jet in hot regions and the experiments were in June and December when the temperature decreased from 69.7 to 36.6°C and also from 47.6 to 31.1°C from the aforementioned two months, respectively, and the transformation and energy efficiency increased by 51.6% and 66.6% respectively through the use of jet cooling for month June and the performance improvement in power production and 49.6% and 82.6% in the conversion efficiency for December [114].

PART 3

THEORETICAL RULE OF STUDY

Energy relations:

The balance of energy equation can be seen in Eq. (3.1) and particular for the PV/T collector and PV module as in Eq. (3.2) and Eq. (3.3):

$$\Delta\dot{E} = \sum \dot{E}_{in} - \sum \dot{E}_{out} \tag{3.1}$$

Eq. (3.1) gives us a characterization of the system energies for each the output and the input. If the system is steady, the resultant difference in energy will be zero.

$$\dot{E}_{solar} = \dot{E}_{electrical} + \dot{E}_{heat\ loss} \tag{3.2}$$

$$\dot{E}_{heat\ loss} = \dot{E}_{convection} + \dot{E}_{radiation} + \dot{E}_{evaporation} \tag{3.3}$$

The applied solar energy to PV modules is given as in Eq. (3.4):

$$\dot{E}_{solar} = SA_{PV.area} \tag{3.4}$$

In Eq. (3.4), S presents solar radiation. Electrical for PV modules can be defined in Eq. (3.5):

$$\dot{E}_{electrical} = VI \tag{3.5}$$

Electrical efficiency for PV modules can be defined in Eq. (3.6):

$$\eta_{electrical} = \frac{\dot{E}_{electrical}}{\dot{E}_{solar}} \tag{3.6}$$

Exergy relations:

General exergy balance is written as in Eq. (3.7):

$$\Delta \dot{Ex} = \dot{Ex}_{inlet} - \dot{Ex}_{outlet} - \dot{Ex}_{destroyed} \tag{3.6}$$

The exergy modify of the system is equal to zero to the steady-state process. The photovoltaic energy balance can be set like in Eq. (3.8):

$$\dot{Ex}_{solar} = \dot{Ex}_{electrical} + \dot{Ex}_{destroyed} \tag{3.7}$$

Exergy solar possible written as in Eq. (3.9)

$$\dot{Ex}_{solar} = \dot{E}_{solar}(1 - \frac{4T_{environment}}{3T_{sun}} + \frac{1}{3}(\frac{T_{environment}}{T_{sun}})^4) \tag{3.9}$$

Electrical exergy of PV modules possible described like in Eq. (3.10)

$$\dot{Ex}_{electrical} = \dot{E}_{electrical} \tag{3.10}$$

Destroyed exergy possible written as in Eq. (3.11):

$$\dot{Ex}_{destroyed} = \dot{Ex}_{inlet} - \dot{Ex}_{outlet} \tag{3.11}$$

The second law of efficiency to PV modules possible written like in Eq. (3.12):

$$\eta_{ex} = \frac{\dot{Ex}_{electrical}}{\dot{Ex}_{solar}} \tag{3.12}$$

Uncertainty analyses

The experimental uncertainty of the study can be estimated with the relation is shown in Eq. (3.13).

$$\partial w = \sqrt{\left(\frac{\partial w}{\partial x_1}\delta x_1\right)^2 + \left(\frac{\partial w}{\partial x_2}\delta x_2\right)^2 + \cdots + \left(\frac{\partial w}{\partial x_n}\delta x_n\right)^2} \tag{3.13}$$

In Eq. (3.13) ∂w is the uncertainty function, x_1, x_2,…x_n are independent parameter. Experimental uncertainty of this study is calculated 5.92%.

PART 4

METHODOLOGY

4.1. CONFIGURATION AND EXPERIMENTAL MEASURING PROCEDURE

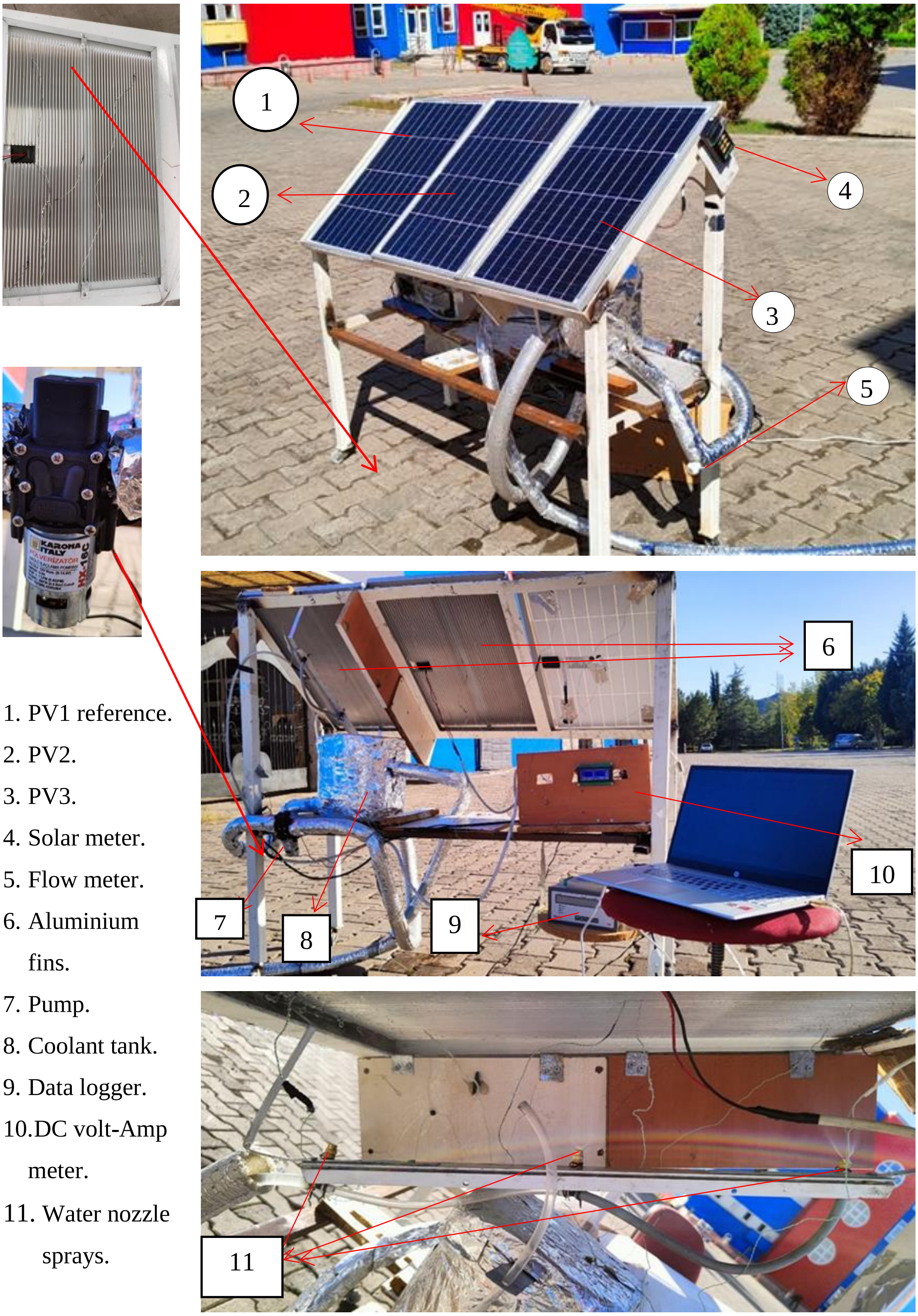
conduct practical experiments on 15/9/2022 at Karabuk University in Turkey from 11:30 in the morning until 16:30 for about five hours. The experiments were on days with sunny weather. Where I gauged the temperature of the outside atmosphere, and the heat of the panels was measured and recorded through their back surface. The voltage, solar radiation, and current were recorded and measured. Three polycrystalline solar panels with a capacity of 50 watts were used, and the metrics of these panels are shown in Table 1.4. I used three solar panels, the first panel without any cooling and it considered as a reference and called PV1 and the second panel with aluminium fins, and called PV2, and the third panel with aluminium fins and three water sprays called PV3. I used a high-pressure pump that works at a pressure of 550 kPa with Connect a flow meter and used water for cooling from an insulated tank and insulated tubes and put thermal paste to ensure excellent thermal conductivity among the back of the panel and the aluminium fins, where A thermocouple was used to record and measure the temperature for panels.

