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SIMULATION BY MATLAB IN RENEWABLE ENERGY SYSTEMS AND DEVICES

Halah Kareem ATTALLA

Master`s Thesis

Supervisor

Asst. Prof. Dr. Merve BULUT YILGÖR

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The thesis titied SIMULATION BY MATLAB IN RENEWABLE ENERGY SYSTEMS AND DEVICES prepared by HALAH KAREEM ATTALLA and submitted on 24/07/2023 has been **accepted unanimously** for the degree Master of Science in Industrial Engineering.

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Halah Kareem ATTALLA

Signature

ABSTRACT

SIMULATION BY MATLAB IN RENEWABLE ENERGY SYSTEMS AND DEVICES

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The purpose of this study is to address the current energy crisis, which is represented by fossil fuels and the increasing rise in fuel prices, as well as the unequal distribution of energy sources, which makes some people unable to use it, as well as some countries that still use traditional sources.
As a result, a safe and environmentally friendly alternative fuel must be discovered at a low cost and widely available to ensure that everyone has access to it.

It was found that hydrogen is an effective and safe element in the use of energy, as it is considered the least harmful element to the environment. It is known that hydrogen does not exist freely in nature, and it can be obtained in many and many ways, but some methods are unsafe.

In this research, a simulation of the production of green hydrogen using solar energy was done by MATLAB and by using the electrolysis device for the water generated from the photovoltaic cell. Then the hydrogen produced was stored in special tanks to be used at a later time, in addition to the use of each of the PID control units, which increased the efficiency of the system with the forward MPPT algorithm to obtain the maximum amount of solar energy contained in the photovoltaic cell.

Keywords: Electrolysis. PID, MPPT, MATLAB.

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ABBREVIATIONS

MPPT	:	Maximum PowerPoint Tacker
PV	:	Photovoltaic
PID	:	Proportional–Integral–Derivative controller
PI	:	Proportional Integral
IEA	:	International Energy Agency
IRENA	:	International Renewable Energy Agency
OPEC	:	Organization of the Petroleum Exporting Countries
API	:	American Petroleum Institute
LSM	:	Strontium Standard Manganese Lanthanum
LSF	:	Lanthanum Strontium Ferrite
SOFC	:	Solid Oxide Fuel Cell
PH	:	Potential of Hydrogen
DC-DC Converter	:	An Electronic Device that Converts a Source of Direct Current (DC) From One Voltage Level to Another
MPP	:	Maximum PowerPoint
PWM	:	Pulse Width Modulation
P&O	:	Perturbation and Observation
IC	:	Incremental Conductance
AC	:	Alternative Current
DC	:	Direct Current
RSH	:	Resistance
EL	:	Electrolysis

LIST OF SYMBOLS

E	:	The Amount of Energy Produced Measured in Watts
W	:	The Amount of Running Water per Litre per Second
H	:	Height of Water Column by The Meter at The Front of The Dam
G	:	Ground Acceleration
P	:	Mechanical power
ρ	:	Air Density
A	:	Area Swept by The Rotor Blades
V	:	Velocity of The Air
η_{carnot}	:	Carnot's Law
u	:	The Change in Potential Energy
Fe	:	Electrical Force
d	:	The Magnitude of The Displacement
ϑ	:	Cosine of The Angle between The Force and The Displacement
E	:	Electric Field
lo& Vo	:	Cell Output Current and Voltage
Irs	:	Cell Reverse Saturation Current
k	:	Boltzmann's Constant
T	:	Cell Temperature
I	:	Discharge Current
IL	:	Current Created by a Photo

I D	:	Diode Current
I SH	:	Shunt Current
Vj	:	Voltage Across both Diode and Resistor RSH
V	:	Voltage across The Output Terminals
I	:	Output Current
RS	:	Series Resistance
Kp	:	The Proportional Term
Ki	:	An Integral Term
Kd	:	Derivative Term
ΔVref	:	Reference Input Voltage Deviation over Temperature Range
$G_c(s)$	:	The Continuous-Time Equivalent expression

1. INTRODUCTION AND PURPOSE

In total energy worldwide each year, around 10 million tons of crude oil are produced. Moreover, this production depends on non-renewable primary sources; due to demographic changes on a global scale, as well as the economic efforts of expansion countries, it was found that there will be a significant increase in energy by 2040-2050. This leads to unequal access to energy among all countries. Increasing global energy consumption will reduce these impacts. Moreover, fossil and nuclear resources cause air pollution and greenhouse effects, deteriorating air quality and causing health barriers. After these risks and adverse effects, it was found that the current energy system is not viable at the medium- and long-term levels.

Climate change is one of the most severe threats to the sustainability of the planet's environment and human health and well-being. In terms of the global economy, it results in the global reserves of oil and natural gas being depleted. The continued rise in fossil fuel prices and long-term insecurity [1].

This has put the global economy in contradiction with the Sustainable Development Goals in increasing the demand for new and non-polluting sources for the environment. It is necessary to ensure a uniform and orderly distribution of energy. This requires the development of a technology for storing solar energy to separate energy demand and production and enable its transportation. This should be compatible with the global production of this Part of our work is the study of solar fuel. The fuel can be transported through pipelines or stored in tanks to be directed to points of consumption, such as (automotive, industry, energy, etc.) and the energy value will be returned.

It is worth noting that the production of fuel from solar energy amounts to storing it in the chemical form of hydrogen associated with many other elements in nature, whose combustion does not lead to pollution, so it is the ideal solar fuel given the promising prospects for fuel cells and hydrogen heat engines, A hydrogen energy system can then be proposed as an alternative or at least a complementary solution to the existing energy system

1.2 GLOBAL ENERGY CONSUMPTION

Energy is considered one of the basics of life because it is involved in many fields such as transportation, agriculture, industry, electricity, and the provision of multiple sources of energy (conventional, renewable) over the decades and the continuation of demand and its increase over recent years. After all, energy has a significant role in meeting consumer demands as it has increased. In many countries of the world, the global consumption of energy is estimated to be approximately 418 oxy joules in 2019, which shows the volume of demand from 1900-2020.

This increase in demand is due to population growth, development, and the use of modern technology, which led to economic growth, as shown in (Figure 1.1) [2].

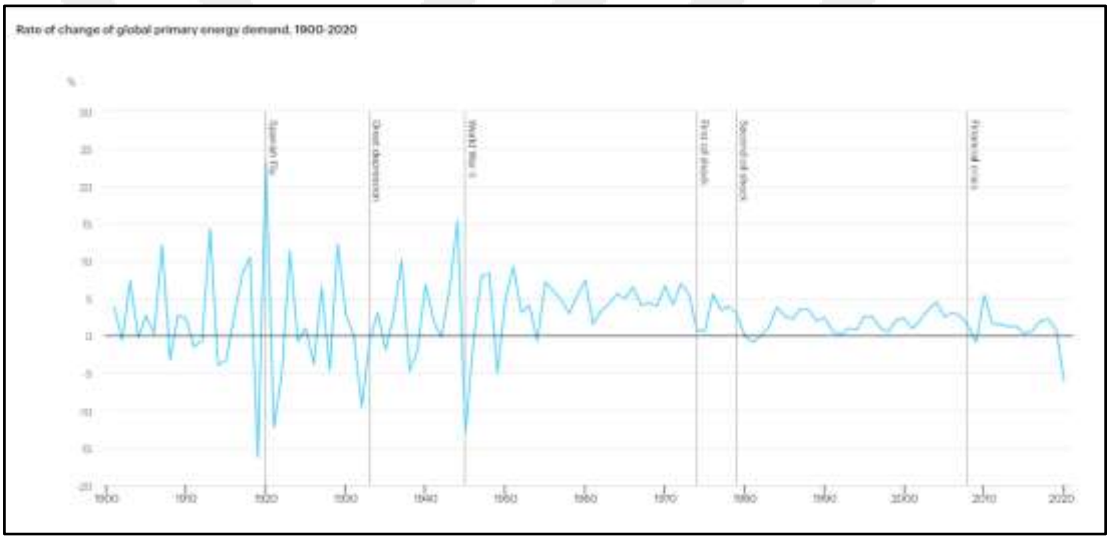


Figure 1.1: Rate of Change of Global Demand, 1900-2020.

The following (Figure 1.2) shows the difference between the volume of demand from 1971-2019 (Figure 1.3) [3]

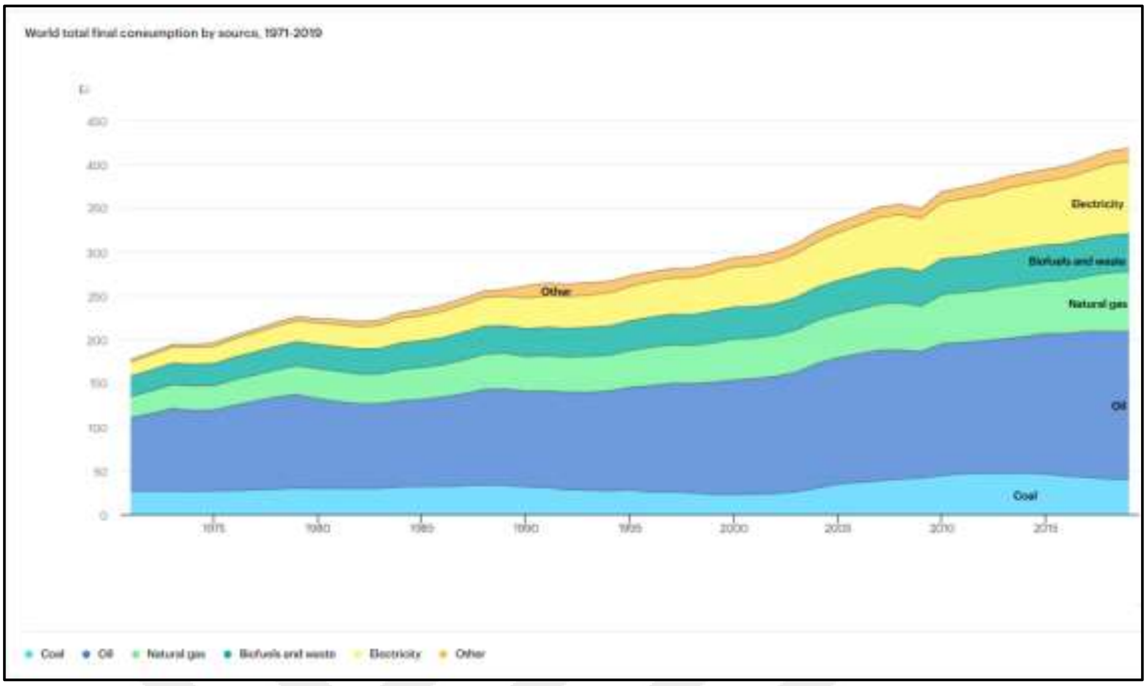


Figure 1.2: The Difference between the Volume of Demand for the Period From 1971-2019. [3].

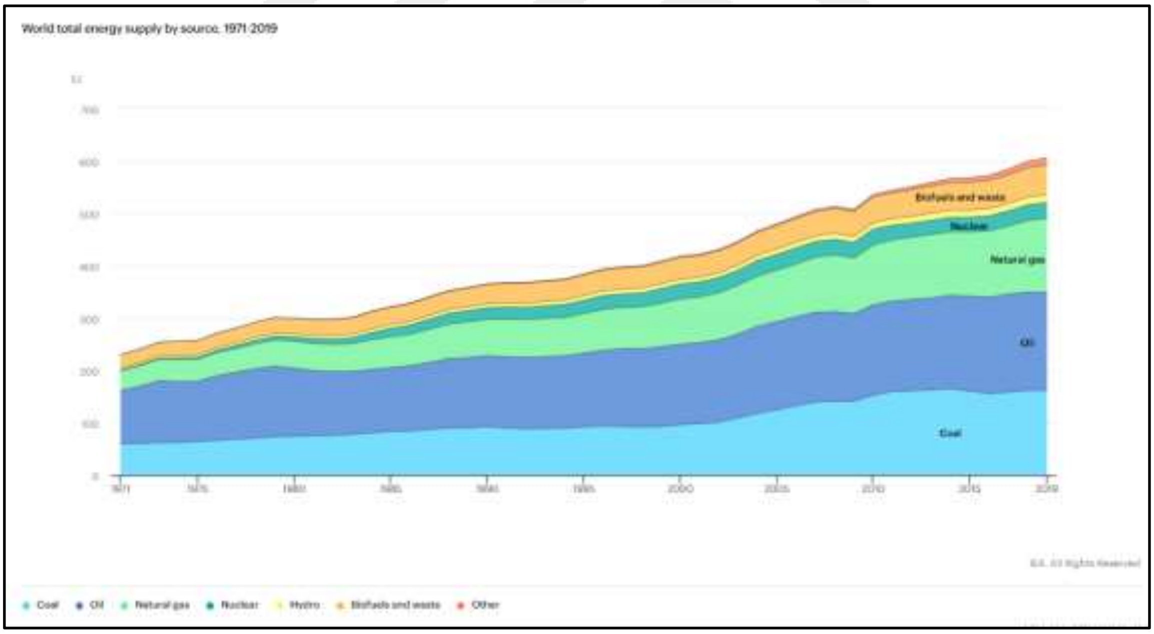


Figure 1.3: World Total Energy Supply by Source, 1971-2019 [3].

This development is restricted and limited due to the emissions of polluting gases such as oxides of sulfur, nitrogen, and methane, which cause an obstacle in the absorption of thermal infrared radiation from the earth into space (Figure 1.4).

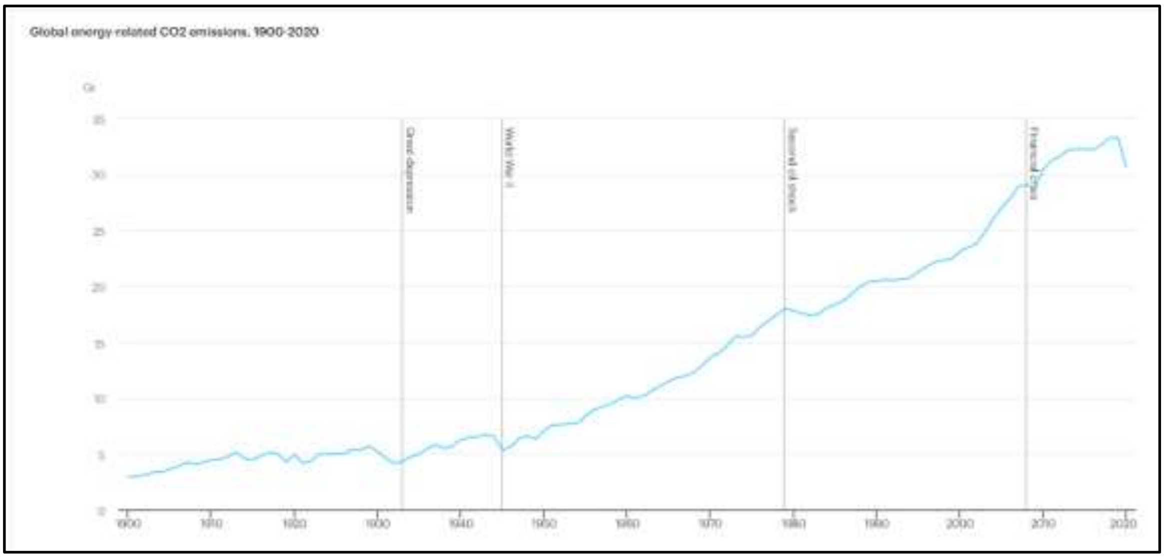


Figure 1.4: Global Energy-Related CO2 Emissions, 1900-2020 [4].

a. This development is restricted and limited due to the emissions of polluting gases such as oxides of sulfur, nitrogen, and methane, which cause an obstacle in the absorption of thermal infrared radiation from the Earth into space, as shown in the figure. It is assumed that the world's population will have access to energy with high efficiency, as it is according to modern, Innovative, safe technology and techniques, so it must include emissions of carbon dioxide and other gases at a lesser or non-existent rate. These are produced due to the limited use of alternative energy sources (coal, oil, gas), which, when burned, produce multiple oxides (nitrogen and sulfur oxides). An attempt to control these emissions by using new techniques during the work of electrostatic precipitates and removing sulfur and nitrogen.

b. Everyone has access to energy in a guaranteed manner and at reasonable prices because some countries are still using primitive sources due to the poverty of that country.

c. Full utilization of what is used or wasted energy to reach energy balance.

Energy is generated according to the following figure that shows the raw energy that enters equipment, stations, and boilers, which is converted according to the function of each device to obtain (electricity, steam, and compressed air) (Figure 1.5).

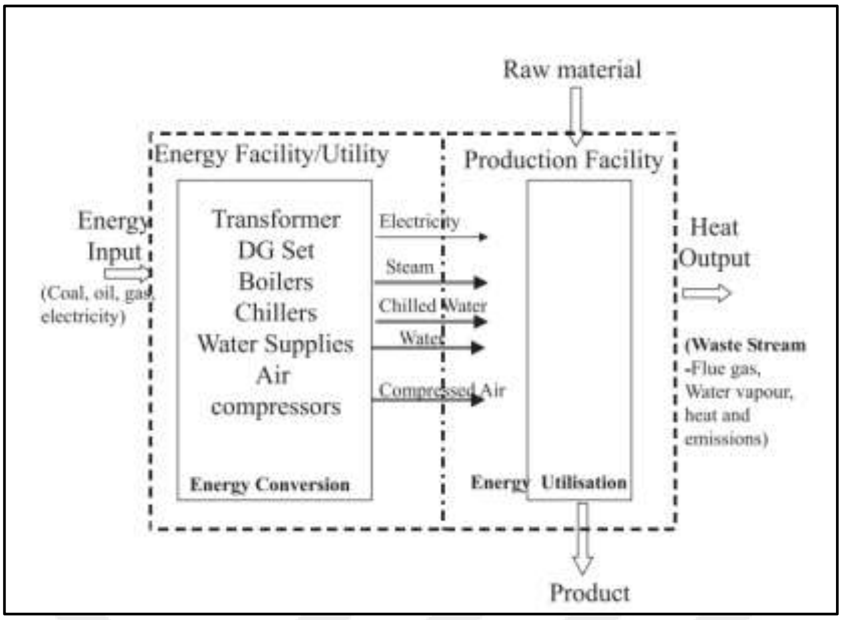


Figure 1.5: Plant Energy System.

Energy sources are of two types:

a. Traditional sources such as (coal, oil, natural gas, and nuclear energy) these sources are available and have been discovered and have been in human use for decades. However, these sources are subject to depletion and are the source of global warming caused by extraction, transportation, refining, and electricity generation at an estimated rate of about 65%, according to the Environmental Protection Agency report. It is expensive in some countries.

b. Alternative sources such as (solar energy, wind energy, ground energy, biomass, hydro power, and tidal energy) can generate electricity or heat and transport and emit little or almost no harmful gases. Energy is abundant, and its price is appropriate and available, but these sources depend on fluctuations and climate, so there must be plans and ideal storage devices to preserve this energy, as in (Figure 1.6), the difference between 1973 and 2019 according to the source.

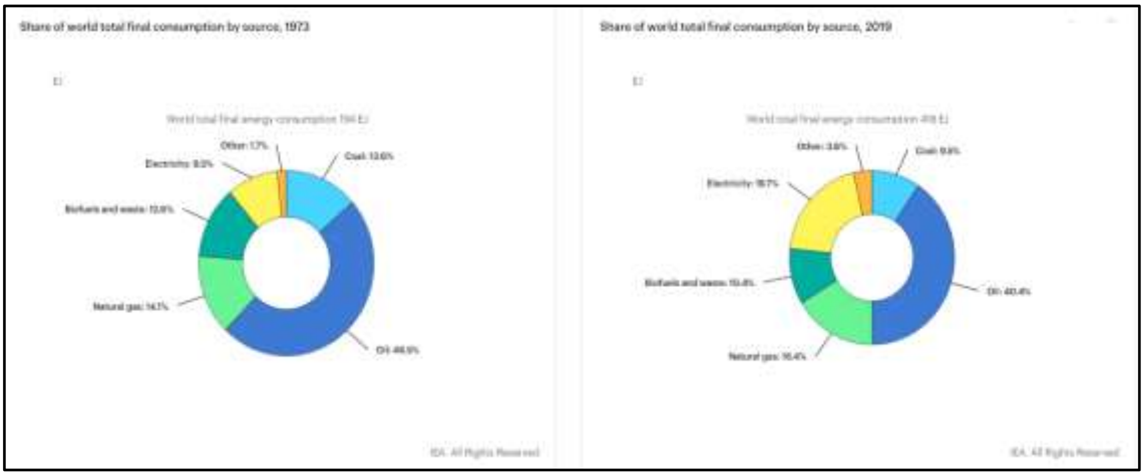


Figure 1.6: Share of World Total Final Consumption by Source, 2019 [5].

1.3 WORLD ELECTRICITY REQUEST AND GENERATION

Electricity is the central pillar of the progress of countries and the essential operational engine in the various areas that enter our daily lives as the world has seen an increase in electricity demand recently, resulting in an increase in greenhouse gas rates in addition to the increase in prices.

Equipment and generators used in the generation and the use of certain types of fuel are the cause of environmental pollution. Electric power generation is usually done using fossil fuels, oil, and coal gas and has been used for many years and continues to put pressure on specific sources that causes the shortage of natural resources and pollution of the environment, so it is better to use a combination of fuel in power plants. In stations, generators, and power processing, it must be a state of balance between supply and demand and balancing variable supply with variable demand.

Demand is expected to reach 38,700 TW h in 2050, while in 2020, it will reach 23,300 TW h and will reach about 30,300 in 2030, as shown by the volume of pollution per source and a comparison between 2020 and 2050, in which emissions should be zero for carbon dioxide (Figure 1.7).

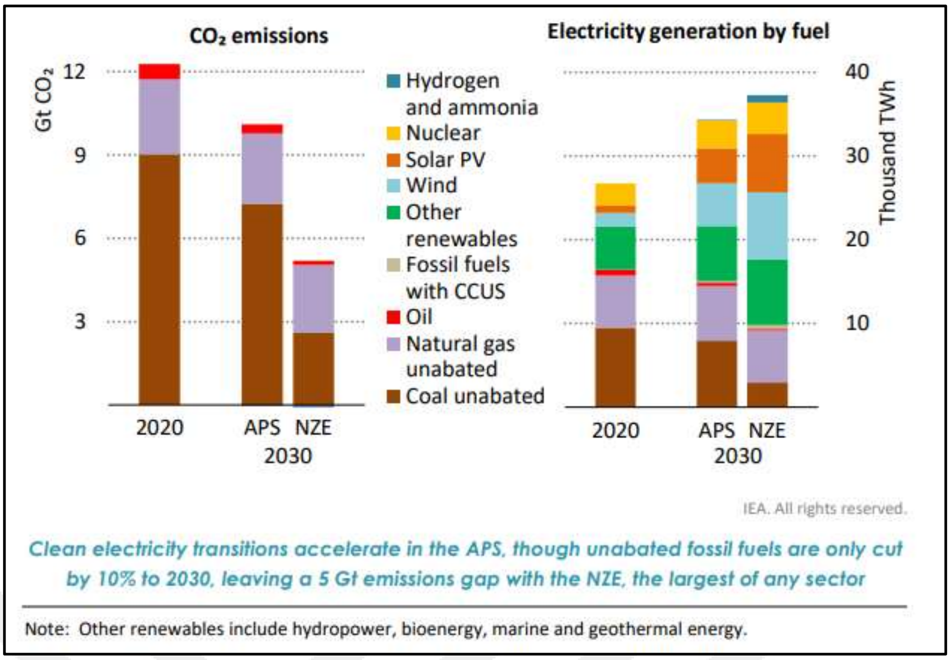


Figure 1.7: Global Electricity Sector CO2 Emissions and Generation by Source in The Announced Pledges and Net Zero Emissions by 2050 Scenarios.

Established nations generate more electricity than their less established counterparts. Knowing that there are still countries without electricity to this day, with an estimated 759 million people, and not everyone has access to electricity is one of the sustainable development goals (The seventh goal), which ensures that everyone has equal access to electricity and the use of new sources of energy, and the percentage of the populace that does not have access to electricity is one indicator of a country's level of development. The world's electricity production is about 27,744,800 terawatts for the year 2020. The figure below shows the global electricity production by type of fuel used from 1985 to 2020.

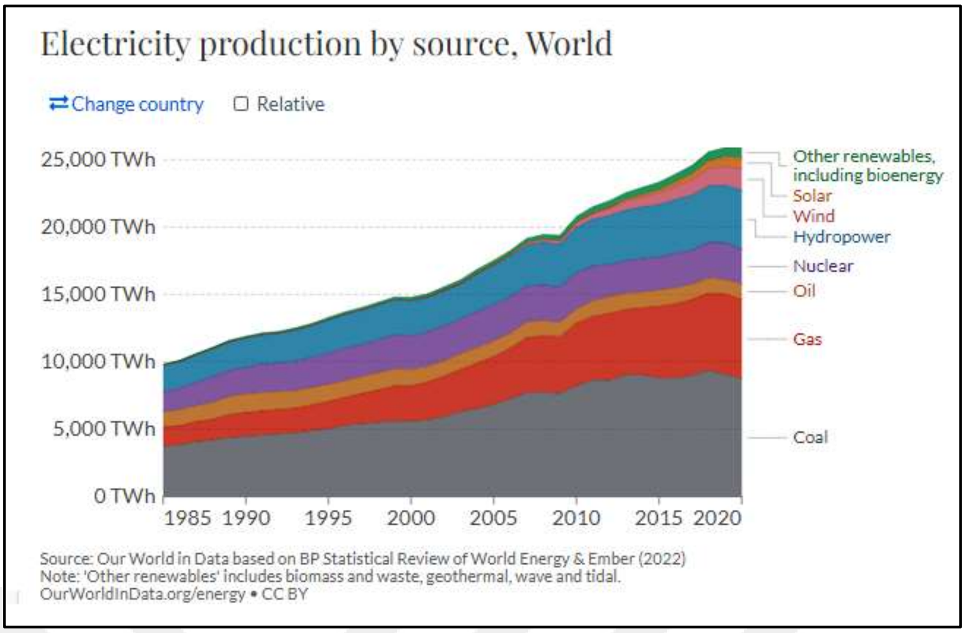


Figure 1.8: Global Electricity Production by Type of Fuel Used for The Period From 1985-2020.

China is one of the world's highest electric power producers, with an estimated electricity production of 5,883,000 TW h.

One of the priorities of energy production is that it should be efficient, reliable, and safe, working according to technical and administrative applications that address the primary inputs and processes to obtain satisfactory and accurate results in energy systems. The energy management mechanism is at reasonable prices. The sectors that have the most impact on air pollution and carbon emissions are the use of coal, if it has the largest share of the pollution rate, and then oil and natural gas in the electricity sector, as shown in the figure that shows electricity generation for the period from 1990-2020.

The sectors that have the most impact on air pollution and carbon emissions are the use of coal. If it has the largest share of the pollution rate, then oil and natural gas are the electricity sector, as shown in (Figure 1.9) which shows electricity generation from 1990-2020.

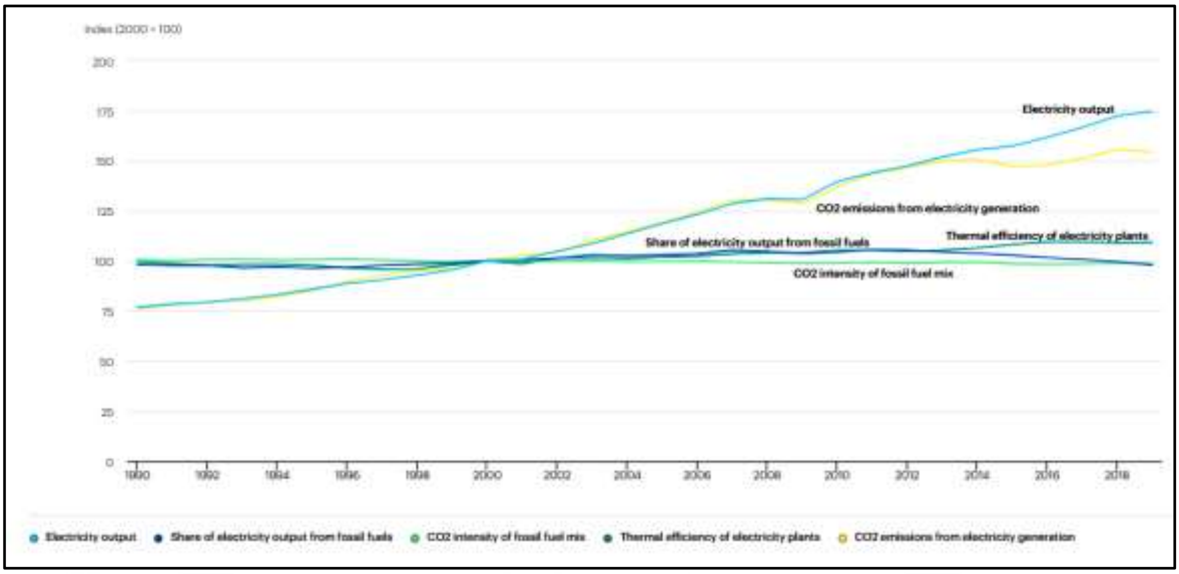


Figure 1.9: Electricity Generation for the period from 1990-2020 [8].

A generation used to come exclusively from fossil fuels, but times have changed. These days, renewable energy sources (such as solar, wind, biomass, and hydrogen) account for a growing share of the global energy supply, and efforts are being made to replace fossil fuel power plants with hybrid ones that run on a broader variety of fuels.

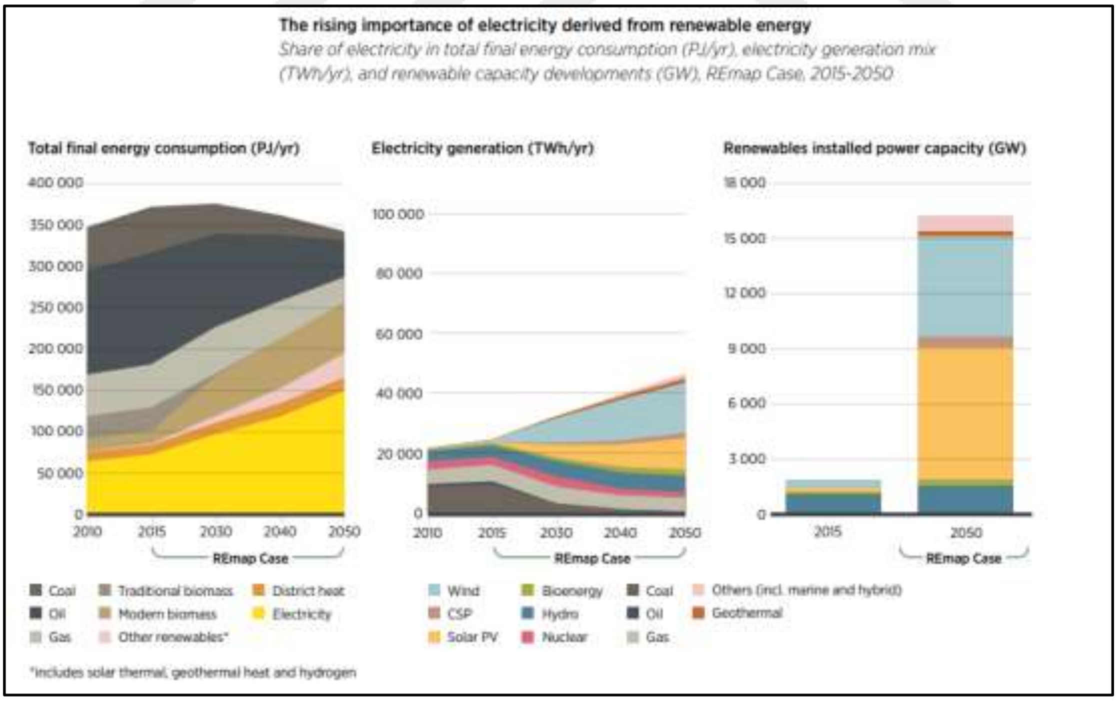


Figure 1.10: The Rising Importance of Electricity Derived from Renewable Energy [9].

1.4 IRAQ REQUEST AND GENERATION

Electricity is the basis of life and people's well-being and a measure of countries' development because it is involved in many fields. It is impossible to live without electricity, and everyone's access to electricity is measured by the scale of the country's progress and the development of the economy. Iraq is considered one of the countries rich in energy sources (fossil fuels) (oil and natural gas), as Iraq occupies the top rank in the world's crude oil reserves, reaching (153) billion barrels. The statistics for 2016 were ranked tenth in natural gas reserves, with an estimated (126.7) trillion cubic feet for 2016 that Iraq burns large amounts of gas associated with oil daily, as it ranks fourth in the world. Figure blew the amount of consumption and production of electrical energy (Figure 1.11) [6].

B

Figure 1.11: The Annual Tons of Crude and Fuel Oil Used to Generate Energy (A) and T Total TJs of Natural Gas Used for This Purpose (B) From 1990 to 2017 [7].

[8], [9]Due to the delay in meeting the standard daily requirements of residents and the increase in energy demand in recent years due to population growth and development, environmental and water quality suffer from a shortage of energy supply and long hours. Knowing that the government has made substantial investments in the field of electricity, as well as the fact that technological and climate change has caused continuous interruptions, which have increased the large gap between the demand for electricity and the maximum network work from (6000) megawatts to (9500) megawatts, has led to an increase in interruptions. As shown in (Figure 1.12), the cost of fixing Iraq's energy problem is expected to exceed a trillion dinars between 2010 and 2020.

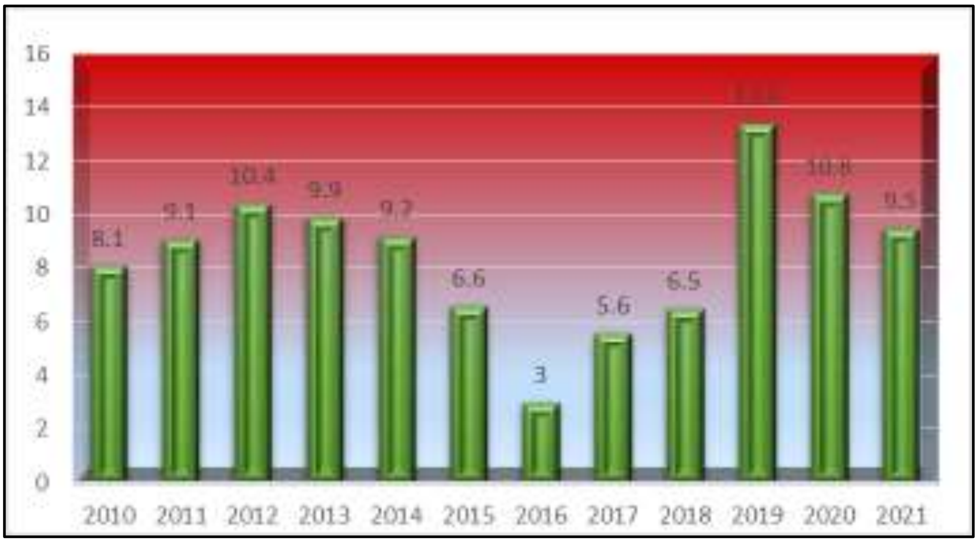


Figure 1.12: The Continuation of The Iraqi Energy Crisis.

Energy consumption of crude oil according to the figure, supply, and demand for energy from 2018 to 2030, as shown in (Figure 1.13).

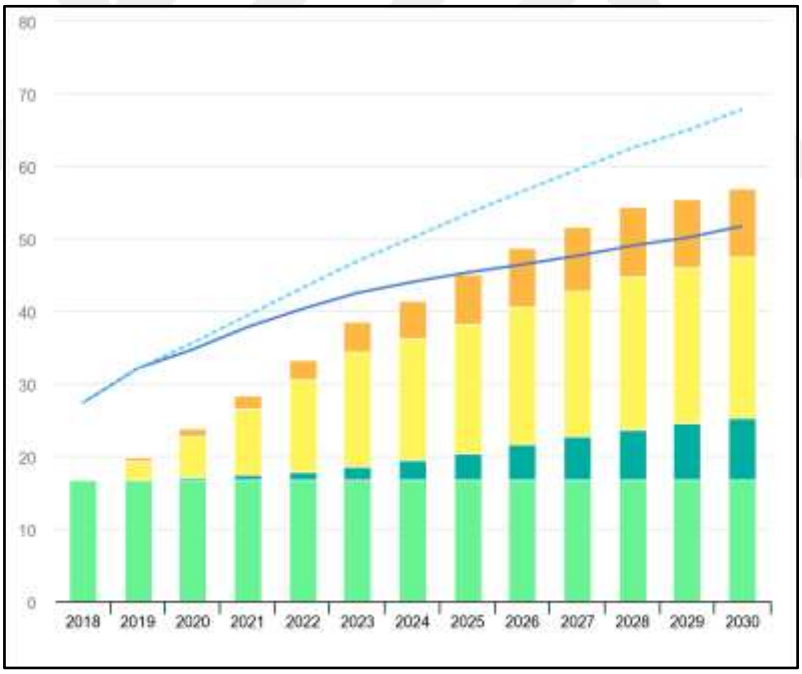


Figure 1.13: Energy Consumption of Crude Oil.

This shows the consumption of electric power from 1990 to 2018.