In this experiment use three solar panels with power 50 W the first panel without any cooling the reference panel it called PV1 and the second one it has cooling with aluminium fins it called PV2 and the third one it has cooling with aluminium fins and three water sprays it called PV3.

Table 4.1. peculiarities of used solar panels.

Rated maximum power (P_{max})	50W
Voltage for the open circuit case (V_{oc})	23.80V
Max power voltage (V_{mp})	20.70V
Max power current (I_{mp})	2.42A
Module application	Class A
Short circuit Current (I_{SC})	2.54A
Weight	3.8 Kg

In the first and second panels, five thermocouples were placed to measure the heat generated by the panels. for the third panel placed six thermocouples, which are to set the temperature of the panel, and the remaining three are connected to a programmed electrical panel to instruct the pump when the average of solar panel temperature arrived to 35°C and stop the pump when a solar panel temp arrived 30°C. The remaining thermocouples are linked to a data logger for the purpose of recording it on the computer per minute in addition to another unit recorder that records the current and voltage of the three panels for every five minutes with a device to measure solar radiation every five minutes, as shown in Figures 4.1.



1. PV1 reference.
2. PV2.
3. PV3.
4. Solar meter.
5. Flow meter.
6. Aluminium fins.
7. Pump.
8. Coolant tank.
9. Data logger.
10. DC volt-Amp meter.
11. Water nozzle sprays.

Figure 4.1. Experiment photography.

In the Table 4.2 is a presentation of the equipment and components of the experiment and measuring devices:

Table 4.2. Technical properties for measuring devices and experiment equipment.

Measurement value	Device	Properties	Parts and details	
Solar radiation	TES 1333R solar power meter	radiating range: 0-2000 W/m$_{2}$, accuracy: ± 10 W/m^2 or ±5	Pump	12V DC, 19W
Data collection	Elimko E680 datalogger	Working ranges −5 to 55°C - 85–265 V AC, Standard working limits −200 + 1300°C		
Temperature	Type K thermocouple	-75°C _ +260°C Length 2m		
Modules power	10-ohm load	50W aluminium resistance		

PART 5

RESULTS AND DISCUSSION

I used polycrystalline solar panels in my experiment on September 11, 2022, at the University of Karabuk, and it was a sunny day. The following figure shows the air temperature and solar radiation. The relationship between ambient temperature and solar radiation is explained, as in the Figure 5.1.

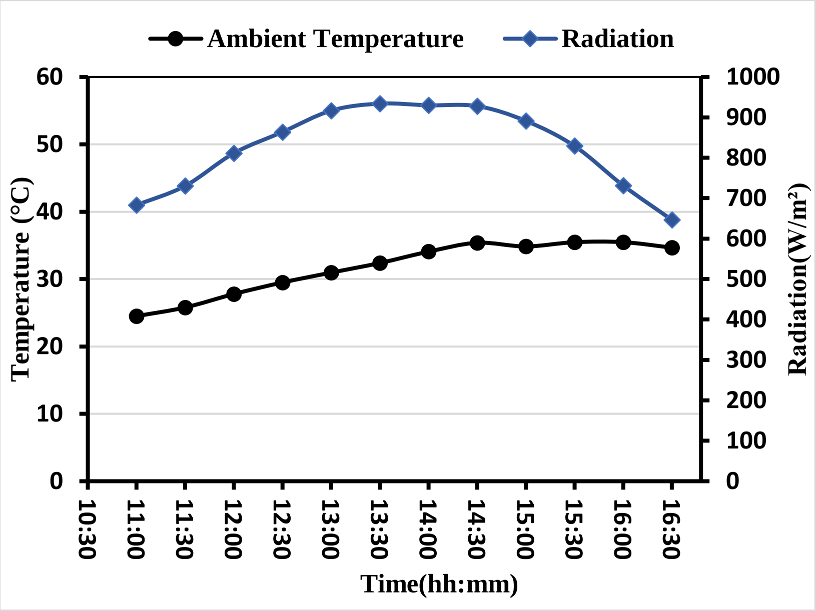


Figure 5.1. Ambient temperature and solar radiation.

We started the experiment at 11:00 and the ambient temp. was 24.5°C, the sun's radiation at 11:00 was 683 W/m^2, while the highest value of radiation was 943 W/m^2 at 13:40 and the ambient temperature was 34.5°C, then the radiation decreased in the afternoon until it reached 604 W/m^2 at 16:30 which is the lowest value of radiation on that. The backside of panel’s temperature is shown in Figure 5.2.

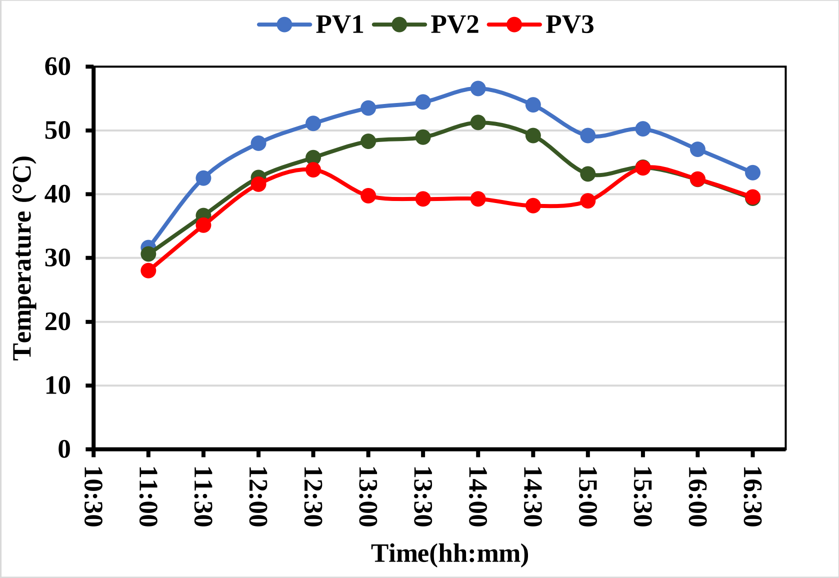


Figure 5.2. lower face of panel’s temperature.