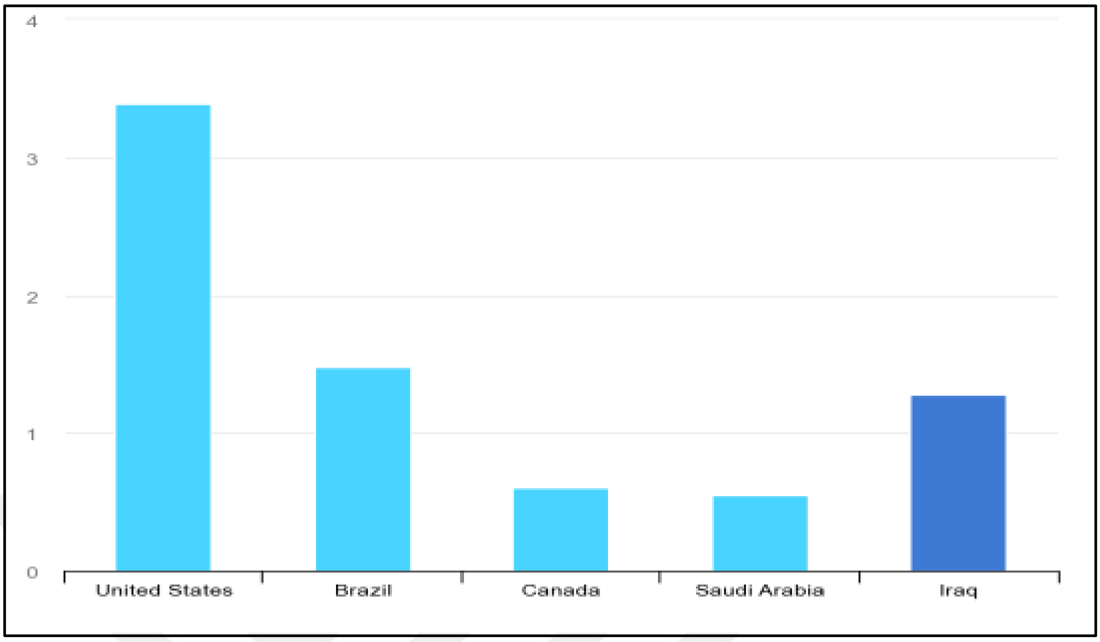


Figure 1.14: The Consumption of Electric Power From 1990 to 2018 [10].

Energy demand is expected to increase by 6000-7000 MW to 26000-32500 MW h in 2025. The power stations in Iraq are divided as follows: -

a. Gas stations are composed of gas turbines and two types of open cycles without using gas extracted from the turbine. The production rate ranges from 1-250 MW at a rate of thermal efficiency (25-40%), and the second type is the combined cycle at a rate of heat efficiency (60%).

b. Steam plants. Electric power is generated by burning crude oil, coal, natural gas, and organic waste to produce heat. The production rate is between 600 and 1000 megawatts (MW) at 40% thermal efficiency.

c. Diesel plants use heavy fuel, diesel, and crude oil. They are among the first generators to enter the country, with a production rate of between 1 and 30 megawatts.

d. Hydroelectric plants, this type of generator is created near the waters of rivers, lakes and waterfalls by passing quantities of water to hydroelectric power stations and rising water High water flow rate, increasing the electric power output according to law and machinery the higher rate of water flow, the higher electric power output according to the following law[13]:

$$E = W * H * G \tag{1.1}$$

Where the units are defined in the law above

E: The amount of energy produced measured in watts

W: Amount of running water per litre per second

H: Height of water column by the meter at the front of the dam

G: Ground acceleration

The production rate is 80-90%, which is the highest percentage compared with other types of products and the cleanest types of breeding. The first electric power system was established in 1917 in Baghdad and was operated by diesel. Subsequently, Basra, Kirkuk, Mosul, and Ramadi stations were built. The period between 1959 and 1979 was characterized by the interest of specialists in producing electric energy using natural gas and fuel, as several stations were built, as shown in the following figure, which shows the number of grids. Since 1990, however, there has been a noticeable decline in production due to the circumstances that have led it to this day. Energy demand has increased without any development or increase in production[13].

The cost of gas-fired power plants is higher than that of steam plants. In addition, the distribution of fuel used has a role in reducing the efficiency of energy production while increasing time and cost. Steam plants are more efficient, inexpensive, and have low response times. Gas plants are more lightweight and can operate in periods of peak demand. Increased load and more efficient, low-cost, full-form electricity generation is based primarily on 50% natural gas, followed by 28% crude oil or hydroelectric fuel, as shown in (Figure 1.15) Iraq's urgent need for gas is due to its weak and limited domestic production, which led it to import gas from neighboring countries to operate the plants, despite having substantial gas reserves.

The reasons for this are the weak distribution and transportation network and the weak monitoring structure, which shows in (Figure 1.13) the energy production.

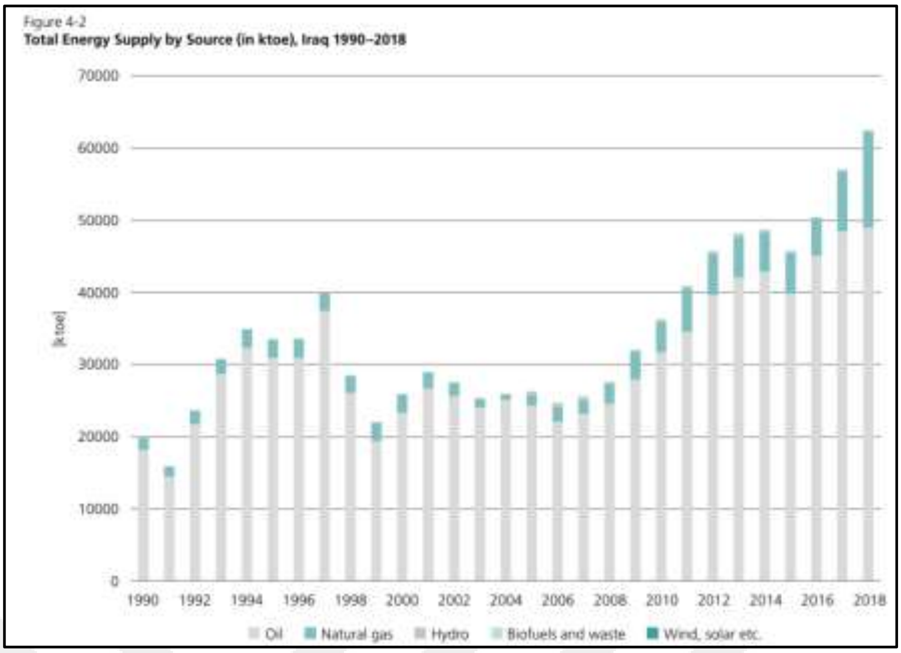


Figure 1.15: Total Energy Supply by Source (in Ktoe), Iraq 1990-2018.

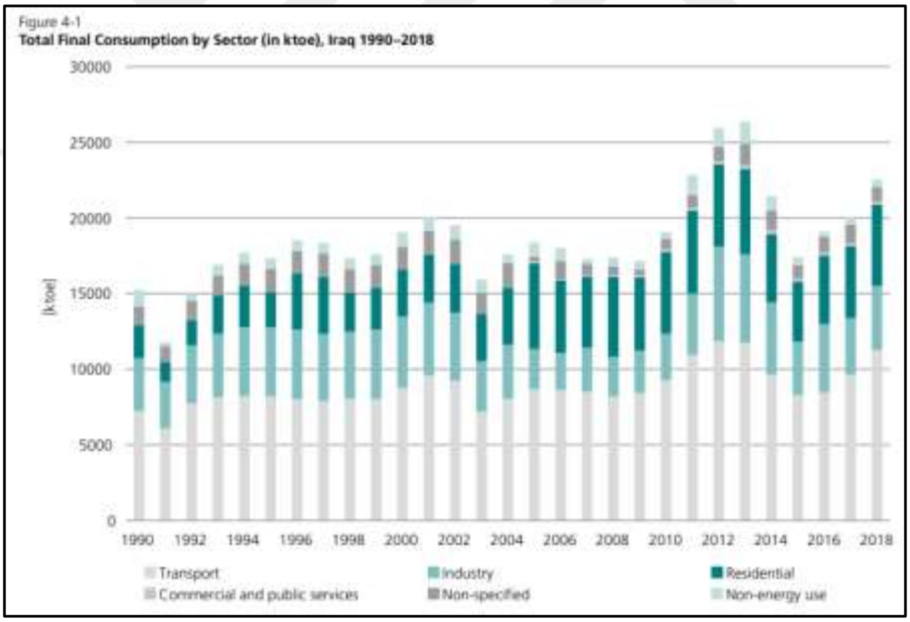


Figure 1.16: Total Final Consumption by Sector (in Ktoe), Iraq 1990-2018.

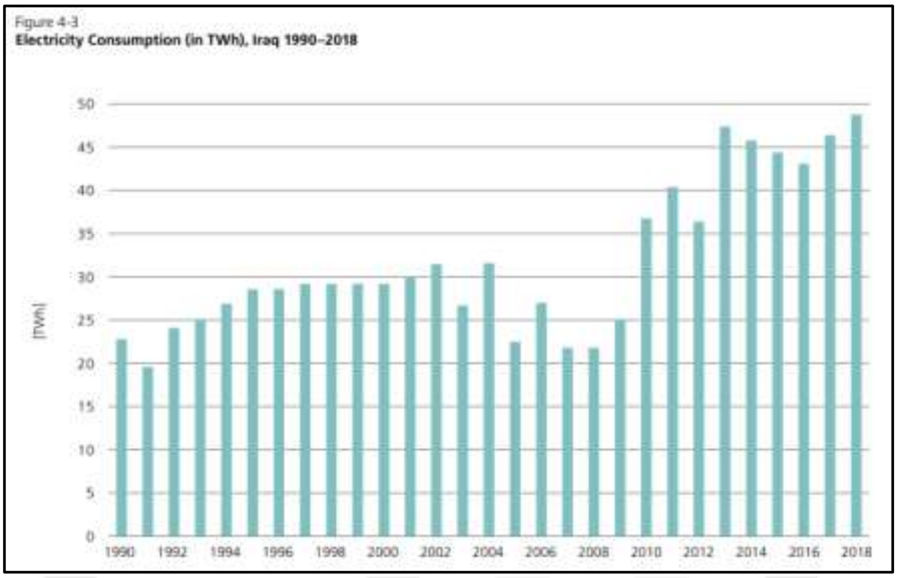


Figure 1.17: Electricity Consumption (in TWh), Iraq 1990-2018.

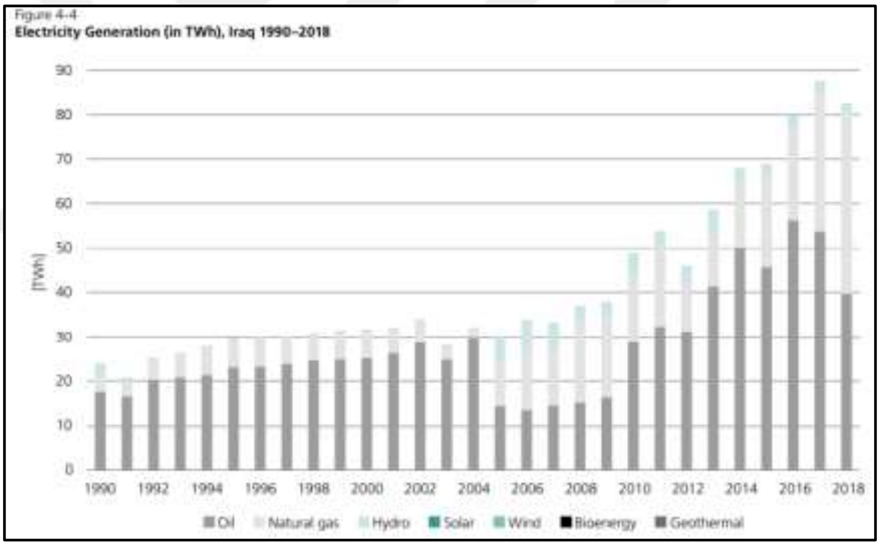


Figure 1.18: Electricity Generation (in TWh), Iraq 1990-2018.

Figure 1–17 shows the production of energy relative to the type of plant, as shown in the figure showing the total amount of electric power. According to the figure, the actual production capacity is not reached due to waste of resources and weak production capacity.

Figure 1-18 compares actual plant production to design capacity. The stark difference between Iraq and other countries demonstrates that there has been a nearly 58% increase in the rate of energy waste.

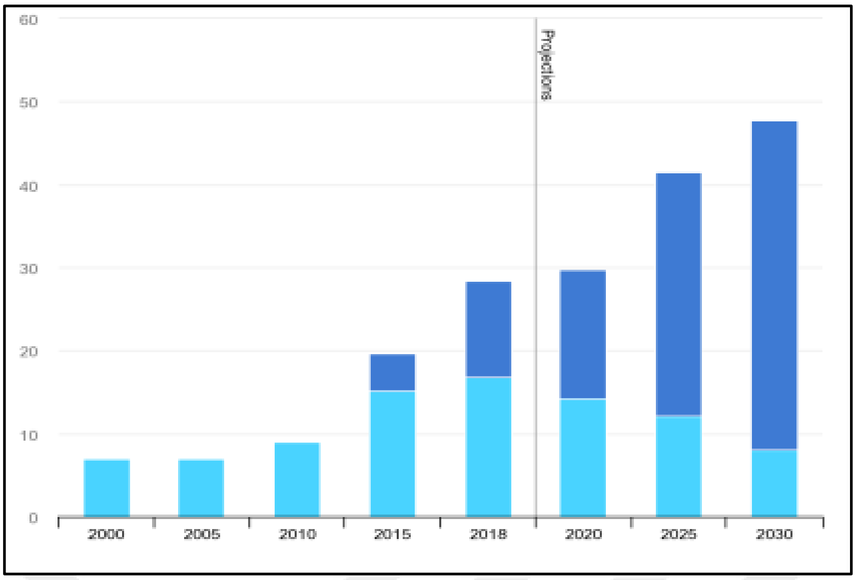


Figure 1.19: Iraq Production [10].

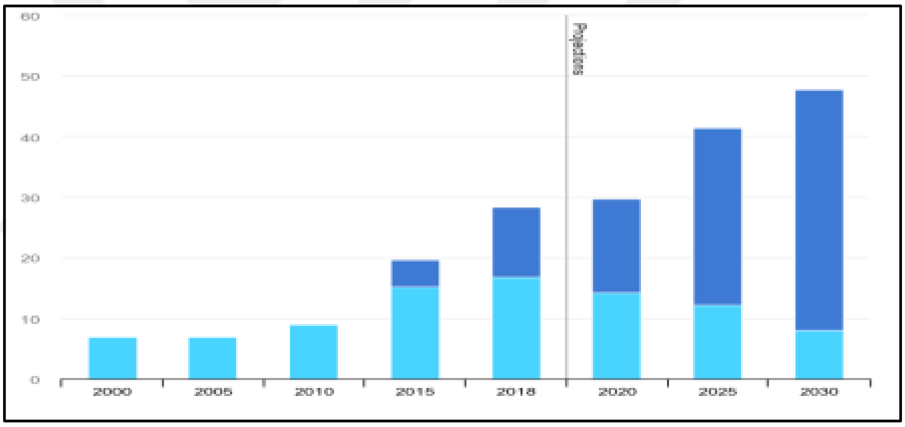


Figure 1.20: Iraq's Flaring and Natural Gas Production, 2000-2030 [10].

Poor management, overloads on the grid, obsolescence of the plants, and lack of periodic efficient maintenance led to a rate of not more than 60% preparation, in addition to the many violations of the power transmission lines and the lack of maintenance required for them, to reduce the pressure and increase production on existing generators, it is possible to increase the number of small generators in addition to the mobile generators, as in the form technology to improve electricity. Renewable sources of energy or more than one source of power generation can be used, and more efficient and responsive methods of generation can be found to meet the need of beneficiaries to move towards sustainable alternatives, as shown in (Figure 1.19) (Figure 1.20) (Figure 1.21).

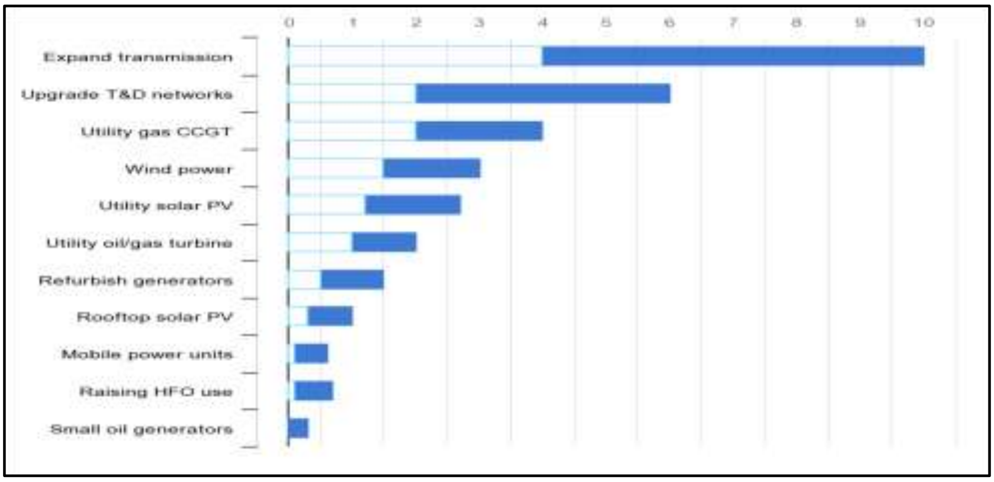


Figure 1.21: Technology Options to Improve Electricity Supply by Development Time in Iraq, 2019 [11].

The abundance of this source is considered a hot country, and the trend towards exploiting this source is depicted in (Figure 1 22) below. This is because of the power generation rate based on natural gas, crude oil, hydropower, and, more recently, the attempt to generate renewable energy sources (solar energy). (Figure 1.23).

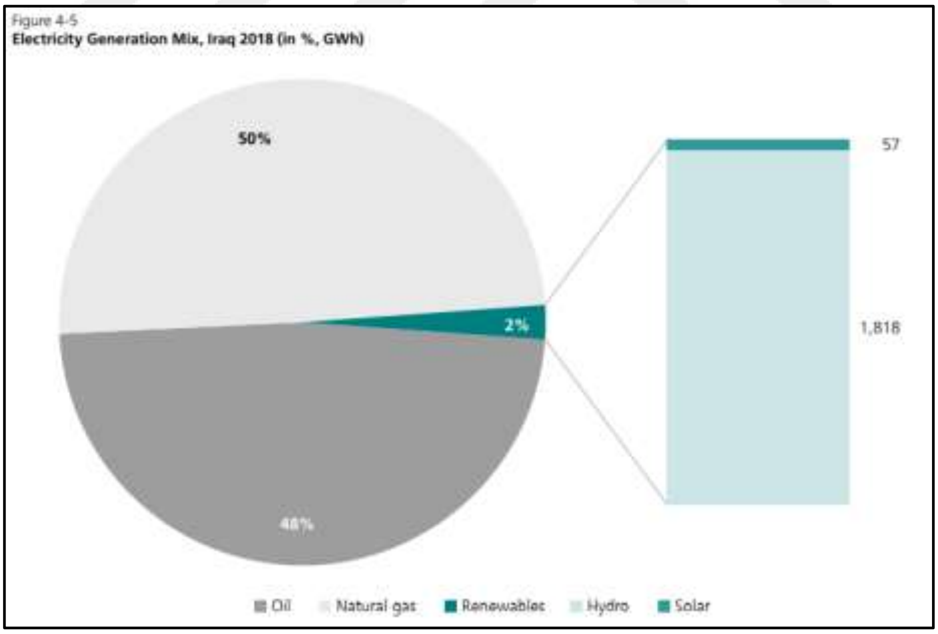


Figure 1.22: Electricity Generation Mix, Iraq 2018 (in %, GWh).

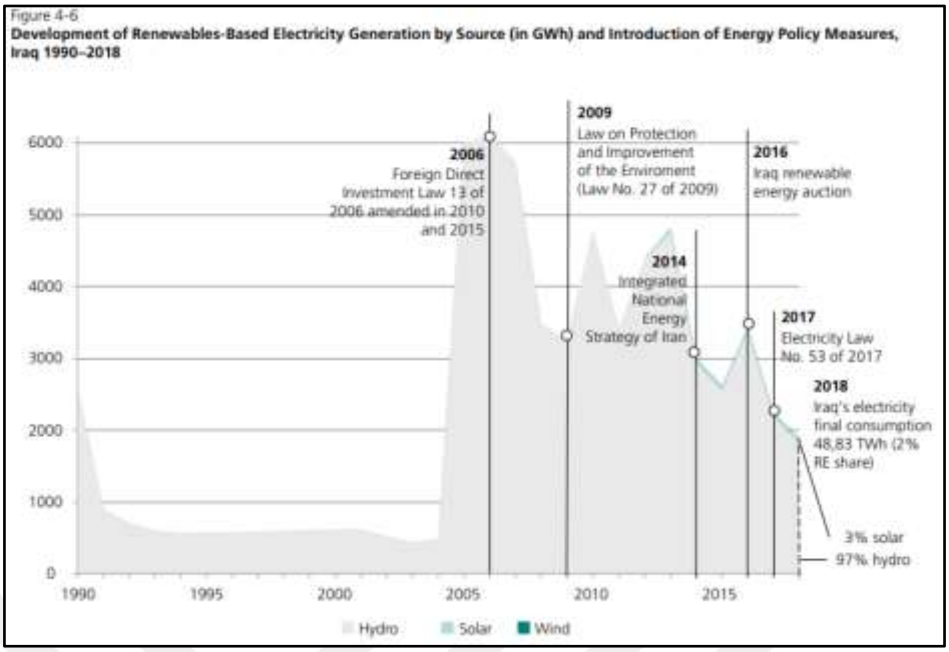
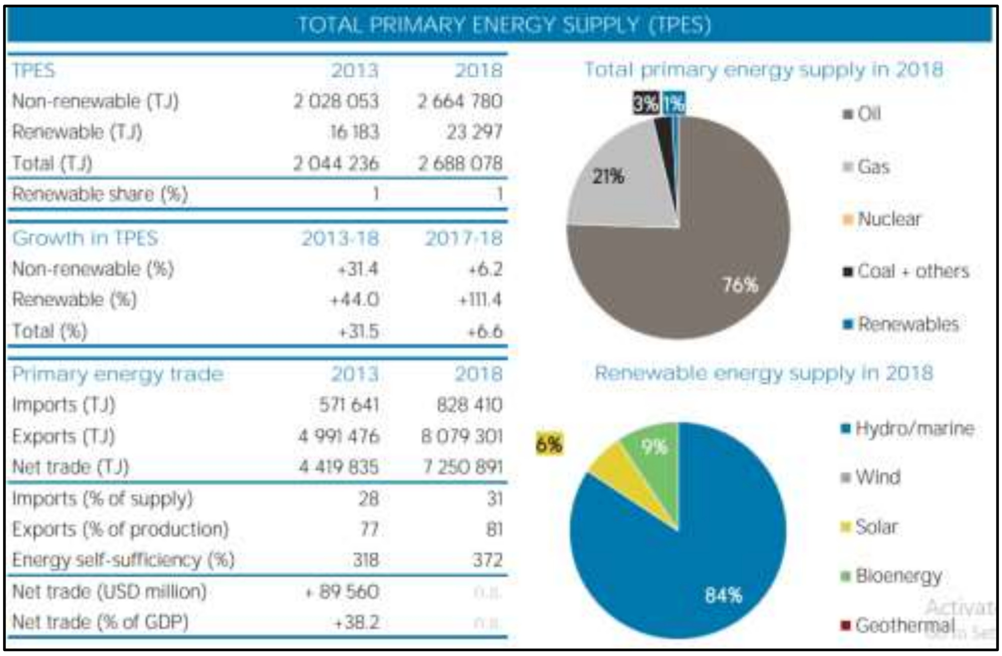


Figure 1.23: Development of Renewables- Based Electricity Generation by Source (in GWh) and Introduction of Energy policy Measures, Iraq 1990-2018.

The report, according to the IRNA (renewable energy agency) for the period 2013-2018, shows the rate of development in the field of renewable energy (solar energy, wind energy) and other sources and the rate of generation and consumption of each source (Figure 1.24).



TOTAL PRIMARY ENERGY SUPPLY (TPES)

TPES	2013	2018
Non-renewable (TJ)	2 028 053	2 664 780
Renewable (TJ)	16 183	23 297
Total (TJ)	2 044 236	2 688 078
Renewable share (%)	1	1
Growth in TPES	**2013-18**	**2017-18**
Non-renewable (%)	+31.4	+6.2
Renewable (%)	+44.0	+111.4
Total (%)	+31.5	+6.6
Primary energy trade	**2013**	**2018**
Imports (TJ)	571 641	828 410
Exports (TJ)	4 991 476	8 079 301
Net trade (TJ)	4 419 835	7 250 891
Imports (% of supply)	28	31
Exports (% of production)	77	81
Energy self-sufficiency (%)	318	372
Net trade (USD million)	+ 89 560	n.a.
Net trade (% of GDP)	+38.2	n.a.

Figure 1.24: IRNA Renewable Energy Agency for 2013-2018.

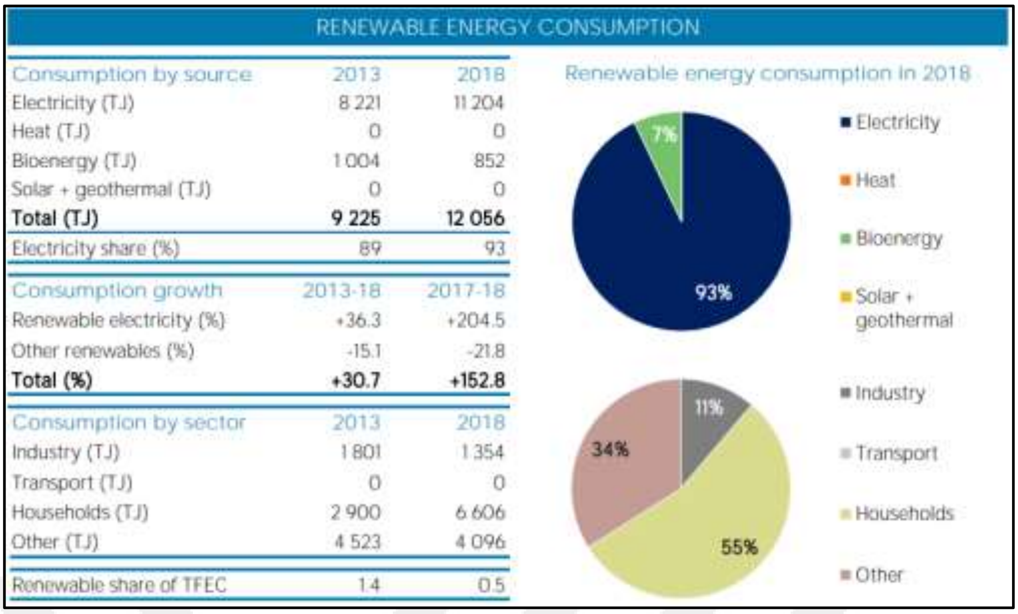


Figure 1.25: Renewable Energy Consumption.

Emissions of greenhouse gases resulting from energy production and the use of private generators have increased air pollution, as shown in (Figure 1.25), and the rise in air pollution from (2005 to 2018).

It is noted that the highest pollution rate is the result of the excessive use of oil gas and the lack of measures such as measures for safety and environmental preservation (Figure 1.26) (Figure 1.27) (Figure 1.28).

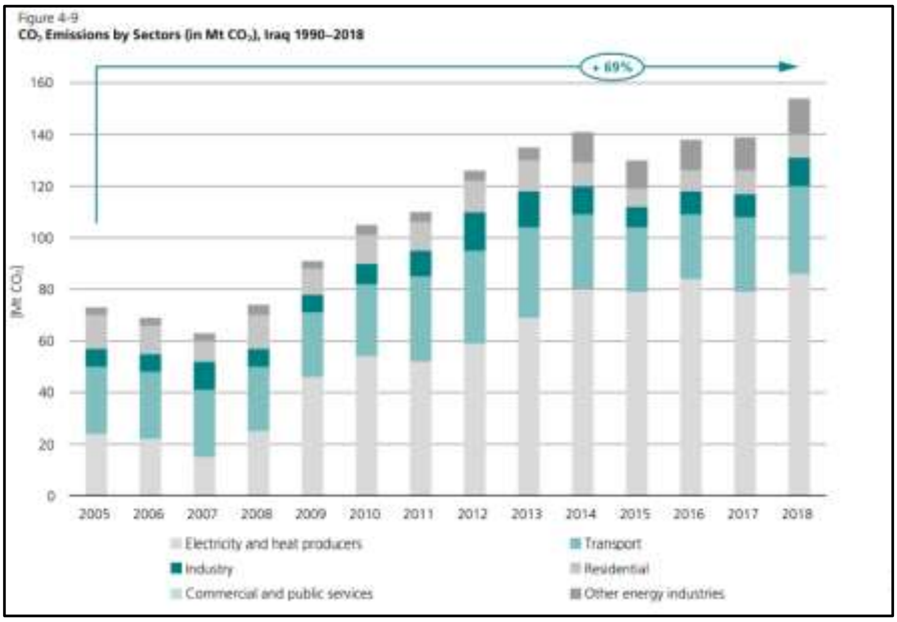


Figure 1.26: CO_2 Emission by Section (in Mt CO_2), Iraq 1990-2018.

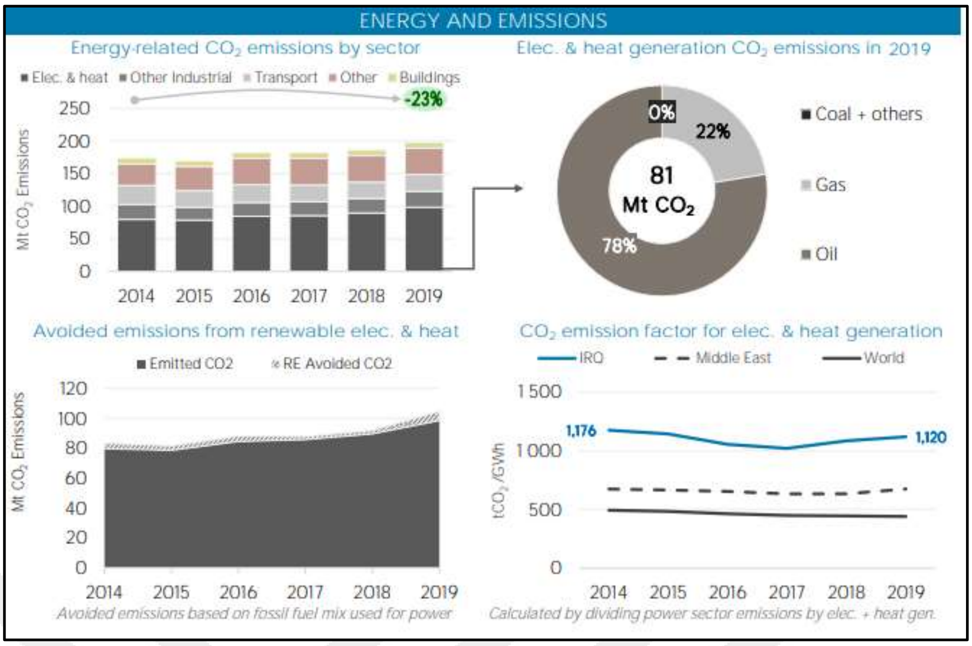


Figure 1.27: Energy and Emissions.

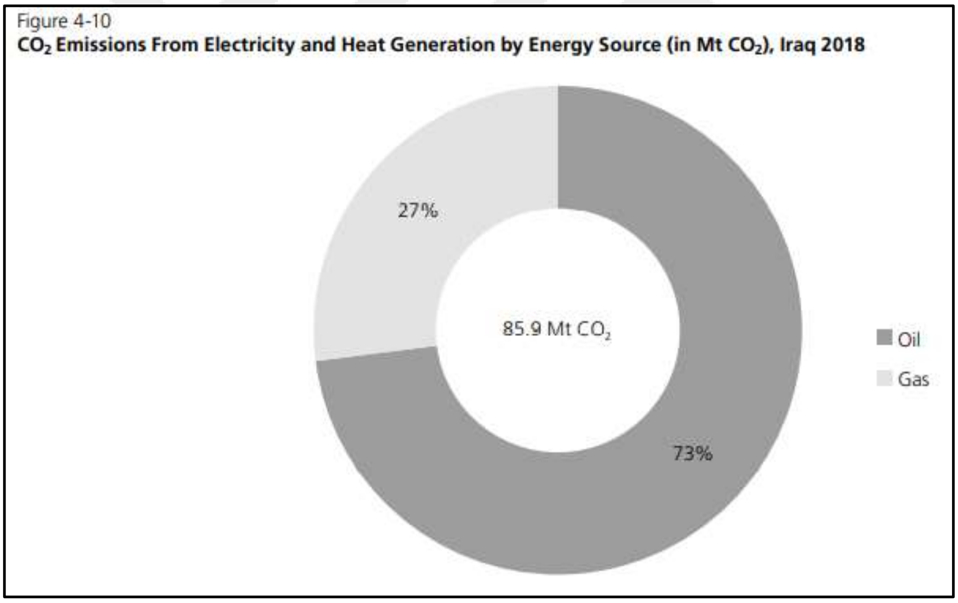


Figure 1.28: CO2 Emissions from Electricity and Heat Generation by Energy Source (in Mt CO2), Iraq 2018.

1.5 TRADITIONAL RESOURCES

1.5.1 Coal

Coal is one of the oldest energy sources on earth and remains used in some countries of the world to this day despite being the biggest polluter of the environment from burning it as a result of greenhouse gas emissions. It is an abundant, inexpensive, versatile, and power-generating resource that enters the industry. It contains much carbon, which makes it flammable in 2020, coal production declined globally by 4.8%. (Figure 1.29).

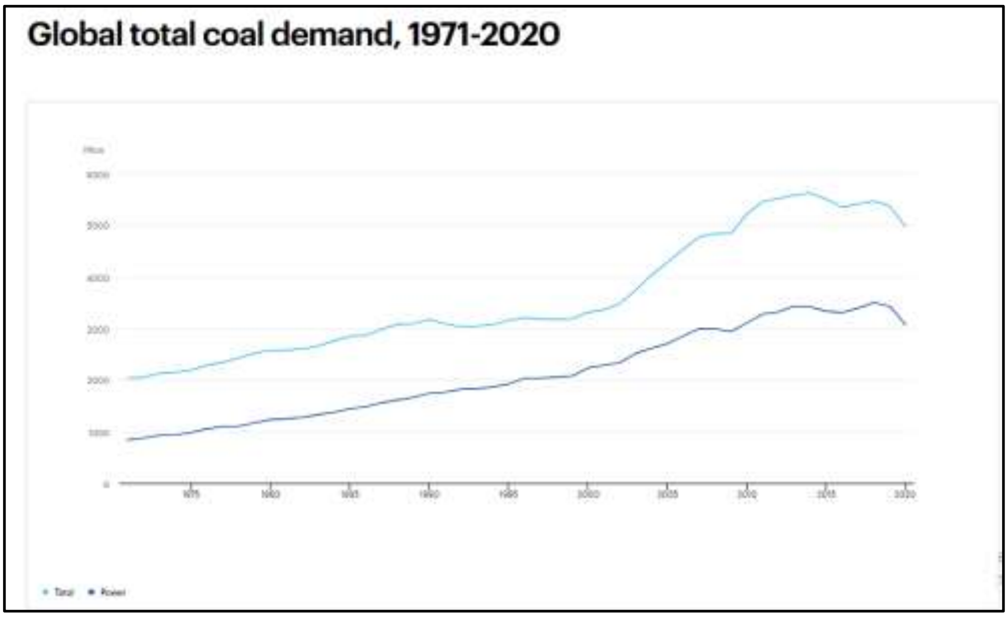


Figure 1.29: Global Total Coal Demand, 1971-2020 [12].

1.5.1.1 Types of coal

thermal coal coke lignite coal roots, coal is the result of a series of complex biochemical and geological processes, millions of years ago, from the residues of plants and algae (organic matter) that are close to the water and accumulate in a specific place, producing methane and carbon dioxide, and formed long underground by compression and heat, generating black matter known as coal prospecting, the excavation is causing emissions from prospecting and coal transport, As a result of the mining operation, water, and air pollution was created by the presence of mines and drilling increased generation of gases such as methane which is considered a greenhouse gas. Coal combustion results in oxide emissions of sulfur, nitrogen, and dust. There is a problem with its continued use, which damages the environment, and the search for cleaner and optimal ways to invest in coal or stop using it. Moreover, preserving the environment reduces consumers' access to energy, which causes energy prices to increase due to population growth and the continuing demand for energy[13].