As we can see in Figure 5.2, the temperature of reference panel which is PV1 at the start of the run was 31.6°C at 11:00 and the highest temperature of the panel was 58.2°C at 13:36 and the temperature of the panel dropped to 40.8°C at 16: 40 The rate temperature of PV1 during the work period was 49.75°C. The second panel with only air fins PV2, its start-up temperature was 30.6°C at 11:00; the highest temperature ever recorded for this board was 52.6°C at 13:85. The board dropped to 36.6°C at 16:40 and the average temperature of the board over the operating period was 44.49°C. The third panel, PV3, containing the air fins and water nozzles, had a starting temperature of 27.9°C at 11:00, and the maximum temperature reached by this panel was 45.8°C at 13:30 afterward. Where the temperature in the board dropped to 37.2°C at 16:40 and the average back temperature of the board over the operating period was 37.28°C. Therefore, PV2 comparison to the reference panel was 11% cooler, and the third panel PV3 comparison to the reference panel was 20% cooler. For this reason, the values of current and voltage produced by the panels differed, and this is shown in the following curves in Figure. 5.3.

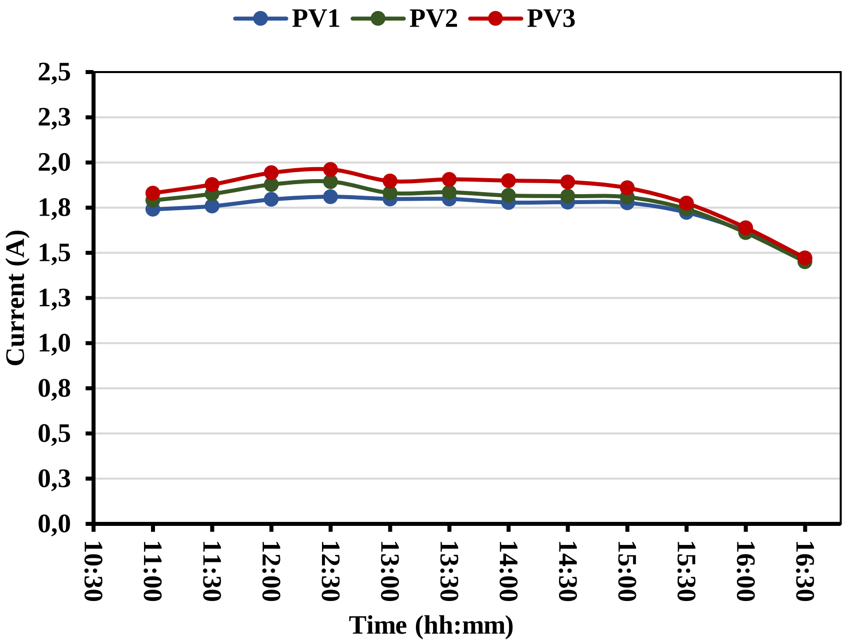


Figure 5.3. Current curves.

The experiment started at 11:00 and the value of the current recorded from the PV1 board, which is the reference board for the current at the beginning of the operation, was 1.74 amperes, while it reached its highest value, which is 1.82 amperes at 13:03, and the average current recorded from this board was of the amount 1.737 amps. As for the second PV2 panel, at 11:00 the current recorded at the beginning was 1.79 amperes, and at 12:09 the highest value of the current was 1.91 amperes, and the average recorded current rate was 1.775 amperes. As for the third PV3 panel, cooled with fins and water spray, the current at 11:00 was recorded at 1.83 amperes, and the highest at 12:10 it was recorded at 1.98 amperes, and the average given from this panel was 1.829 amperes. The voltage values are illustrated in Figure 5.4.

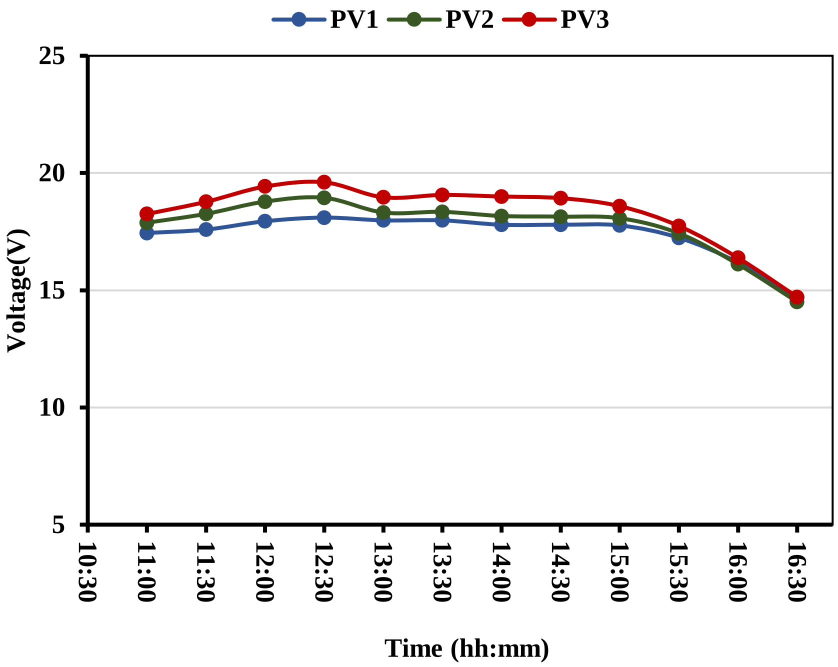


Figure 5.4. Voltage curves.

In 11:00 the value of the voltage recorded from the PV1 board, which is the reference board for the voltage at the beginning of the operation, was 17.44 V, while it reached its highest value, which is 18.19 V at 13:03, and the average voltage recorded from this board was of the amount 17.372 V. As for the second PV2 panel, at 11:00 the voltage recorded at the beginning was 17.88 V, and at 12:14 the highest value of the voltage was 19.12 V, and the recorded voltage rate was 17.744 V. As for the third PV3 panel, cooled with fins and water spray, the voltage at 11:00 was recorded at 18.25 V, and the highest at 12:14 it was recorded at 19.82 V, and the average given from this panel was 18.285 volts. The Figure 5.5 indicates the change in electrical energy output by the three panels.

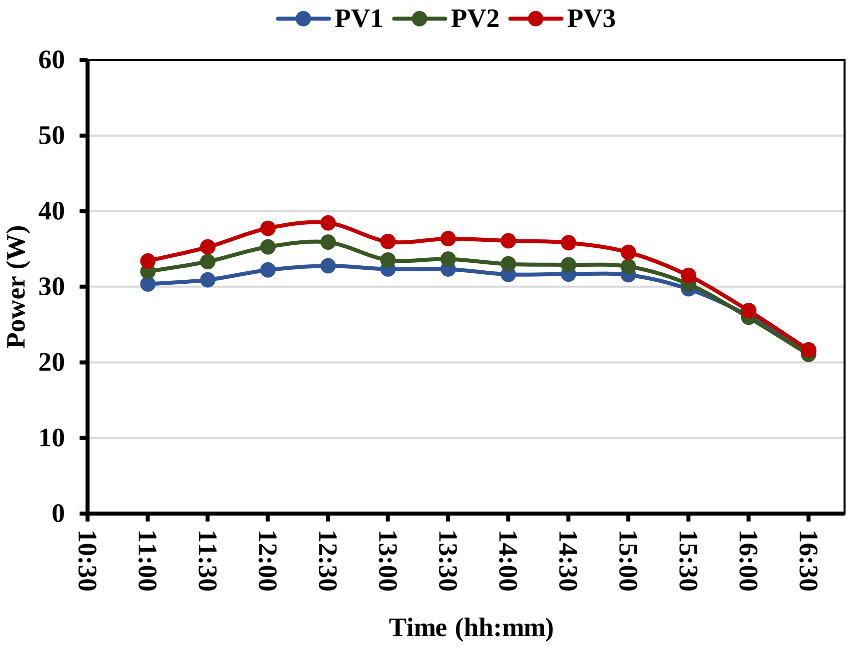


Figure 5.5. Electric power curves.

Electricity power account was obtained from the panels count on the values of the voltage and current from each panel, as the electrical power values for each of the first PV1 panels which were without cooling or the reference panel, the second panel cooled by thermal fins PV2, and the third panel cooled by thermal fins and water sprays were 32.76 W, 35.88 W, and 38.45 W, on the sequence. The electrical energy of the second PV2 panel increased by 1% and the third PV3 panel increased by 17% matching to a reference panel. Because of the decrease in a temperature of the panel, a panel efficiency raises. As for the efficiency of a panel in transform solar radiation into electrical energy panels, it is shown in Figure 5.6.

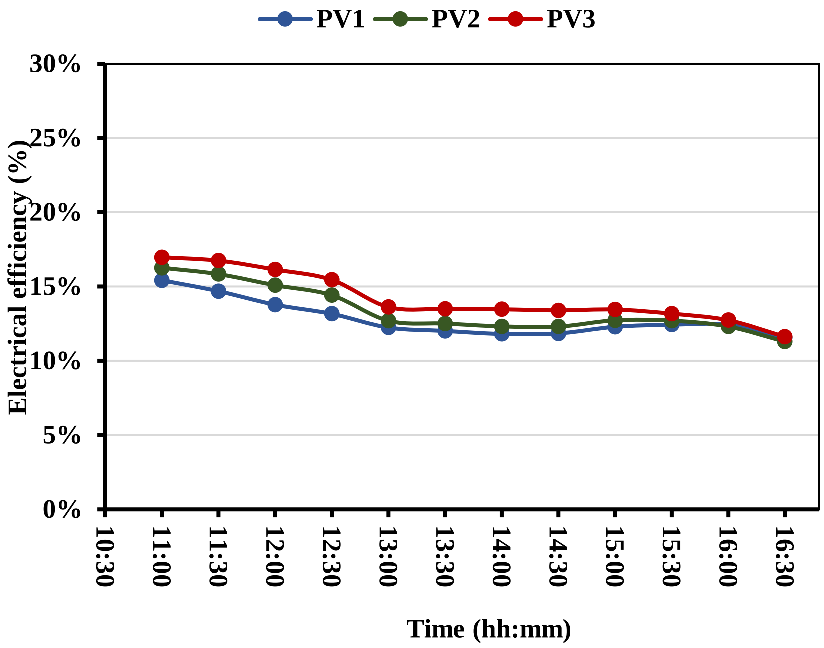


Figure 5.6. Electrical efficiency.

The electric efficiency of a solar panels is enumerated in accordance with the first and second law of thermodynamics, as there is a clear temperature difference among the panels as shown as in Figure 5.2, where the rate of electric efficiency of a first reference panel PV1 is 12%, while the rate of efficiency of the second panel cooled by thermal fins PV2 is 13%, while the efficiency rate of the third board, which is cooled by thermal fins and water sprays, is 14.2%, and the highest value of the electrical efficiency of this board reaches 17%. In Figure 5.7, the exergy efficiencies of the solar panels are shown.

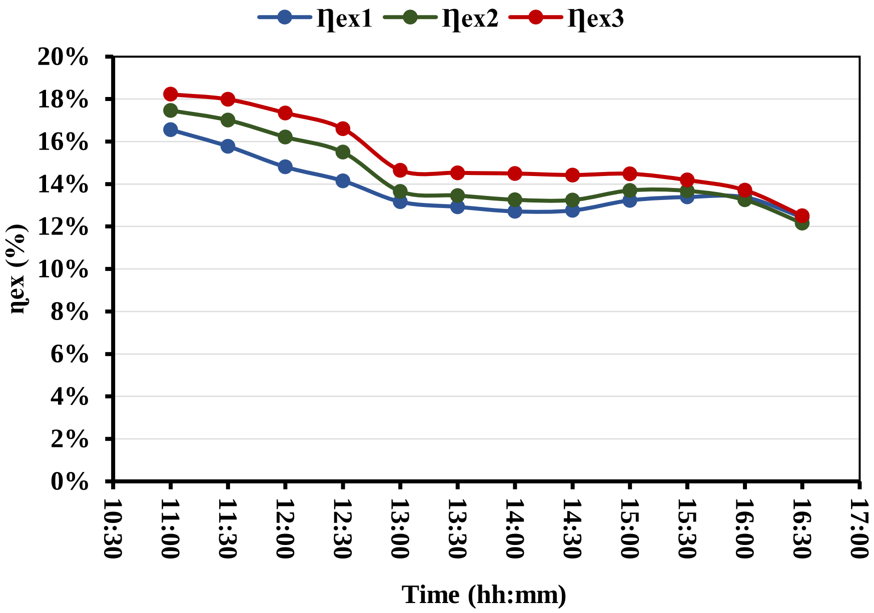


Figure 5.7. Exergy efficiencies.

The solar cells are inefficient relatively in conversion Solar radiation into electrical energy, as in Figure 5.7, where the exergy efficiency rate of the first panel, PV1, is about 13%, while the second panel, PV2, is 14%, while the efficiency of the third panel, PV3, is about 15%. The highest value for this panel reaches 18%. The value of irreversibility has been calculated for all panels as in Figure 5.8.