1.5.1.2 Use of coal in electricity

Electric power production was linked to coal, and in 1882, the first coal-fired steam station was built, and it was instrumental in the industry at the time and steam-powered transportation. It has been used for converting its chemical energy into thermal, mechanical, and electrical energy from generators coal accounts for 40% of the world's electricity production and 30% of its energy production. Its use remains in place throughout China and Indonesia, where it is the world's largest coal consumer, unlike the United States and Europe, where coal consumption declined from 1978 to 2020 as in (Figure 1.30):

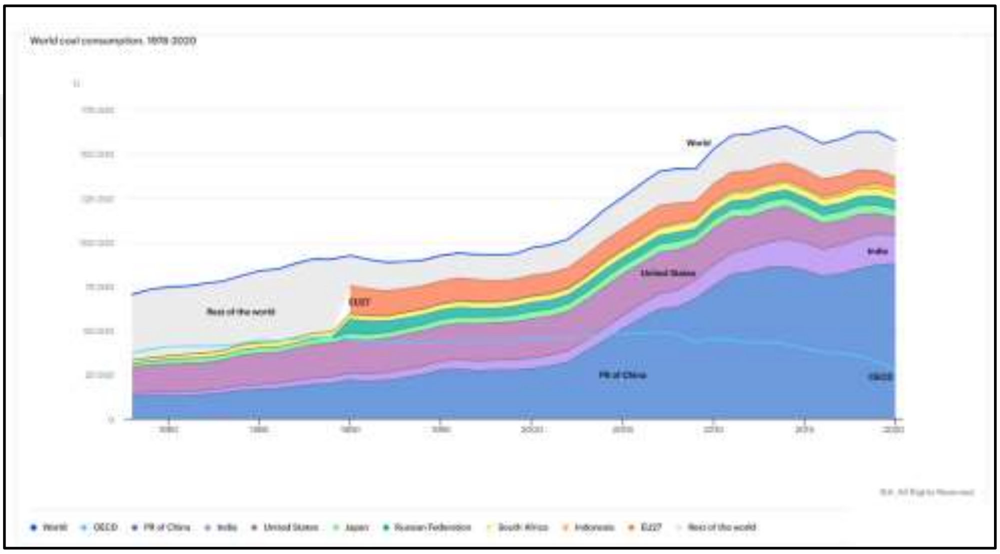


Figure 1.30: World Coal Consumption, 1978-2020 [14].

Noting that the most coal-producing country is China, shows China at the top and that Germany still produces coal for the period 1971-2020

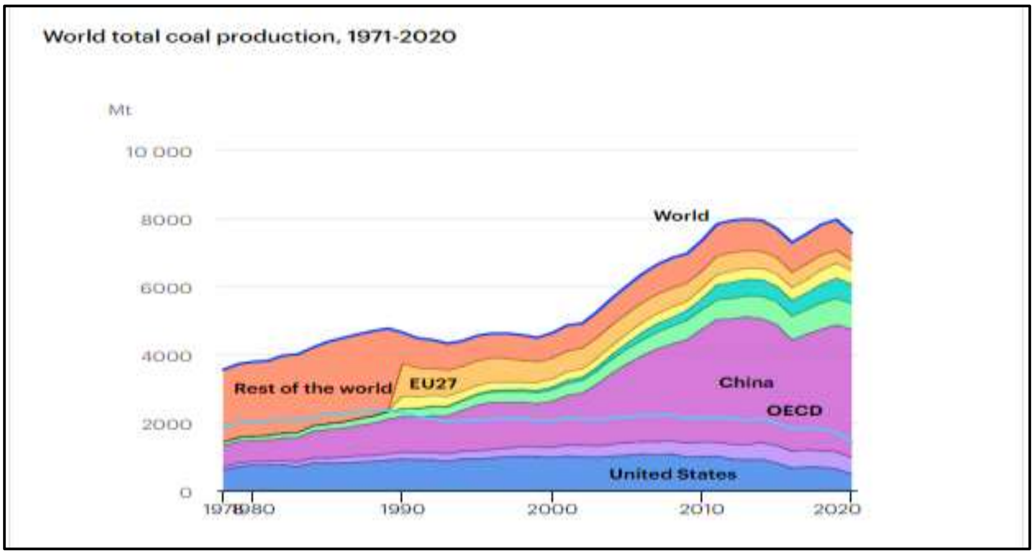


Figure 1.31: World Total Coal Production, 1971-2020.

The following (Figure 1.32) shows the ratios of electricity generation by source for 2015 – 2024.

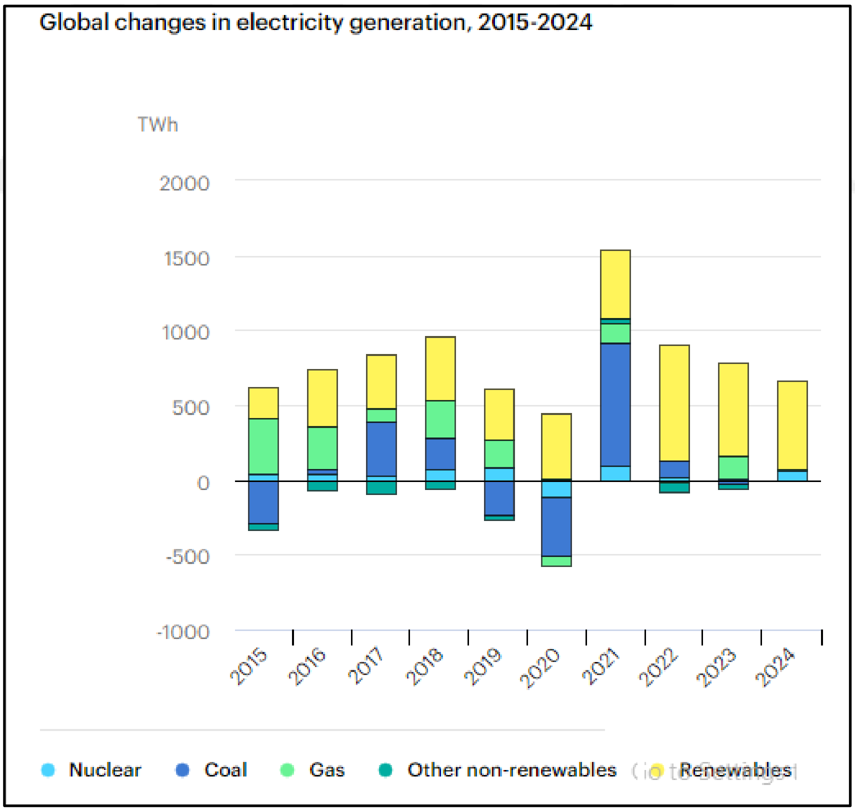


Figure 1.32: Global Electricity Generation Changes 2015-2024 [15].

India is the world's leading energy exporter in Asia, with 71%, and China, 76%. Continuing to use coal poses a challenge to the environment and environmental conditions, not finding more efficient and safer ways of using it.

1.5.2 Natural Gas

Natural gas is a source of electricity generation and is distinguished by being the cleanest traditional energy source, which is in demand internationally, and the trend towards increasing its investment in the coming years to avoid pollution of the environment.

1.5.2.1 Natural gas origin

Its carbon-hydrogen composition is produced by geologic changes over a long period of years and from the waste products of plants and animals by heat and pressure, formed by the same conditions as crude oil; the way it is found in rocks; gas is emitted by these rocks [16].

1.5.2.2 Electric gas usage

It is considered one of the best sources used in electric power generation because it is cheap and efficient in generating, maintaining, and speeding for natural gas plants. The following (Figure 1.33) shows the production of each source from 1974 to 2020, that is, the increase in demand for natural gas.

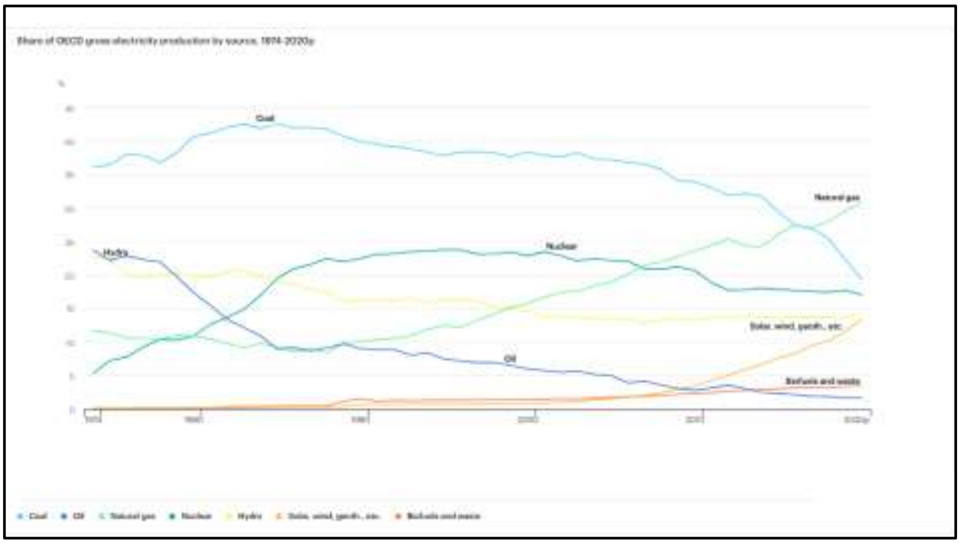


Figure 1.33: Share of OECD Gross Electricity Production by Source, 1974-2020 [17].

1.5.2.3 Natural gas consumption

The proportion of natural gas consumption has increased in recent years, according to the following (Figure 1.34), which shows the rate of increase from 1990 to 2018.

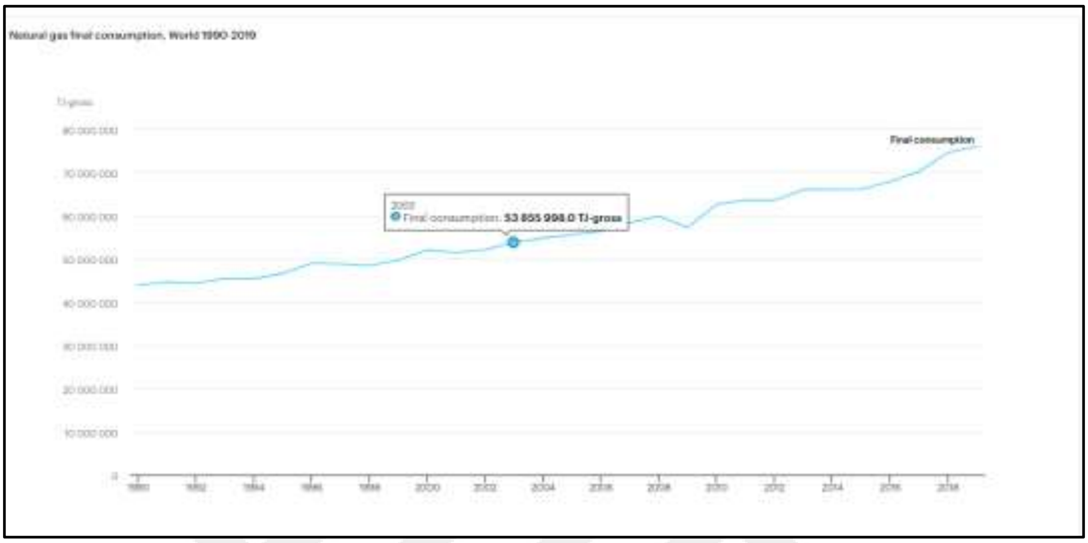


Figure 1.34: Natural Gas Final Consumption, World 1990-2019[21].

1.5.3 Petrol

Petrol is considered one of the most important substances on earth, essential in transportation, energy, heat, and industry. In addition to being used in the industry of other substances, oil usually consists of a mixture of complex hydrocarbons. It consists of one carbon atom, as in methane, and hundreds of carbon atoms, as in paraffin, estimated at 300 atoms, present in paraffin or isomers. It can occur in a solid, liquid, or gaseous form containing the following: -

The carbon ratio is 84 to 87%, hydrogen, 11 to 14%, sulfur, 0.3 to 3%,0.3 to 1% nitrogen, and 2-3% oxygen. Its carbon-rich structure makes it a prime source of fuel [18].

1.5.3.1 Petrol origin

The origin of petrol can be traced to organisms, plant, and animal wastes that became decomposed millions of years ago, mixed with water, mud, and sand, and surrounded by sediments with multiple layers, and to the surrounding environment, where different kinds of petrol formed until they were converted to petrol discovered in 1850, and petrol refining started in 1862. The first areas to witness noticeable development in the oil sector are the

United States and Russia. Subsequently, Indonesia and Mexico moved to the Middle East. When refined, petrol produces liquid, gaseous, solid, and semi-solid derivatives due to different boiling points for each product and component, including nitrogen, sulfur, oxygen, and metal compounds. The products' various characteristics and defects vary according to the original crude oil, so enter the viscosity factor and the sensitivity and quantity of the metals.

Petrol is usually drilled with equipment and techniques for the research process. By drilling wells, 30,000 to 90,000 feet, and then by compressing the gas associated with petrol or by injecting water or steam, other materials, such as polymers or carbon dioxide and solvents, are used to reduce the viscosity of crude oil Petrol refining is done by representative physical processes (separation) chemical processes, processing operations the standard process of refining is by heating distillation, or by using other methods such as adsorption, absorption, and crystallization. New constituents such as kerosene, heavy oil, petroleum, and gas oils are separated. Other processes for the rest of crude oil, such as thermal and catalytic cracking, can be converted from large to small particles. The refining industry for oil derivatives witnessed significant development and increased demand in the world's countries from 1990-2000. However, the growth in demand and consumption of oil products started to decline and increase from 2000 to 2018. the decline was substantial in 2004-2008 due to the economic crisis, and the rise was slow, as shown in (Figure 1.35).

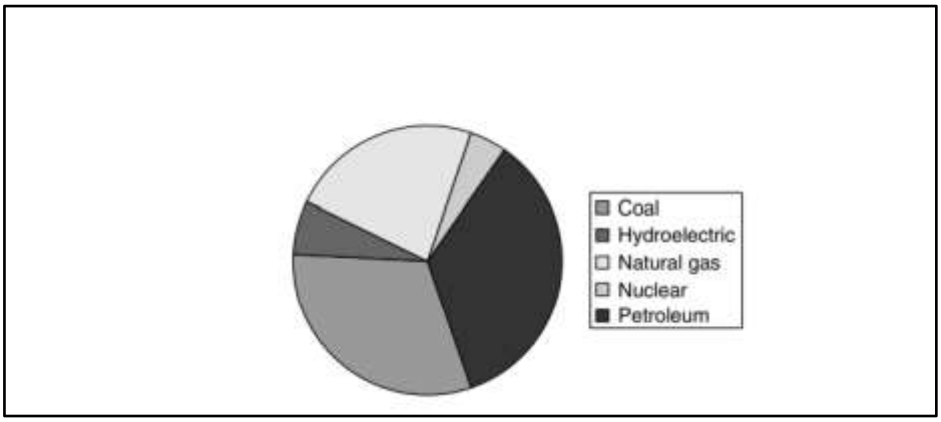


Figure 1.35: Distribution of World Energy Resources.

1.5.3.2 Petrol industry

has faced many challenges, including slow demand during specific periods as well as problems or obstacles in refining and production equipment and the need to change the necessary equipment and machinery based on the demand in oil markets and OPEC, environmental challenges, and the fear of running out of oil reserves, because oil products are used in aviation fuel, cars, gas oil used in cooking, and candles that enter into other industrial uses. Oil is not a significant source of electricity generation, but despite all this, it is still in the first place in demand. By qualitative weight and intensity, the US Petroleum Institute (API) inversely correlates with specific weight. The more carbon atoms there are, the more carbon intensity there is, and the more oil-type API is a symbol of culture cycles when oil with a high weight density is low and vice versa. The degrees of oil intensity are divided as follows:

10-24 Light Oil API

24-34 API Oil

34API - Above heavy oil

Furthermore, this one has about 0.1% sulfur, its sweet oil, but if it increases and becomes 1%, it becomes acidic. knowing what oil is good, efficient, and desirable depends on the percentage of sulfur and density per price type. Light oil is priced differently from heavy oil, as light oil is more expensive than heavy oil [19].

1.5.4 Nuclear Power

Nuclear power is considered one of the efficient sources of electricity, but its use is limited in certain countries. Development in this area is limited by storage methods, protection of these stores, provision of professional staff, and caution in dealing with the disposal of nuclear waste and the use of nuclear fuel, which may cause a risk of uranium emissions.

1.5.4.1 Use of nuclear power for electricity generation

Electrical power is produced by forming water vapor to reach the fission phase in nuclear reactors, where the fuel used is uranium, and then the heat is transferred to electrical plants.

The number of nuclear reactors in the world for 2019 was an estimated 433 nuclear reactors with a capacity of 392.1 GW and distributed by several reactors per region as in (Figure 1.36) [20].

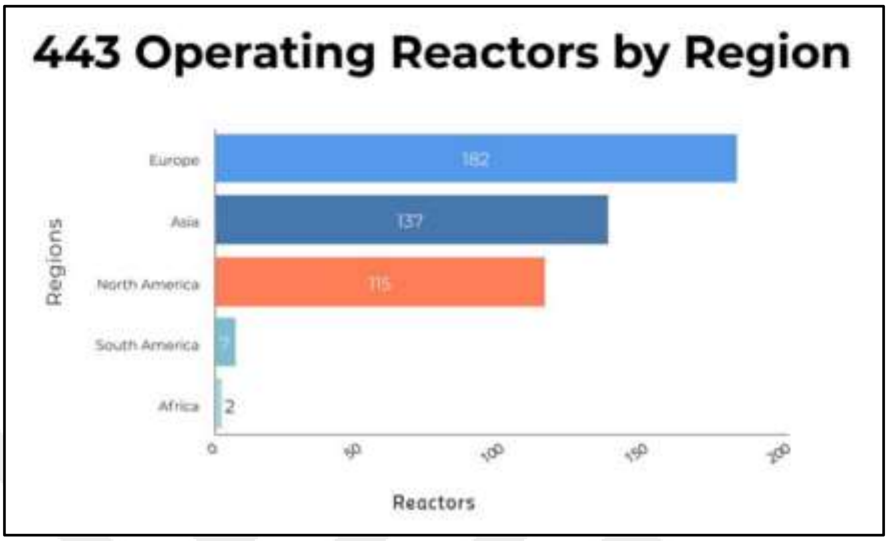


Figure 1.36: Operating Nuclear Power Reactors in 2019.

The first to use nuclear power in the electricity sector was the United States of America in 1951. The nuclear power states are about 30. Nuclear power production is about 92%, which puts it at the forefront compared to other power sources. Nuclear-powered plants have few failures and long-term work [21].

(Figure 1.37) below is the magnitude of the growth in nuclear power in electrical power generation from 1990-2019 [18].

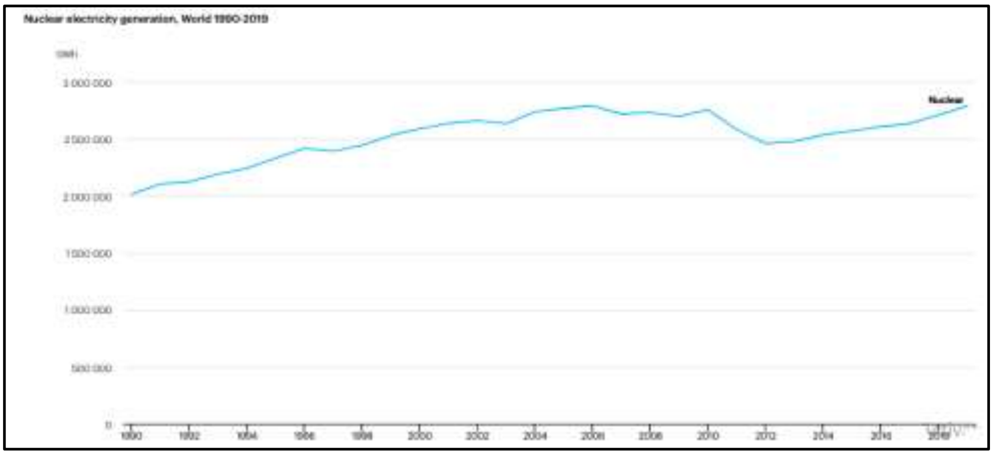


Figure 1.37: The Magnitude of The Growth in Nuclear Power in Electrical Power Generation From 1990-2019 [25].