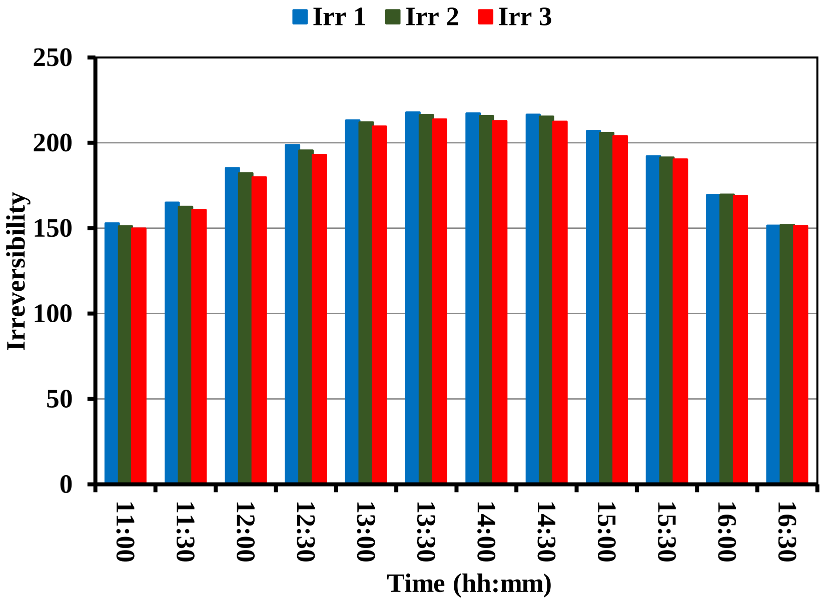


Figure 5.8. Irreversibility.

Here we see that the average value of irreversibility for the first panel, reference panel PV1, is 190.58 W, the rate for the second panel cooled with thermal fins PV2 is 189.21 W, and the rate of irreversibility for the third panel cooled with thermal fins and water sprays PV3 is 187.22 W, and the reflectivity is the waste energy or not used in the panel.

PART 6

CONCLUSION

The solar radiation drops on the solar cells, part of it converts into electric energy and another part turns in heat in a solar panel, and this last part negatively affects converting the sun's radiation on the panel in electrical energy. Many researchers have worked to minimize the temperature of a solar cell or solar panel to raise transformation efficiency. Inside it, in this experiment, I reduced the temperature by adding thermal fins made of aluminium to raise the area of heat exchange with the surroundings. Water sprays were added from an isolated container and a pump to spray water on these thermal fins at the lower face of a solar panel to minimize the temperature. whenever it reached a temperature of 45°C the pump working, and the pump stops Spraying water when the temperature reached 35°C was able to increase efficiency and reduce heat. Where the temperature rate decreased in the second and third panels, PV2, and PV3, by 11%, and 24%, in the same order, compared to the reference panel, which increased in the electrical conversion process, as the electrical efficiency of PV3, PV2 became 13%, 14%, respectively, and the value of the exergy efficiency increased. For PV3, PV2 was 14%, and 15% respectively emulation to the reference panel, and the electrical power raise for PV3, and PV2 by 31.63 watts, and 33.63 watts compared to the reference panel which gives 30.26 W.

PART 7

SUMMARY

In this experiment, use three monocrystalline panels, where cool a solar panel, and increased the efficiency and profitability of a solar panels as much as possible by using aluminium fins in the second panel and using aluminium fins with water spraying in the third panel, reducing temperatures, and increasing the power generated from each panel, the current and potential difference were calculated. Exergy efficiency compared to the reference panel is called the first panel that obtained an increase in the current, voltage difference, and energy generated from the solar panels, where the efficiency increased as an outcome of lowering the panel temp. in a simple and economically inexpensive way.

REFERENCES

1. Eicker, U., Colmenar-Santos, A., Teran, L., Cotrado, M., and Borge-Diez, D., "Economic evaluation of solar thermal and photovoltaic cooling systems through simulation in different climatic conditions: An analysis in three different cities in Europe", ***Energy And Buildings***, 70: 207–223 (2014).

2. Fumo, N., Bortone, V., and Zambrano, J. C., "Comparative analysis of solar thermal cooling and solar photovoltaic cooling systems", ***Journal Of Solar Energy Engineering***, 135 (2): (2013).

3. Trivella, A., Mohseni-Taheri, D., and Nadarajah, S., "Meeting corporate renewable power targets", ***Management Science***, (2022).

4. "Https://Www.Iea.Org/Reports/Renewable-Power", .

5. Internet: Eia, "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis / TODAY IN ENERGY", **https://www.eia.gov/todayinenergy/detail.php?id=42555** (2023).

6. Internet: 2022, B. S. R. of W. E., "World Electricity Generation - World Energy / Annual Shares Data", **https://www.worldenergydata.org/world-electricity-generation/** (2023).

7. Sawin, J. L., Sverrisson, F., Rutovitz, J., Dwyer, S., Teske, S., and Murdock, H. E., "Renewables 2018 - Global status report A comprehensive annual overview of the state of renewable energy Advancing the global renewable energy transition", France, (2018).

8. Mcbrien, J., "The Banality of the Anthropocene-Christophe Bonneuil and Jean-Baptiste Fressoz, The Shock of the Anthropocene: The Earth, History and Us, transl. by David Fernbach (New York, NY, Verso Books, 2015)", ***European Journal Of Sociology/Archives Européennes De Sociologie***, 59 (3): 399–407 (2018).

9. Mitchell, W. C., "Sombart’s Hochkapitalismus", ***The Quarterly Journal Of Economics***, 43 (2): 303–323 (1929).

10. Araújo, K., "The emerging field of energy transitions: Progress, challenges, and opportunities", ***Energy Research & Social Science***, 1: 112–121 (2014).

11. Hulme, M., "Reducing the future to climate: a story of climate determinism and reductionism", ***Osiris***, 26 (1): 245–266 (2011).

12. Laird, F. N., "Avoiding transitions, layering change: The evolution of American energy policy", Germany’s Energy Transition, ***Springer***, 111–131 (2016).

13. Turnbull, T., "Energy, history, and the humanities: against a new determinism", ***History And Technology***, 37 (2): 247–292 (2021).

14. "Https://Www.Theworldcounts.Com/Challenges/Climate-Change/Energy/Global-Energy-Consumption", .

15. Hashimoto, K., "The Future of Energy Consumption", Global Carbon Dioxide Recycling, ***Springer Singapore***, Singapore, 33–35 (2019).

16. . K. M. K., Murugaiyan, C., Sridharan, M., Murugan, S., and Elakiya, E., "An IoT based Green Home Architecture for Green Score Calculation towards Smart Sustainable Cities", ***KSII Transactions On Internet And Information Systems***, 15: 2377–2398 (2021).

17. "World Energy Use | Physics | | Course Hero", **https://www.coursehero.com/study-guides/physics/7-9-world-energy-use/** (2022).

18. "Sources of Energy - U.S. Energy Information Administration (EIA)", **https://www.eia.gov/energyexplained/what-is-energy/sources-of-energy.php** (2023).

19. "Http://Www.Earthtrends.Wri.Org/Pdf_library/Data_tables/Cli4_2003.Pdf. Accessed Nov 2005", **http://www.earthtrends.wri.org/pdf_library/data_tables/cli4_2003.pdf. Accessed Nov 2005** .

20. Lewis, N. S., Crabtree, G., Nozik, A. J., Wasielewski, M. R., Alivisatos, P., Kung, H., Tsao, J., Chandler, E., Walukiewicz, W., and Spitler, M., "Basic research needs for solar energy utilization. report of the basic energy sciences workshop on solar energy utilization, april 18-21, 2005", ***DOESC (USDOE Office of Science (SC))***, (2005).