1.6 REGULATION ENERGY

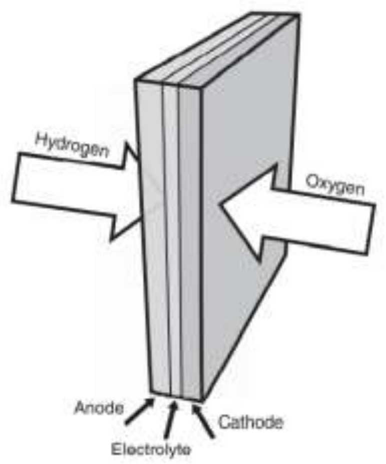
Energy regulation is one of the essential basics of energy. To know how energy is transferred, there must be a mechanism for energy regulation to know the path of energy transmission and the compatibility between supply and demand and to keep it in times of demand when it is not possible to generate energy for technical reasons there is a balance between supply and energy consumption in a balanced manner energy storage is of the following types:

a. Electric storage can be in two forms capacitors, which are relatively expensive and used quickly. Inductors have a small storage ratio in addition to their work requiring high voltage.
b. Mechanical storage kinetic energy is used to generate electrical energy, and this type is used for short and medium-time potential energy is used for water storage at high altitudes with the need for pumps.
c. Chemical Storage It is two types. Electrolysis is the breakdown of water into its primary elements, hydrogen, and oxygen, and then turns into electricity by burning or conversion, which is in fuel cells. Electrochemistry is done by chemical analysis of the substance (electrolyte solution) and the anode and cathode electrodes that produce electrical energy [22].

Fuel cells are more efficient at generating electricity than engines or batteries and lower greenhouse gas emissions due to a chemical reaction rather than combustion [23].

1.6.1 Fuel Cell

The cell is the essential electrochemical component of a battery, which may consist of one or more cells. The cell consists of a positive electrode, a negative electrode, and an electrolyte following (Figure 1.38) shows the fuel cell. [27]



Simplified planar anode–electrolyte–cathode structure of a fuel cell.

Figure 1.38: The Fuel Cell.

1.6.1.1 Mechanism of action+

It depends on its work on hydrogen and oxygen with an analyser to generate electricity. It consists of two negative and positive electrodes where the negative electrode is oxygen, and the positive electrode is hydrogen, and then an electric current is generated, is in the (Figure 1.39) shown below[27].

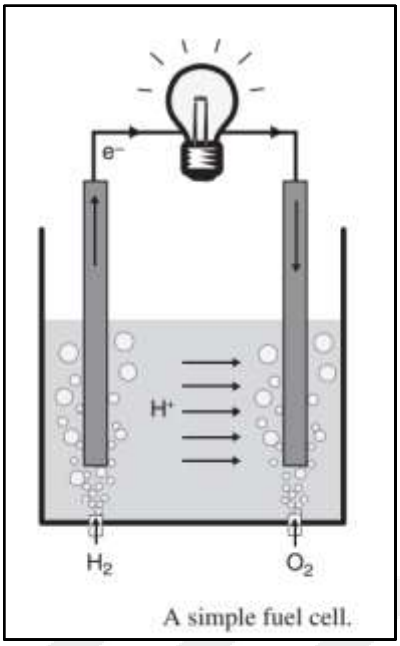


Figure 1.39: Simple Fuel Cell.

The following (Figure 1.40) shows how the electrochemical cell is generated in terms of material transfer, electrochemical reaction, electrolytic conduction, and products that are removed at the end of the reactions[27].

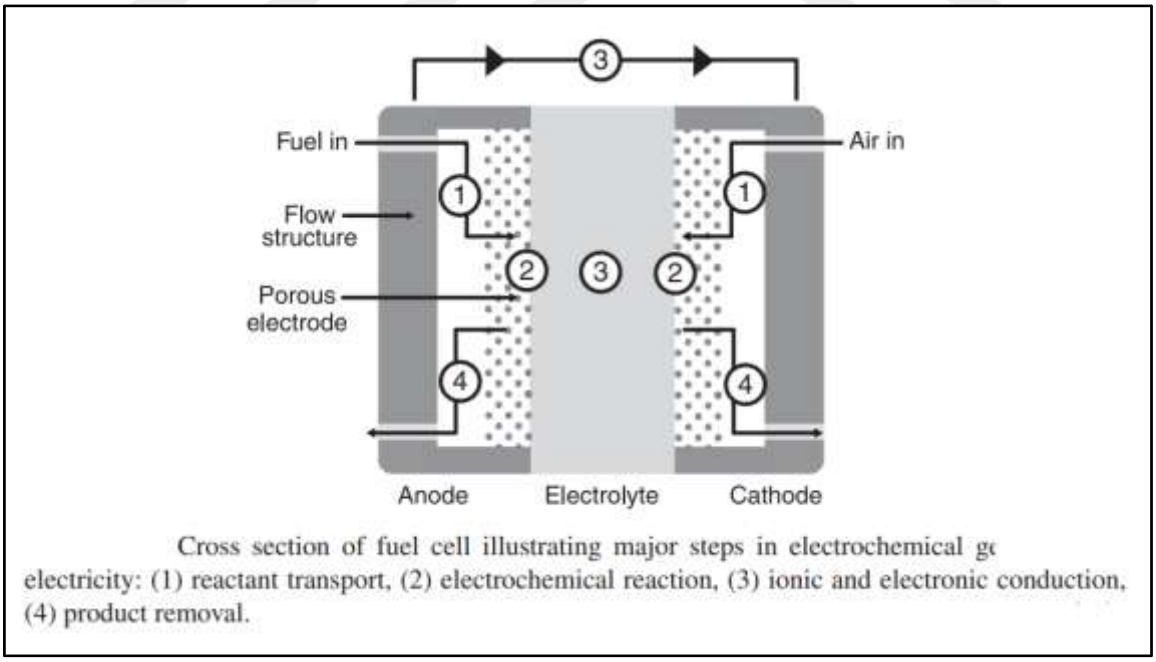


Figure 1.40: The Electrochemical Cell is Generated in Terms of Material Transfer, Electrochemical Reaction, Electrolytic Conduction, and Products That are Removed at the End of the Reaction.

1.6.1.1 Types of cells

A. Alkaline Fuel Cell

The alkaline fuel cell is considered one of the highly efficient cells compared to its counterparts of other types, as it produces electrical energy by about 70% of this cell through a chemical reaction by oxidation of hydrogen in the middle of an alkaline solution, which is potassium hydroxide [24]. As shown in the following reaction:

$$2H_2 + 40H - {}^\wedge 4H_2O + 4e'' \qquad (1.2)$$

The electrons begin to flow through the cathode to produce water, and the percentage of oxygen decreases in this process, as shown in the following reaction.

$$O_2 + 2H_2O + 4e''{}^\wedge 40H- \qquad (1.3)$$

In this reaction, hydroxide ions are returned, electrons are returned, and the electrons are consumed [24]

Here, the anode is separated from the cathode using a saturated porous membrane using an alkaline liquid electrolyte solution. This type of cell is considered a lightweight cell but has a very high cost. It is now used[22].

B. Polymeric Electrolytes

These cells depend on their formation on a polymeric membrane delivered by the proton, and the exchange is on both the anode and the cathode poles. This film is thin and movable and plated with platinum on both sides. The type of polymer used is a sulfonic acid polymer saturated with fluorine. The cell is made up of two electrodes, a stimulator, and an electrolyte membrane where the reactions occur as in the following equations below:

Anode:

$$H_2 \rightarrow 2H^+ + 2e^- \qquad (1.4)$$

Cathode:

$$1\ 2O_2 + 2H^+ + 2e^- \rightarrow H_2O \qquad (1.5)$$

Features of Cells

It has a very high energy density compared to the rest of the cells, about 93%. It has a start and stops capability that defects these cells. The catalyst used in these cells is costly platinum, and the polymer used is expensive in cars and camcorders.

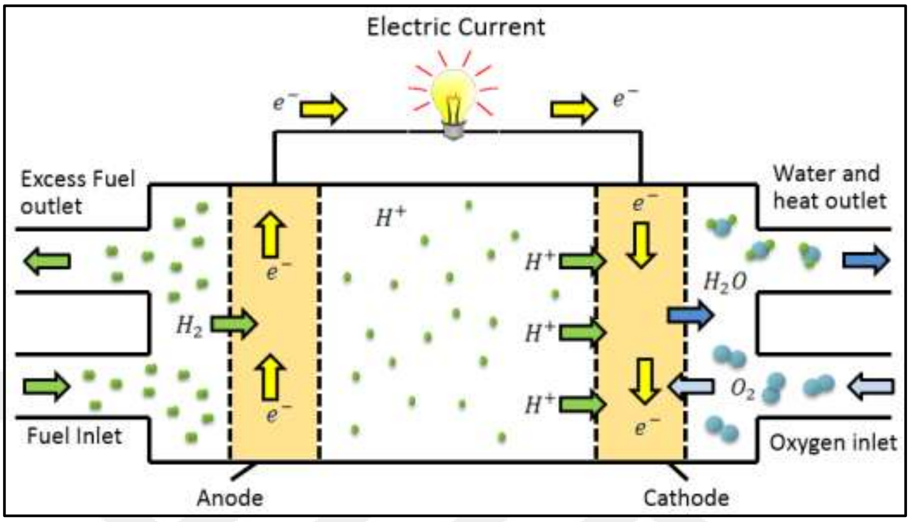


Figure 1.41: Polymer Cell [25].

C. Molten Carbonate

These cells have the advantage of high efficiency in converting fuel into electricity. In addition to the high consumption of fuel consisting of coal, the temperature used is 649 degrees Celsius[26].

The efficiency of using multiple generations is 85%[26]. Instead of platinum, which is cheaper than platinum, nickel can use recycled gas from hydrocarbons, such as soil [26] (Figure 1.42). Mechanism of

Cathode:

$$2CO + O + 4e\ 2CO\ 22\ 3 \rightarrow 2\text{- -} \quad (1.6)$$

Anode:

$$2H + 2CO\ 2HO \rightarrow + 2CO + 4e\ 23\ 2\ 2 \quad (1.7)$$

Overall reaction:

$$2H + O 2H O 22 2 \tag{1.8}$$

In these reactions, water is produced from oxygen and hydrogen from carbon [27].

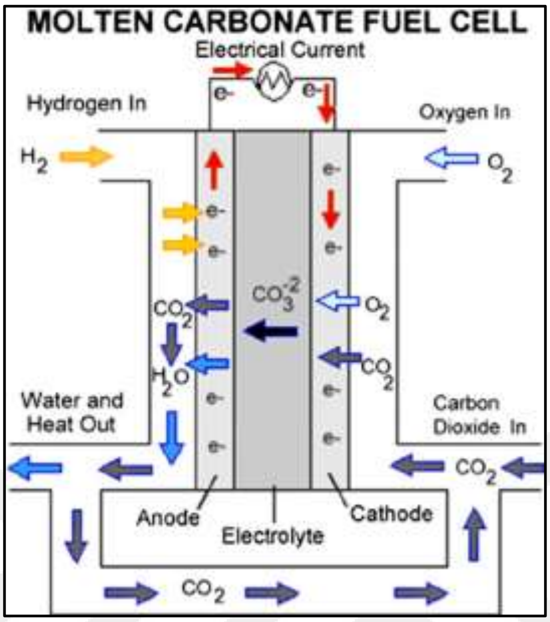


Figure 1.42: Molten Carbonate Fuel Cell [28].

D. Direct Methanol Cells

This type of cell is one of the new types of fuel cells and is similar to polymer cells. The material used for the electrolyte is a polymer in this cell. The anode electrode takes the hydrogen from this cell's methanol liquid working efficiency is 40%. This cell operates at a temperature between (48.9-87.8) degrees Celsius. It can be highly efficient at high temperatures[26].

These cells produce electricity from liquid fuels such as methanol or ethanol or acids such as formic acid or borohydride solution. This liquid fuel oxidizes into water, and carbon produces electricity. This type of cell is desirable because it has a high energy density[27].

The Reaction of the Cell

anode is

$$CH3OH + 6OH- \rightarrow CO2 + 5H2O + 6e- \tag{1.9}$$

The cathode reaction is

$$2\ O2 + 3H2O + 6e- \rightarrow 6OH- \quad (1.10)$$

Total

$$CH3OH + H2O \rightarrow CO2 + 6H+ + 6e \quad (1.11)$$

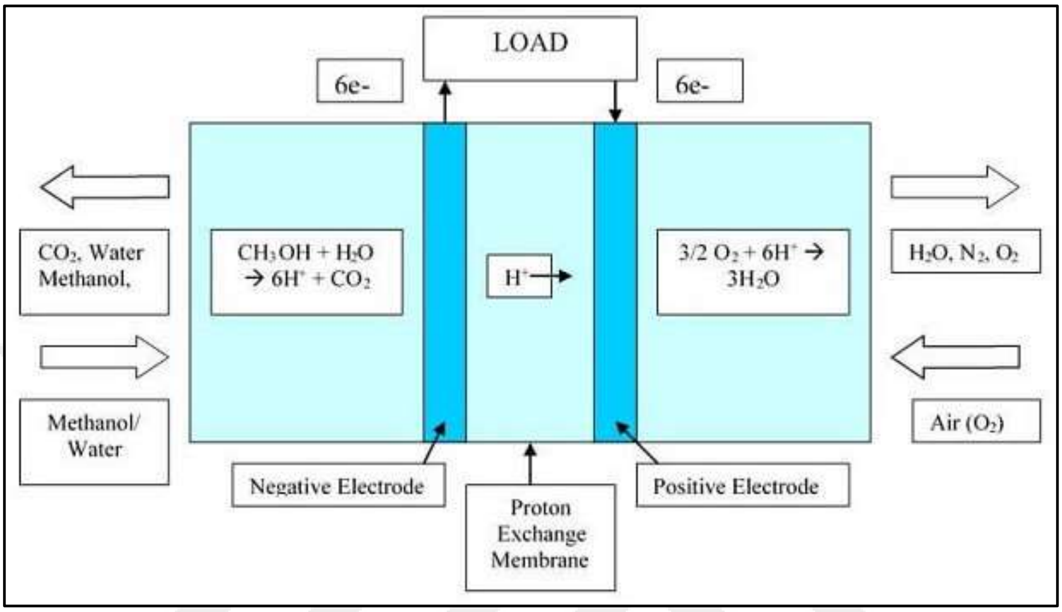


Figure 1.43: Direct Methanol Fuel Cell [33].

E. Solid Oxide Cells

This cell type is used in large or high-power generation fields such as significant or industrial power plants and car engines. Liquid electrolyte is replaced with a ceramic material, a porous metal representing the electrolyte, and the temperature can reach 1000 degrees Celsius without needing an auxiliary agent—energy efficiency 60%[26].

The Reactions

The reaction of the anode is Anode:

$$H2 + O2- \rightarrow H2O + 2e- \quad (1.12)$$

The cathode reaction is Cathode:

$$1\ 2O2 + 2e- \rightarrow O \quad (1.13$$

The metal used is strontium-saturated manganese lanthanum (LSM) and lanthanum-strontium ferrite (LSF). This is characterized by its excellent resistance to oxidation and stimulation.

Cell Advantages

a. It is flexible, and the metal is used with a cheap catalyst because it is the same as the electrolytic metal with a high operating temperature. The electrolyte is a solid substance.

b. High intensity of energy production.

Cell Negatives

Material problems due to high temperature, some of the components the cell is made of are expensive[27].

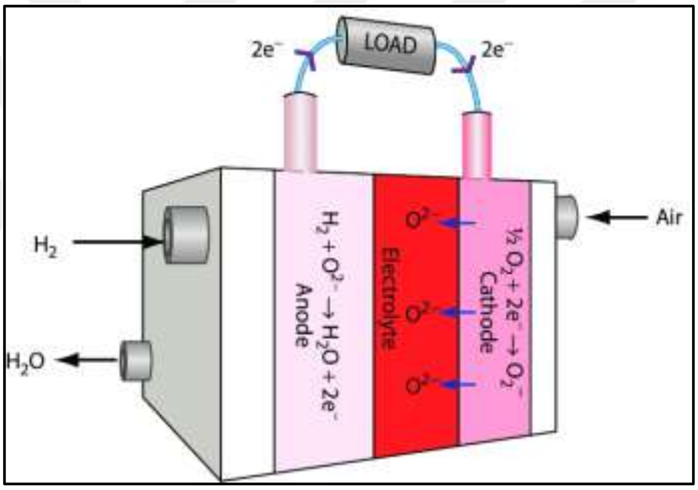


Figure 1.44: Solid-Oxide Fuel (SOFC) [34].

F. Phosphoric Acid

This type of cell is characterized by being the most developable cell type and is used in many areas, schools, hotels and hospitals, batteries, buses, and trains. The efficiency rate for electricity generation is approximately 40% and is environmentally friendly. Approximately 85% of the steam produced from other fuel cells is used in the case of multiple generations[26].It is done by oxygenating hydrogen in the inner circle to protons and electrons, and this interaction is in the anode pole. In the cathode pole, the outer circle is, in effect, the electrons, which cause the power generation. Through these processes, protons and electrons are associated with oxygen. Water consists of oxygen associated with protons and electrons. In this cell is a platinum catalyst. Heat generated is used to heat water. The following equations generate power

Anode:

$$2H2 \rightarrow 4H + + 4e - \tag{1.14}$$

Cathode:

$$4H + + 4e - + O2 \rightarrow 2H2O \tag{1.15}$$

Overall reaction:

$$2H2 + O2 \rightarrow 2H2O \tag{1.16}$$

Cell Advantages

Advanced technology long cell life

Cell Negatives

The platinum catalyst is expensive the electrolyte solution decreases with use, so the cell must be constantly filled [27] (Figure 1.45).

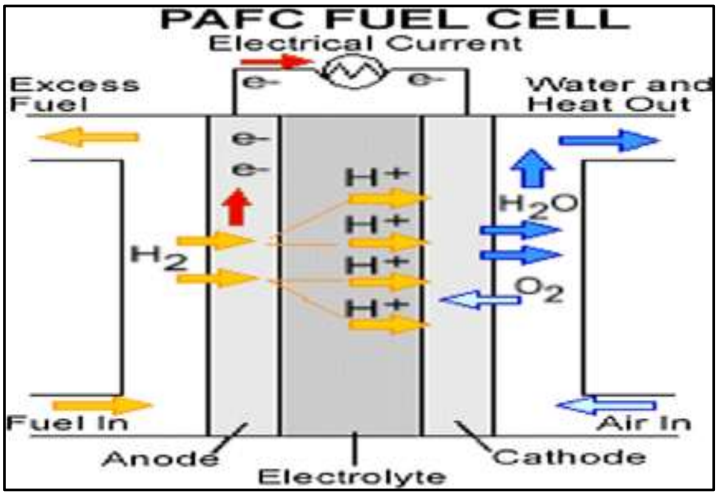


Figure 1.45: PAFC Fuel Cell [32].