21. "Http://Www.Worldwildlife.Org/Climate/Basic.Cfm. Accessed Nov 2005", .

22. De Soto, W., Klein, S. A., and Beckman, W. A., "Improvement and validation of a model for photovoltaic array performance", ***Solar Energy***, 80 (1): 78–88 (2006).

23. Ellabban, O., Abu-Rub, H., and Blaabjerg, F., "Renewable energy resources: Current status, future prospects and their enabling technology", ***Renewable And Sustainable Energy Reviews***, 39: 748–764 (2014).

24. Donovan, P., Woodward, W., Cherry, W. E., Morse, F. H., and Herwig, L. O., "An assessment of solar energy as a national energy resource", (1972).

25. "In 2019 the Solar PV Market Increased an Estimated 12% to around 115 GW | REVE News of the Wind Sector in Spain and in the World", **https://www.evwind.es/2020/07/05/in-2019-the-solar-pv-market-increased-an-estimated-12-to-around-115-gw/75561** (2022).

26. "In 2019 the Solar PV Market Increased an Estimated 12% to around 115 GW | REVE News of the Wind Sector in Spain and in the World", **https://www.evwind.es/2020/07/05/in-2019-the-solar-pv-market-increased-**

an-estimated-12-to-around-115-gw/75561 (2022).

27. "Solar Energy Advantages And Disadvantages Essay In Points English - WoR", **https://www.worthofread.com/solar-energy-advantages-and-disadvantages-essay-points-english/** (2022).

28. Zobaa, A. F. and Bansal, R. C., "Handbook of Renewable Energy Technology", ***World Scientific***, (2011).

29. "Explain the Construction and Working of the Solar Cell.", **https://www.toppr.com/ask/question/explain-the-construction-and-working-of-the-solar-cell/** (2022).

30. Jäger, K.-D., Isabella, O., Smets, A. H. M., van Swaaij, R. A., and Zeman, M., "Solar Energy: Fundamentals, Technology and Systems", ***UIT Cambridge***, (2016).

31. Bilgen, S., Keleş, S., Kaygusuz, A., Sarı, A., and Kaygusuz, K., "Global warming and renewable energy sources for sustainable development: a case study in Turkey", ***Renewable And Sustainable Energy Reviews***, 12 (2): 372–396 (2008).

32. "MPPT vs PWM Solar Charge Controllers – EPEVER Blog", **https://blog.epever.com/mppt-vs-pwm-solar-charge-controllers/** (2022).

33. Nault, R. M., "Basic research needs for solar energy utilization", ***Argonne National Laboratory***, (2005).

34. "Working Principle of a Solar Cell | Download Scientific Diagram", **https://www.researchgate.net/figure/Working-principle-of-a-solar-cell_fig1_322628682** (2022).

35. Jasim, O. M. J., Selimli, S., Dumrul, H., and Yilmaz, S., "Closed-loop aluminium oxide nanofluid cooled photovoltaic thermal collector energy and exergy analysis, an experimental study", ***Journal Of Energy Storage***, 50: 104654 (2022).

36. McEneny, E. and Parker, L., "Recent Advancements in Solar Energy", .

37. Kumavat, P. P., Sonar, P., and Dalal, D. S., "An overview on basics of organic and dye sensitized solar cells, their mechanism and recent improvements", ***Renewable And Sustainable Energy Reviews***, 78: 1262–1287 (2017).

38. Schmidt, F., Schonheit, D., and Kober, M., "Energy Solutions for Off-grid Applications", ***Deustche Energie-Agentur GmbH (Dena): Berlin, Germany***, 43 (2017).

39. "PV System Types and Components | AE 868: Commercial Solar Electric Systems", **https://www.e-education.psu.edu/ae868/node/872** (2022).

40. "Which Is Better – Crystalline or Thin-Film Module? - Ask Solar Mango",

https://www.solarmango.com/ask/2015/10/05/which-is-better-crystalline-or-thin-film-module/ (2022).

41. "What Are the Different Types of PV Modules? - Kern Solar Structures", **https://solar.kernsteel.com/what-are-the-different-types-of-pv-modules/** (2022).

42. Mesquita, D. de B., Silva, J. L. de S., Moreira, H. S., Kitayama, M., and Villalva, M. G., "A review and analysis of technologies applied in PV modules", (2019).

43. "Solar Panels and Difference Between Monocrystalline and Polycrystalline", **http://learn4electrical.altervista.org/difference-between-monocrystalline-and-polycrystalline-solar-panels/** (2022).

44. Green, M. A., Hishikawa, Y., Dunlop, E. D., Levi, D. H., Hohl-Ebinger, J., Yoshita, M., and Ho-Baillie, A. W. Y., "Solar cell efficiency tables (version 53) Progress in Photovoltaics", ***Res. Appl***, 27: 3–12 (2019).

45. Residencial, E. S. and Solar, G. D. E. E., "Tipos de painel solar fotovoltaico", ***PORTAL SOLAR***, 1–8 (2016).

46. Gordillo, G., "Photoluminescence and photoconductivity studies on ZnxCd1−xS thin films", ***Solar Energy Materials And Solar Cells***, 25 (1–2): 41–49 (1992).

47. "Thin-Film Solar Panels: What You Need To Know | EnergySage", **https://news.energysage.com/types-of-thin-film-solar-panels/** (2022).

48. Alkhalidi, A. and Dulaimi, N., "Design of an Off-Grid Solar PV System for a Rural Shelter", (2018).

49. Pathak, S. K., Sharma, P. O., Goel, V., Bhattacharyya, S., Aybar, H. Ş., and Meyer, J. P., "A detailed review on the performance of photovoltaic/thermal system using various cooling methods", ***Sustainable Energy Technologies And Assessments***, 51: 101844 (2022).

50. "Classification of Cooling Techniques | Download Scientific Diagram", **https://www.researchgate.net/figure/Classification-of-Cooling-Techniques_fig1_341875505** (2022).

51. Haidar, Z. A., Orfi, J., and Kaneesamkandi, Z., "Experimental investigation of evaporative cooling for enhancing photovoltaic panels efficiency", ***Results In Physics***, 11: 690–697 (2018).

52. Sato, D. and Yamada, N., "Review of photovoltaic module cooling methods and performance evaluation of the radiative cooling method", ***Renewable And Sustainable Energy Reviews***, 104: 151–166 (2019).

53. "Multi-Level Fin Heat Sinks for Solar Module Cooling – Pv Magazine International", **https://www.pv-magazine.com/2022/02/01/multi-level-fin-**

heat-sinks-for-solar-module-cooling/ (2022).

54. Wu, S.-Y., Zhang, Q.-L., Xiao, L., and Guo, F.-H., "A heat pipe photovoltaic/thermal (PV/T) hybrid system and its performance evaluation", ***Energy And Buildings***, 43 (12): 3558–3567 (2011).

55. Mehrotra, S., Rawat, P., Debbarma, M., and Sudhakar, K., "Performance of a solar panel with water immersion cooling technique", ***International Journal Of Science, Environment And Technology***, 3 (3): 1161–1172 (2014).

56. Dwivedi, P., Sudhakar, K., Soni, A., Solomin, E., and Kirpichnikova, I., "Advanced cooling techniques of PV modules: A state of art", ***Case Studies In Thermal Engineering***, 21: 100674 (2020).

57. Nižetić, S., Čoko, D., Yadav, A., and Grubišić-Čabo, F., "Water spray cooling technique applied on a photovoltaic panel: The performance response", ***Energy Conversion And Management***, 108: 287–296 (2016).

58. Moharram, K. A., Abd-Elhady, M. S., Kandil, H. A., and El-Sherif, H., "Enhancing the performance of photovoltaic panels by water cooling", ***Ain Shams Engineering Journal***, 4 (4): 869–877 (2013).

59. "Tapered-Edge Spray Distribution - Flat Spray Pattern Hydraulic Nozzles", **https://www.ikeuchi.eu/products/hydraulic-nozzles/flat-spray-pattern/mountain-shaped-spray-distribution/** (2022).

60. Suherman, S., Sunarno, A., Hasan, S., and Harahap, R., "Water and heat-sink cooling system for increasing the solar cell performances", ***EAI Endorsed Transactions On Energy Web***, 7 (26): (2019).

61. Hasan, H. A., Sherza, J. S., Mahdi, J. M., Togun, H., Abed, A. M., Ibrahim, R. K., and Yaïci, W., "Experimental Evaluation of the Thermoelectrical Performance of Photovoltaic-Thermal Systems with a Water-Cooled Heat Sink", ***Sustainability***, 14 (16): 10231 (2022).

62. Sultan, T. N., Farhan, M. S., and ALRikabi, H. T. H. S., "Using Cooling System for Increasing the Efficiency of Solar Cell", (2021).

63. Ghorpade, S., Farakte, B., Kulaye, S., Pawar, S., and Wagh, D., "EFFICIENCY IMPROVEMENT OF SOLAR PANEL USING DIFFERENT COOLING TECHNIQUES-A REVIEW", .

64. Ali, A. H., Abdalrahman, K. H. M., and Wahid, S. S., "STUDYING THE INFLUENCE OF DIFFERENT COOLING TECHNIQUES ON PHOTOVOLTAIC-CELLS PERFORMANCE", ***Journal Of Modern Research***, 1 (1): 13–18 (2019).

65. Irwan, Y. M., Leow, W. Z., Irwanto, M., Fareq, M., Hassan, S. I. S., Safwati, I., and Amelia, A. R., "Comparison of solar panel cooling system by using dc brushless fan and dc water", (2015).

66. Abdulgafar, S. A., Omar, O. S., and Yousif, K. M., "Improving the efficiency of polycrystalline solar panel via water immersion method", ***International Journal Of Innovative Research In Science, Engineering And Technology***, 3 (1): 8127–8132 (2014).

67. Hussien, H. A., Numan, A. H., and Abdulmunem, A. R., "Improving of the photovoltaic/thermal system performance using water cooling technique", (2015).

68. Pathipooranam, P., "An Enhancement of the Solar Panel Efficiency–A Comprehensive Review", ***Frontiers In Energy Research***, 1090 .

69. Hassan, Y., Orabi, M., Alshreef, A., M. Al-Rabghi, O., Habeebullah, B. A., El Aroudi, A., and A. Ismeil, M., "Improvement of Extracted Power of Pole Mounted Solar Panels by Effective Cooling Using Aluminum Heat Sink under Hot Weather and Variable Wind Speed Conditions", ***Energies***, 13 (12): 3159 (2020).

70. Hasan, I. A., "Enhancement the performance of PV panel by using fins as heat sink", ***Engineering And Technology Journal***, 36 (7 Part A): 798–805 (2018).

71. Ibrahim, A. K., "Improving the Solar Panel Efficiency by Using Cooling and Cleaning Techniques", ***Journal Of University Of Babylon, Engineering Sciences***, (1): (2018).

72. Yesildal, F., Ozakin, A. N., and Yakut, K., "Optimization of operational parameters for a photovoltaic panel cooled by spray cooling", ***Engineering Science And Technology, An International Journal***, 25: 100983 (2022).

73. Laseinde, O. T. and Ramere, M. D., "Efficiency Improvement in polycrystalline solar panel using thermal control water spraying cooling", ***Procedia Computer Science***, 180: 239–248 (2021).

74. Alzaabi, A. A., Badawiyeh, N. K., Hantoush, H. O., and Hamid, A. K., "Electrical/thermal performance of hybrid PV/T system in Sharjah, UAE", ***International Journal Of Smart Grid And Clean Energy***, 3 (4): 385–389 (2014).

75. Schiro, F., Benato, A., Stoppato, A., and Destro, N., "Improving photovoltaics efficiency by water cooling: Modelling and experimental approach", ***Energy***, 137: 798–810 (2017).

76. Ceylan, I., Gürel, A. E., Demircan, H., and Aksu, B., "Cooling of a photovoltaic module with temperature controlled solar collector", ***Energy And Buildings***, 72: 96–101 (2014).

77. Kabeel, A. E. and Abdelgaied, M., "Performance enhancement of a photovoltaic panel with reflectors and cooling coupled to a solar still with air injection", ***Journal Of Cleaner Production***, 224: 40–49 (2019).

78. Elminshawy, N. A. S., El-Ghandour, M., Elhenawy, Y., Bassyouni, M., El-

Damhogi, D. G., and Addas, M. F., "Experimental investigation of a V-trough PV concentrator integrated with a buried water heat exchanger cooling system", ***Solar Energy***, 193: 706–714 (2019).

79. Bahaidarah, H., Subhan, A., Gandhidasan, P., and Rehman, S., "Performance evaluation of a PV (photovoltaic) module by back surface water cooling for hot climatic conditions", ***Energy***, 59: 445–453 (2013).

80. Rajasekar, R., Prasannaa, P., and Ramkumar, R., "Efficiency of solar PV panel by the application of coconut fibres saturated by earthen clay pot water", ***Environmental Technology***, 42 (3): 358–365 (2021).

81. Rajvikram, M. and Sivasankar, G., "Experimental study conducted for the identification of best heat absorption and dissipation methodology in solar photovoltaic panel", ***Solar Energy***, 193: 283–292 (2019).

82. Abdo, S., Saidani-Scott, H., Borges, B., and Abdelrahman, M. A., "Cooling solar panels using saturated activated alumina with saline water: experimental study", ***Solar Energy***, 208: 345–356 (2020).

83. Ghadikolaei, S. S. C., "An enviroeconomic review of the solar PV cells cooling technology effect on the CO2 emission reduction", ***Solar Energy***, 216: 468–492 (2021).

84. Lari, M. O. and Sahin, A. Z., "Effect of retrofitting a silver/water nanofluid-based photovoltaic/thermal (PV/T) system with a PCM-thermal battery for residential applications", ***Renewable Energy***, 122: 98–107 (2018).

85. Peng, Z., Herfatmanesh, M. R., and Liu, Y., "Cooled solar PV panels for output energy efficiency optimisation", ***Energy Conversion And Management***, 150: 949–955 (2017).