G. Renewable Fuels

The work of these cells is based on the separation of water into hydrogen and oxygen by a solar-powered device. The fuel cell produces electricity, water, and heat. The water produced by the cell can be used again and used to store the energy the use of both as a fuel and as an oxidizing agent to produce electrical energy H_2 O_2 [26][31].

H. Biofuels Cells

This cell works by using biofuels in addition to bio-stimulating materials whose composition is due to organisms, and the microorganism's biofuel here is represented by methanol or simple sugars, as in glucose, by which electrical energy is produced. In this cell, electrical energy is directly obtained through catalytic activity resulting from the action of bacteria and enzymes. The action of bacteria produces electrons that are directed toward the graphite electrode, As in the following reaction[27]:

$$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^- \tag{1.17}$$

Fuel Cell Applications

The work of these cells is unique in the generation of central energy, Multi-fuel power generation; It is used in self-driving cars, it is used in home power stations, and It can also be used in specialized applications[31].

1.6.2 Batteries

Batteries are defined as a group of electrochemical cells where chemical energy is converted into electrical energy, and this energy is formed as a result of several reactions. Each cell comprises electrodes represented by an anode and a cathode condition that must be met in batteries. It should have a long life when used or not, it can move quickly in terms of pressure, and transportation voltage is single-phase stable.

1.6.2.2 Types of Batteries

a. A simple (primary) battery, such as a mercury cell, and a dry cell of this type cannot be reversed. The reaction is done once in one direction.
b. A secondary battery, such as a lead cell and a nickel-cadmium cell, can reverse the reactions by applying external energy.
c. A flow battery is like a hydrogen cell - an oxygen cell. These cells allow materials, products, and electrons to flow through the cell constantly; how the battery works, the battery is based on generating electrical energy and storing chemical energy through an

electrochemical reaction. The process of generating energy is by the flow of electrons generated by a chemical reaction at the electrodes.

The process of flowing these electrons from the negative electrode to the cell's positive electrode [29]–[31].

1.6.2.2 Types of Battery

A. Primary batteries

a. Mercury battery

This cell is small and commonly used in hearing equipment and watches.

b. Battery Configuration

It consists of two electrodes, an anode, and a cathode.

The anode is represented by zinc. The cathode is represented by mercury. The electrolyte is a substance that is dissolved in electricity, ZnO, and KOH, as shown in the following: -

Reaction at anode

$$Zn + 2OH^- \rightarrow ZnO_{(s)} + H_2O + 2e^- \quad (1.18)$$

Reaction at the cathode:

$$HgO_{(2)} + H_2O + 2e^- \rightarrow Hg_{(1)} + 2OH^- \quad (1.19)$$

Total interaction

$$Zn + HgO_{(s)} \rightarrow ZnO_{(s)} + Hg_{(1)} \quad (1.20)$$

In this cell, the voltage is always constant at 1.35 because it does not contain an ionic solution.

B. Dual Batteries

Cumulative lead cell battery is distinguished by the fact that it is used as two types of cells, which are electrolytic and voltaic; in the case of a voltaic cell, it provides electrical energy, and in the case of a non-electrolytic cell, it works to recharge.

Battery Configuration

It consists of (6-3) voltaic cells connected in series, producing 6-12 volts. The anode electrode is made of lead. The cathode electrode is made of lead dioxide. All anode electrodes are connected in parallel, and connect all cathode electrodes in parallel, whereas the insulator used is a glass fibre or rubber material.

Battery Work

At the anode, lead is oxidized into ions for the cathode electrode. It is converted as in the following reaction, PBO2 to PB2.

At anode:

Lead is oxidized to Pb^{2+} ions, which combine with insoluble $PbSO_4$.

$$Pb_{(s)} \rightarrow Pb^{2+}{}_{(aq)} + 2e^{-} \qquad 1.21)$$

At cathode

$$Pb^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4(s)} \qquad (1.22)$$

Overall anode Reaction:

$$Pb_{(s)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_{4(s)} + 2e^{-} \qquad (1.23)$$

The cell can be charged by passing a reverse current to the cell reaction.

Cell Uses

Buses, big cars, gas engines, hospitals, and in power generation

C. Hydrogen-Oxygen Battery

It is considered one of the best fuel types because it is simple and cheap. The work of the cell is by the continuous flow of fuel with hydrogen oxide, oxygen, and a liquid substance dissolved in electricity.

Battery Configuration

This cell's electrodes are made of compressed carbon and composed of platinum and silver catalysts, and sodium hydroxide is considered an electrolyte configuration solution. In battery interaction, the anode is where hydrogen molecules are oxidized to produce electrons, cathode electrode is oxygen. The oxygen flow is the oxidizing substance, as in the reactions below:

Cell Reactions

At anode:

$$2H_2 + 4OH^- \rightarrow 4H_2O + 4e^- \tag{1.24}$$

At cathode:

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \tag{1.25}$$

Overall, Cell Reaction**:**

$$2H_2 + O_2 \rightarrow 2H_2O \tag{1.26}$$

The emf of the cell = 0.8 to 1.0V

Advantages of Battery

A. It is one of the continuous sources of energy generation.
B. It has a high-power generation efficiency, with an efficiency of more than 70%
C. It does not produce waste that is harmful to the environment, so it is safe and environmentally friendly, the uses of this battery are in the field of submarines, military vehicles, and in space, and it is important to use this type of battery in space because of the need for pure water. Despite the above, there is no perfect battery today[35].

Uses of Batteries

In lighting, photography, lighting, digital devices, games, and watches, batteries are easy to use, comfortable, and need maintenance in some periods, and they must be compatible in size and shape. The life of the batteries ranges from 2-5 years, while lithium batteries have a lifespan of up to 10 years, and in addition, they have a storage rate of up to 70 degrees Celsius.

Types of Batteries

Primary battery Mercury battery, this cell is small and commonly used in hearing equipment and watches battery configuration; it consists of two electrodes, an anode and a cathode.

Anode is represented by zinc, the cathode is represented by mercury, and the electrolyte is a substance dissolved in electricity, ZNO, and KOH, as shown in the following reaction.

1.7 WHY USE RENEWABLE ENERGY?

Since renewable energy is originally natural and abundantly available, renewable, and continuously configurable, such as sun, wind, and biomass, it is available everywhere. It is not depleted or destroyed, unlike traditional sources that may be depleted at any time, such as fossil fuels filled with coal and natural gas oil, because its presence is non-renewable and configurable again only after very long periods. The world to this day depends mainly on traditional energy sources, which, when used, produce greenhouse gases that cause global warming, and there are fears that its consequences will continue to be envisaged.

The most important pollutants emitted from fossil fuels are nitrogen, Sulphur, carbon dioxide, and nuclear pollutants such as uranium. The use of renewable energy has been progressing in recent decades, such as solar and wind, with an installed capacity of more than 256 kWh in 2020, representing electricity, accounting for 29% of renewable energy sources. One of the essential advantages of renewable energy use

a. Is not emit greenhouse gases or is few compared to traditional energy sources, and this is clean or environmentally friendly and does not produce harmful by-products or affect temperature; alternative energy sources help preserve the environment as well as conserve natural resources or wealth from depletion and continue to generate and the (Figure 1.46) shows the size of co2 emissions for the period 2010-2050.

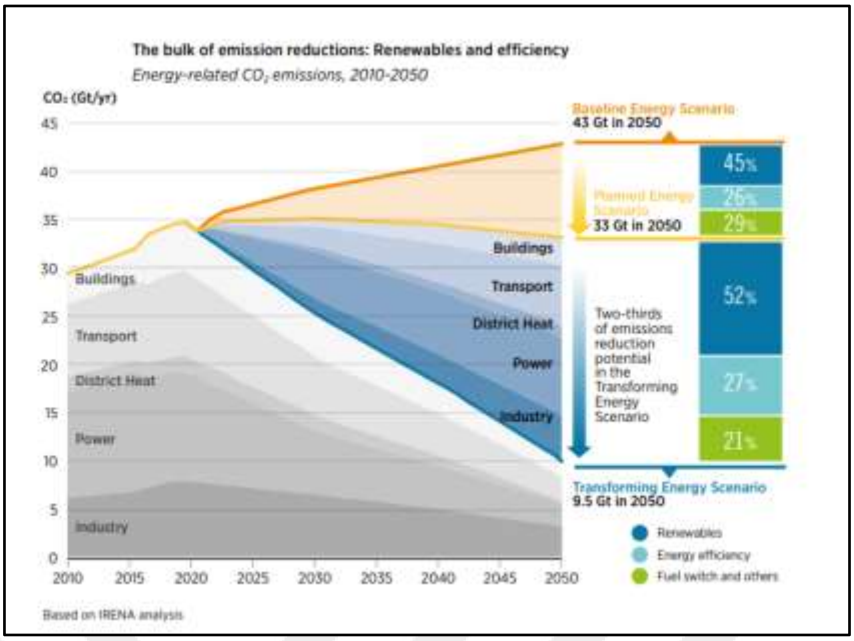


Figure 1.46: The Size of Co2 Emissions for 2010-2050.

b. Using alternative energy sources encourages sustainable development and circular harvesting as an essential factor in increasing and developing economic and social growth.

c. Renewable energy sources are low-cost when used, which is why they compete with traditional sources in equipment and machinery that are easy and low cost because fossil fuels are constantly and volatilely rising in price.

d. The use of nuclear energy raises environmental and political concerns, and some states are reluctant to use it.

e. Alternative energy sources, when used, require staff to work, which opens up new horizons and reduces unemployment to work in research, development, manufacturing, and operation.

f. Renewable energy increases energy efficiency because it is used in the event of a lack of energy supply or a weak grid, which is complementary to traditional energy sources and is widely used in electricity and heating plants. After all, its use does not cause greenhouse gas emissions, as in greenhouses, which encourages increased investment in this sector.

g. The hybrid power system is easy and flexible in the event of a delay in work and can use more than one source to save energy if it is considered complementary to some of them, which enhances the operating efficiency and reduces cost, as shown in the (Figure 1.47) below.

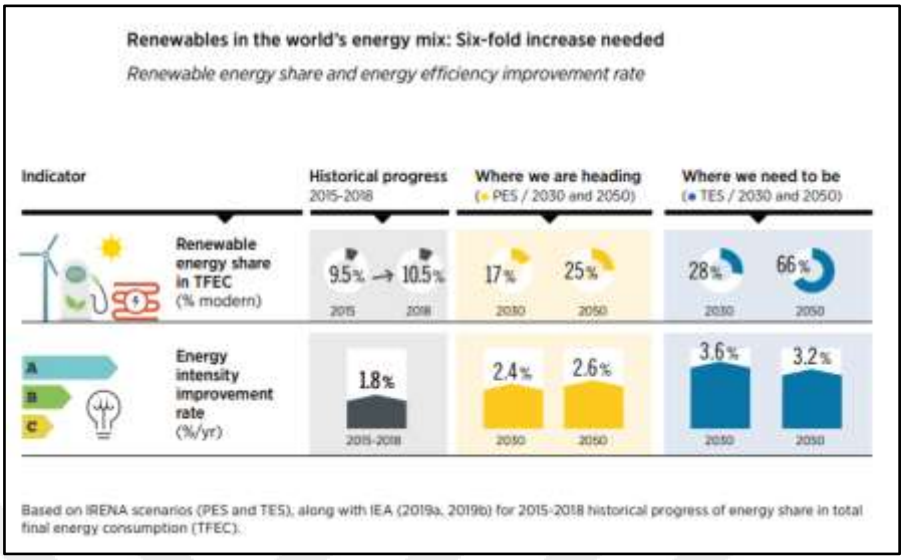


Figure 1.47: Renewable Energy Share and Energy Efficiency Improvement Rate.

h. It is increasing the efficiency and effectiveness of electrical energy by using renewable sources and, as in (Figure 1.48) for multiple periods [32].

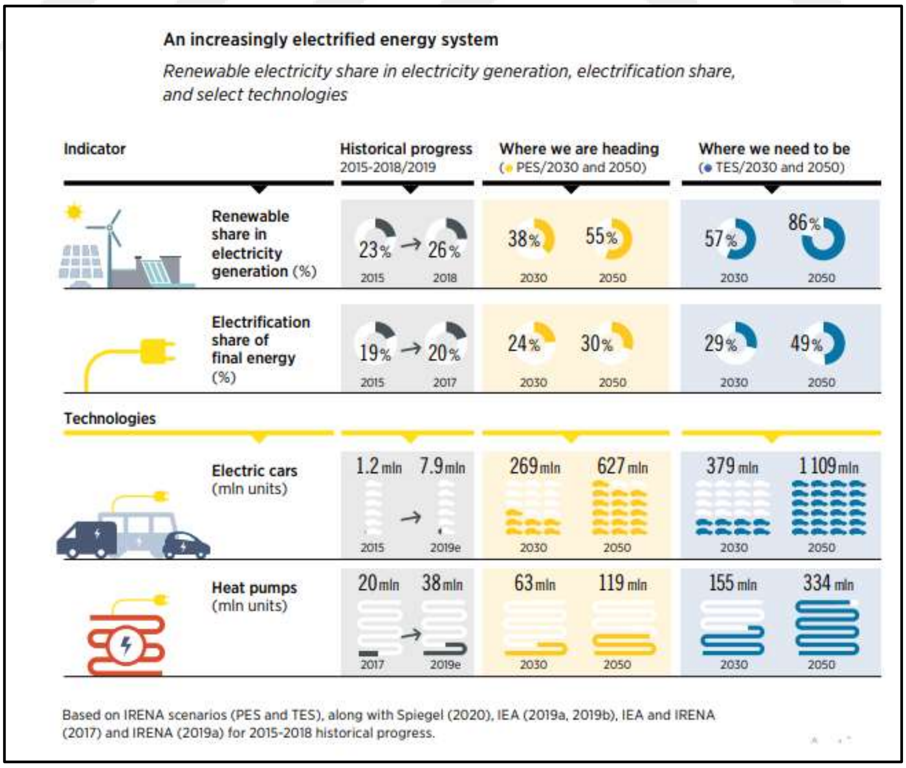


Figure 1.48: Renewable Electricity Share in Electricity Generation, Electrification Share, and Select Technologies.

i. Since alternative energy sources are available and found everywhere, this is cheap and accessible to everyone, and this increases development and growth, as it is effective and suitable for poor countries, as the techniques used are simple and can be manufactured in such countries, which is unlike traditional sources that are limited to specific locations [33].

j. Energy can be used in all fields, such as industry, electricity, transportation, heating, and cooling, which reduces the accumulation and accumulation of waste and environmental pollutants.

k. The world is increasing energy consumption to meet all needs, so relying on traditional energy sources has become insufficient at present and in the future, and other sources must be found [34].

A. Renewable energy sources do not need high voltage systems or high-pressure transmission lines because the generation source is near the load and from the power distribution center, As shown in (Figure 1.49) below: [35].

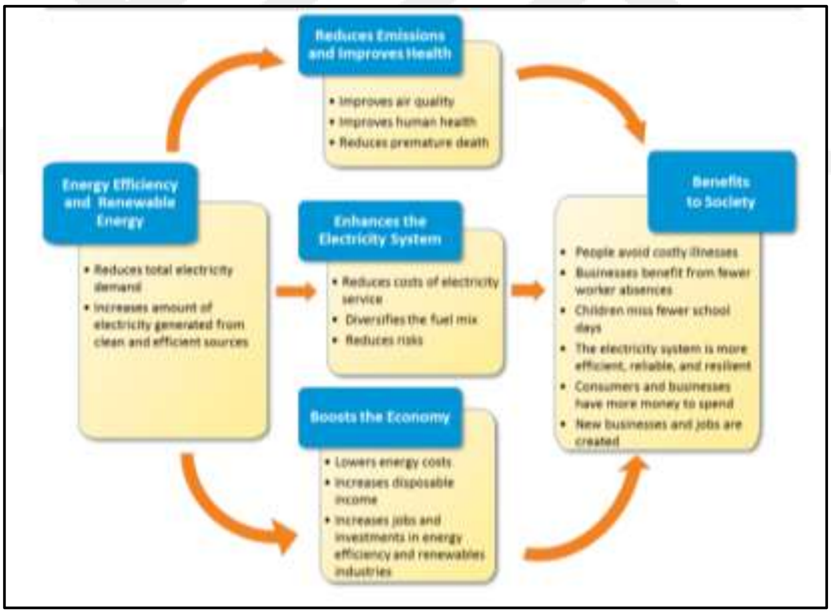


Figure 1.49: The Multiple Benefits of Energy Efficiency and Renewable Energy.

1.8 RENEWABLE ENERGY SOURCES

Renewable sources are sources that are in abundance, that are inexhaustible, or can be regenerated and do not require extended periods in their formation, as in fossil fuels, and working with them does not cause the emission of greenhouse gases or they are almost non-existent or very few, and most important of these sources:

a. Solar Energy
b. Wind Energy
c. Biomass Energy
d. Earth's Energy
e. Thermoelectric Energy

To clarify the difference between conventional energy sources and renewable energy from the table in his ears [36].

Table 1.1: Status of Conventional and Renewable Power Sources.

Status of Conventional and Renewable Power Sources	
Conventional	Renewable
Coal, nuclear, oil, and natural gas Fully matured technologies Numerous tax and investment subsidies are embedded in national economies. Accepted in society under a "grandfather clause" as a necessary evil	Wind, solar, biomass, geothermal, and ocean Rapidly developing technologies. Some tax credits and grants are available from federal and some state governments. Being accepted on their merit, even with a limited valuation of their environmental and other social benefits

1.8.1 Solar Energy

Among the most important sources of renewable energy is solar energy, as the rays emitted from the sun can be benefited from. Solar energy is the best and most important alternative energy source because it is more available than other sources; the source of the sun alone is sufficient to power all human needs for a whole year, in addition to being one of the clean and pollution-free sources because it does not produce harmful by-products. In solar energy, there are two types:

a. Radiation light
b. Ray heat rays

Work began in this field several centuries ago and was used in burning through mirrors, heating, lighting, and burning military ships. Europe's first use in the heating sector was.

1.8.1.1 Mechanism of action

It is the conversion of light into electricity through cells called photovoltaics, as the incoming light into the cell is captured by the electrons in the cell and transmitted inside the cells to the semiconductor where they are part of the electric flow, and this process is called the electric field. His energy can generate current in a light bulb. The semiconductors are of the (N) type and have a high amount of negatively charged electrons, and other semiconductors are of the (B) type and contain many positively charged holes P(n). These electrons and holes combine to produce electrical energy, which results from contact with silicon to result in movement in (B and N).