86. Castanheira, A. F. A., Fernandes, J. F. P., and Branco, P. J. C., "Demonstration project of a cooling system for existing PV power plants in Portugal", ***Applied Energy***, 211: 1297–1307 (2018).

87. Siahkamari, L., Rahimi, M., Azimi, N., and Banibayat, M., "Experimental investigation on using a novel phase change material (PCM) in micro structure photovoltaic cooling system", ***International Communications In Heat And Mass Transfer***, 100: 60–66 (2019).

88. Rajput, U. J. and Yang, J., "Comparison of heat sink and water type PV/T collector for polycrystalline photovoltaic panel cooling", ***Renewable Energy***, 116: 479–491 (2018).

89. Abdo, S., Saidani-Scott, H., Benedi, J., and Abdelrahman, M. A., "Hydrogels beads for cooling solar panels: Experimental study", ***Renewable Energy***, 153: 777–786 (2020).

90. Khanjari, Y., Pourfayaz, F., and Kasaeian, A. B., "Numerical investigation on using of nanofluid in a water-cooled photovoltaic thermal system", ***Energy***

Conversion And Management, 122: 263–278 (2016).

91. Irwan, Y. M., Leow, W. Z., Irwanto, M., Amelia, A. R., Gomesh, N., and Safwati, I., "Indoor test performance of PV panel through water cooling method", ***Energy Procedia***, 79: 604–611 (2015).

92. Bahaidarah, H. M., Rehman, S., Gandhidasan, P., and Tanweer, B., "Experimental evaluation of the performance of a photovoltaic panel with water cooling", (2013).

93. Bijjargi, Y. S., Kale, S. S., and Shaikh, K. A., "Cooling techniques for photovoltaic module for improving its conversion efficiency: A review", ***Int. J. Mech. Eng. Technol.(IJMET)***, 7 (4): 22–38 (2016).

94. Rajasekar, R., Ramkumar, R., and Prasannaa, P., "An experimental evaluation on revamping the productivity of solar PV panel using wind tunnel as an optimizer", (2021).

95. Bashir, M. A., Ali, H. M., Amber, K. P., Bashir, M. W., Ali, H., Imran, S., and Kamran, M. S., "Performance investigation of photovoltaic modules by back surface water cooling", ***Thermal Science***, 22 (6 Part A): 2401–2411 (2018).

96. Gotmare, J. A. and Prayagi, S. V, "Enhancing the performance of photovoltaic panels by stationary cooling", ***Int J Sci Eng Technol***, 2 (7): 1465–1468 (2014).

97. Elnozahy, A., Rahman, A. K. A., Ali, A. H. H., Abdel-Salam, M., and Ookawara, S., "Performance of a PV module integrated with standalone building in hot arid areas as enhanced by surface cooling and cleaning", ***Energy And Buildings***, 88: 100–109 (2015).

98. Ali, M., Ali, H. M., Moazzam, W., and Saeed, M. B., "Performance enhancement of PV cells through micro-channel cooling", ***WEENTECH Proceedings In Energy GCESD, Technology Park***, 24: 211 (2015).

99. Masalha, I. A. L., Abdullah, N. N., and Rawashdeh, M. O., "Experimental and numerical investigation of PV module for better efficiency using porous media", ***International Journal Of Mechanical And Production Engineering Research And Development***, 9 (4): 1283–1302 (2019).

100. Salih, S. M., Abd, O. I., and Abid, K. W., "Performance enhancement of PV array based on water spraying technique", ***Int. J. Sustain. Green Energy***, 4 (16): 8–13 (2015).

101. Salameh, T., Tawalbeh, M., Juaidi, A., Abdallah, R., and Hamid, A.-K., "A novel three-dimensional numerical model for PV/T water system in hot climate region", ***Renewable Energy***, 164: 1320–1333 (2021).

102. Manasrah, A., Alkhalil, S., and Masoud, M., "Investigation of multi-way forced convective cooling on the backside of solar panels", ***Int. J. Energy Convers.(IRECON)***, 8: 181 (2020).

103. Vittorini, D. and Cipollone, R., "Fin-cooled photovoltaic module modeling–Performances mapping and electric efficiency assessment under real operating conditions", ***Energy***, 167: 159–167 (2019).

104. Chandrasekar, M., Suresh, S., and Senthilkumar, T., "Passive cooling of standalone flat PV module with cotton wick structures", ***Energy Conversion And Management***, 71: 43–50 (2013).

105. Baloch, A. A. B., Bahaidarah, H. M. S., Gandhidasan, P., and Al-Sulaiman, F. A., "Experimental and numerical performance analysis of a converging channel heat exchanger for PV cooling", ***Energy Conversion And Management***, 103: 14–27 (2015).

106. Rahimi, M., Valeh-e-Sheyda, P., Parsamoghadam, M. A., Masahi, M. M., and Alsairafi, A. A., "Design of a self-adjusted jet impingement system for cooling of photovoltaic cells", ***Energy Conversion And Management***, 83: 48–57 (2014).

107. Valeh-e-Sheyda, P., Rahimi, M., Karimi, E., and Asadi, M., "Application of two-phase flow for cooling of hybrid microchannel PV cells: a comparative study", ***Energy Conversion And Management***, 69: 122–130 (2013).

108. Younas, M. F., Abubaker, M., Ali, H. M., Nawaz, M. A., Hassan, M., Awan, M. J., Hassan, R. S., Rasool, A., and Sultan, K. A., "Effect of active water cooling on the performance of PV module using steel channels", ***VW Applied Sciences***, 2 (1): 52–58 (2020).

109. Arshad, R., Tariq, S., Niaz, M. U., and Jamil, M., "Improvement in solar panel efficiency using solar concentration by simple mirrors and by cooling", (2014).

110. Singh, P., Khanna, S., Newar, S., Sharma, V., Reddy, K. S., Mallick, T. K., Becerra, V., Radulovic, J., Hutchinson, D., and Khusainov, R., "Solar photovoltaic panels with finned phase change material heat sinks", ***Energies***, 13 (10): 2558 (2020).

111. Fakouriyan, S., Saboohi, Y., and Fathi, A., "Experimental analysis of a cooling system effect on photovoltaic panels’ efficiency and its preheating water production", ***Renewable Energy***, 134: 1362–1368 (2019).

112. Odeh, S. and Behnia, M., "Improving photovoltaic module efficiency using water cooling", ***Heat Transfer Engineering***, 30 (6): 499–505 (2009).

113. Wongwuttanasatian, T., Sarikarin, T., and Suksri, A., "Performance enhancement of a photovoltaic module by passive cooling using phase change material in a finned container heat sink", ***Solar Energy***, 195: 47–53 (2020).

114. Bahaidarah, H. M. S., "Experimental performance evaluation and modeling of jet impingement cooling for thermal management of photovoltaics", ***Solar Energy***, 135: 605–617 (2016).

RESUME

Omar Rashid Ismael ISMAEL, a mechanical engineer, graduated from the College of Engineering, Tikrit University, and obtained a bachelor's degree in 2003. He is currently studying a master's degree at Karabuk University, Department of Mechanical Engineering.