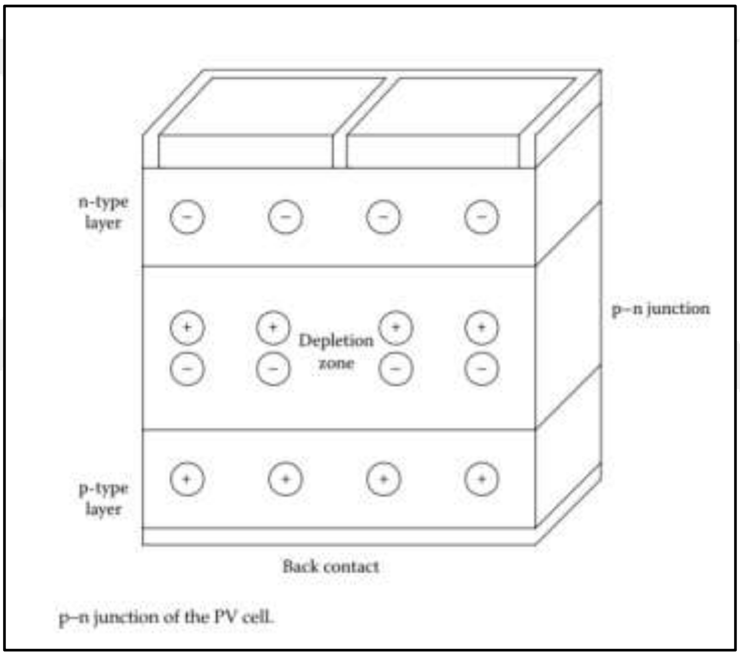


Figure 1.50: P-V Cell.

Silicon is in monocrystalline, polycrystalline, and amorphous states. It is one of the most widely used solar cells and is one of the abundant elements in the earth's crust. However, single-crystal silicon cannot be used in its natural form unless purification is performed on it, and this purification is in a very high state of about 99.999%, i.e., reshaping and arranging the silicon atoms. This process is necessary to increase the conductive efficiency of silicon. As for crystalline silicon, it causes a decrease in the electron flow due to its formation of several crystals, and it is a semiconductor of electricity.

The solar energy system requires a dependable mechanism to determine when the sun's efficiency is solid or insufficient. or at night and the sun's location to choose the best site for absorbing energy. In addition needs to store this energy in a battery, and there must be a transformer to see if there is an imbalance between the generated power, required power, and loads. (Figure 1.51) shows the solar energy system.

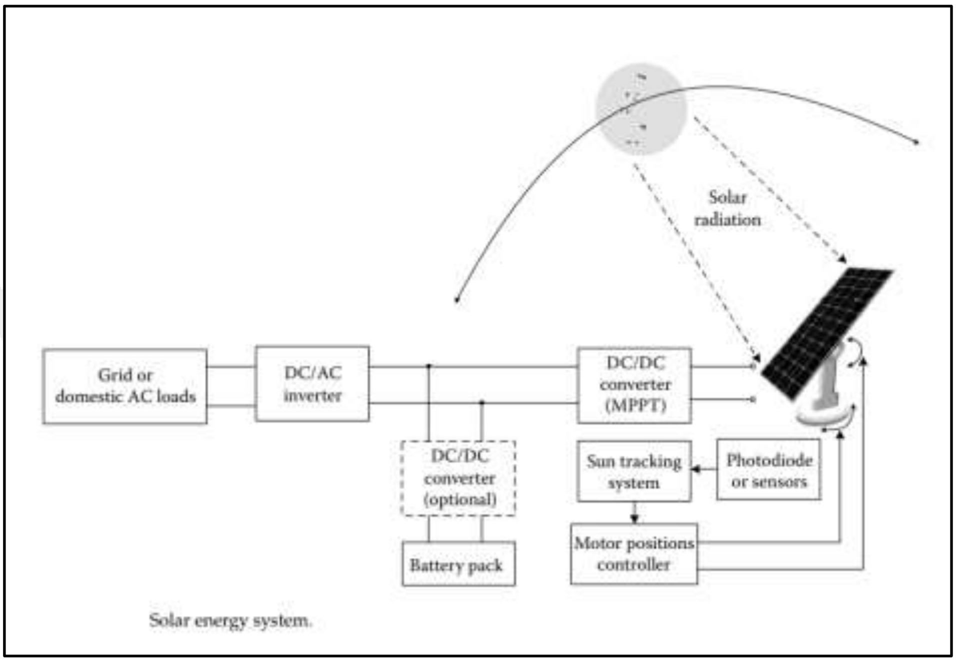
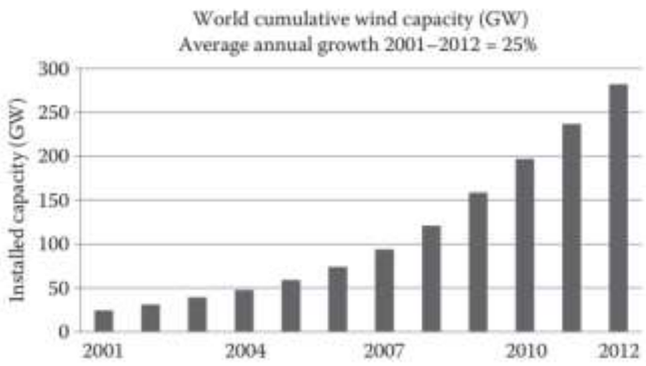


Figure 1.51: Solar Energy System.

It is the conversion of light reaching the ground into electrical energy used in residential neighbourhoods and vehicles.

1.8.2 Wind Energy

has been used for decades, and windmills were known to power both pumps and small electric generators to charge batteries. Over the decades, improvements have been made to this tool in addition to costs, reaching $1,000 per kilowatt-hour. We can see from (Figure 1.52) below the energy evolution.



World total wind power installed capacity. (From WWEA 2012, http://www.wwindea.org/webimages/WorldWindEnergyReport2012_final.pdf.)

Figure 1.52: World Total Wind Power Installed Capacity.

Wind energy is estimated at 55 terawatts worldwide, representing 40% of the world's generation capacity.

1.8.2.2 Mechanism of action

It converts kinetic energy into mechanical and electrical, as this movement generates electricity depending on the wind speed. It is required that this area be regular in wind energy over the decades.

Wind energy has been witnessing rapid development in recent years as it is a pollution-free and available source that does not need high-voltage transmission lines. In 1830 AD, the first windmill was connected to generate electricity, which generated energy. In 1979 AD, a wind turbine was connected to a grid that produced 2 megawatts. Production capacity increased to 300 kWh in the 1990s if power generation wages fell to 4 cents/kWh in 2004 from 35 cents/kWh in 1980 [36].

Wind energy is the most affordable source in the world compared to other traditional energy sources. The production volume in 2020 reached about 100,000 megawatts, the most important factor that increased the energy demand.

a. Create large, low-cost blades from the materials from which they are made.
b. Low electronics prices for wind devices
c. It contains variable speed to obtain maximum power generation.
d. Improvements to operating systems reach 95%
e. There is noticeable progress in this field due to the old experiences that reach 40% wind is one of the sources that help preserve the environment.

It is a set of turbines. These turbines extract energy from the wind through a rotor device consisting of blades connected to an electric generator mounted on the turbine. Several turbines were built to set up a wind farm to generate electric power[42].

The following law determines how to calculate the generated speed and power.

$$\text{kinetic energy} = 1/2\ mv\ 2 \qquad (1.27)$$

Depending on the amount of kinetic energy in the air, which is denoted by m and the speed v, a force's magnitude when applied to flowing air, the rate of kinetic energy flow per second is expressed in terms of watts' power mass flow per second and is equal to (1: 22 V).

power mass flow per second = (122 V) If P = mechanical power in the moving air (watts),

ρ = air density (kg/m3)

A = area swept by the rotor blades (m2)

V = velocity of the air (m/sec), then the volumetric flow rate is AV, the mass flow rate of the air in kilograms per second is ρAV, and the mechanical power coming from the upstream wind is given by the following in watts: (3.3).

Kinetic energy = (122 Mv).

power mass flow per second = (122 V) P, AV = 1 2 1 2 2 3 t

Here, the mass flow rate of the air in kilograms per second is equal to AV, the volumetric flow rate is equal to AV, and the mechanical power generated by the upstream wind is equal to the following in watts: P, AV = = 1 /2 (pAv)v2=1/2pAV2[39].

1.8.3 Biomass Energy

It is any substance that has biological origins, such as plants, waste, animal fats, and food waste. The first biomass known since ancient times is wood, as it is the basis of biomass, as solid fuels are converted into gaseous or liquid fuels. Biomass is considered one of the alternative energy sources and has the advantage of being available and clean. The fuel extracted from biomass is biodiesel or ethanol. Biodiesel is a renewable fuel. Raw biomass materials vary according to the composition of the original materials, and this is due to the structure of the cell and chemical composition. The basic composition is cellulose, starch, or sugar, which depends on photosynthesis from the sun's energy. It results in simple sugar, as in the following reaction:

$$6CO+6H_2o+\text{light (min 8 photonics)} = C_6H_{12}O_6(\text{glucose})+6O_2 \tag{1.28}$$

$$6CO_2+H_2O=C_6H_{12}O_6+6O_2-480KJ/mol \tag{1.29}$$

We note here that the output is glucose and oxygen, the ratio of photosynthesis is due to temperature, and photosynthesis requires carbon dioxide and water to produce sugars. Photosynthesis efficiency is the basis for forming biofuels[31].

Biomass includes: -

a. Crops represented by corn, soybeans, and wheat that produce sugars and oils.
b. Residues of crops, such as in the stems and leaves, as corn husks
c. Herbaceous crops such as perennials such as bamboo, and miscanthus
d. Woody crops such as willow, maple, and cotton
e. Residues of ends obtained from harvesting, removing, or cutting.
f. Aquatic crops such as seaweed and algae

g. Industrial crops: the materials used to produce chemical waves or industrial intermediates such as Al-Tanaf.
h. Animal waste resulting from animal and human waste.
i. Waste of residential, commercial, and industrial cities, the sources of biomass resulting from agricultural lands, and secondary sources of animal waste and residues and food residues as in (Figure 1.53), where the first figure shows the sources of biomass[31].

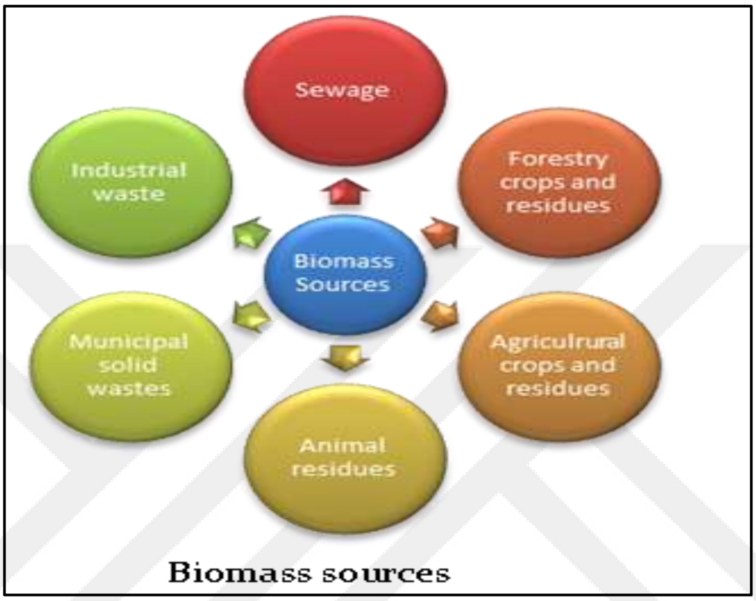


Figure 1.53: Biomass Sources [37].

The second (Figure 1.54) shows the sources and use of biomass after treatment.

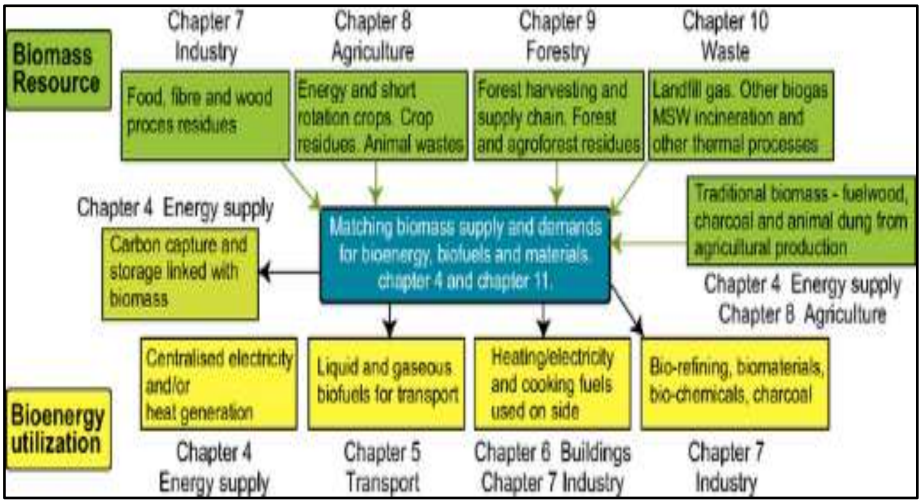


Figure 1.54: Sources and Use of Biomass after Treatment [38].

Materials from biomass: -

a. Ethanol liquid fuel is used as fuel, and methanol is used as secondary fuel.
b. Biodiesel, and vegetable oils, dissolved at 17-20 MJ/kg.
c. Gaseous fuel, biogas, consists of 55-70% methane and carbon dioxide.
d. Synthesis gas consisting of carbon dioxide and hydrogen is shown in (Figure 1.55).

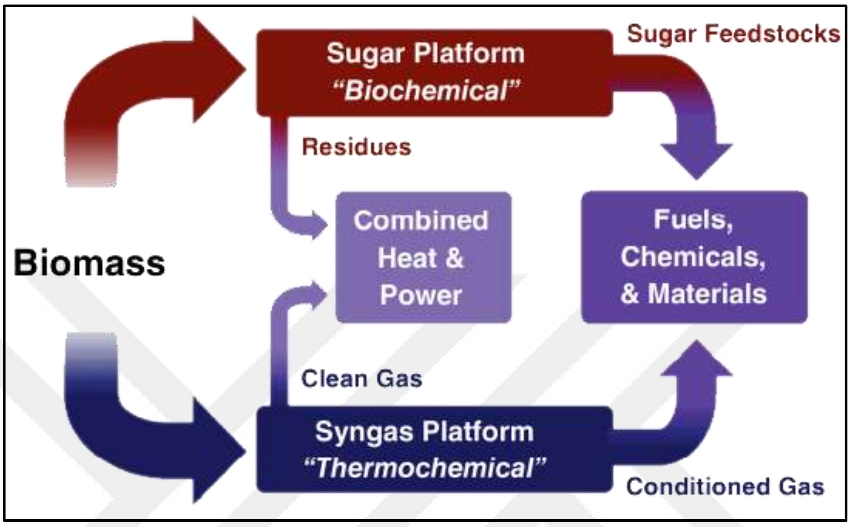


Figure 1.55: Synthesis Gas [39].

The site of SeinCat University in Beijing for studies is the Synfuel Laboratory in China, which shows syngas and its chemical formula (Figure 1.56) [46].

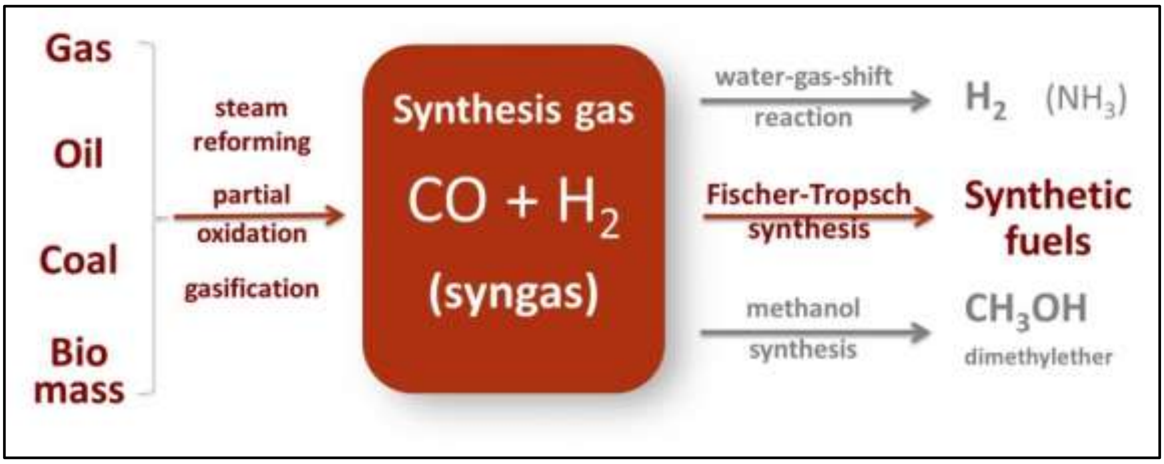


Figure 1.56: Chemical Formula Syngas.

1.8.3.1 Biomass conversion

The transformations of biomass are classified into several fields, according to the reactions and mechanisms of decomposition, depending on the conditions and factors used in each field, as shown in the (Figure 1.57) below:

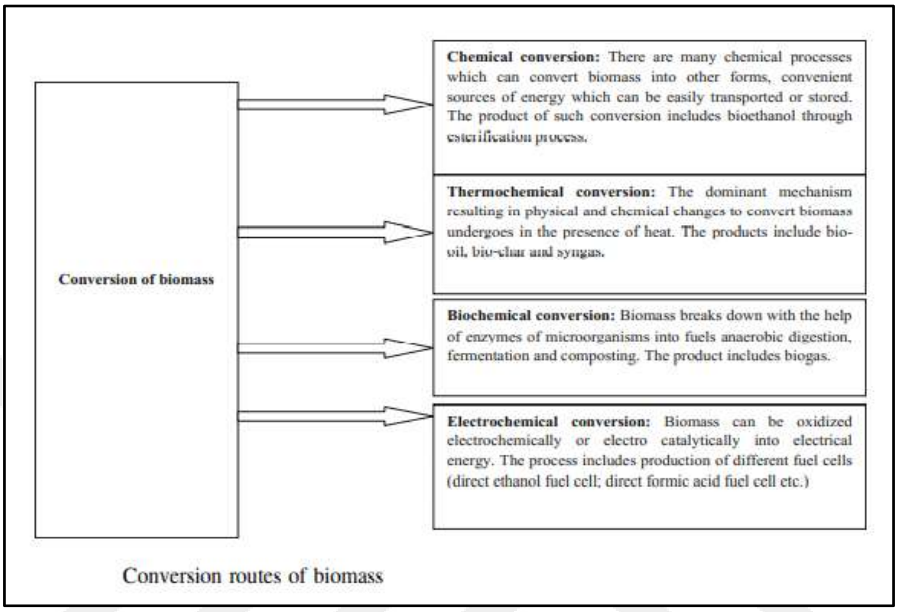


Figure 1.57: Conversion Routes of Biomass[40], [41].

Biomass conversion is divided into two types: -

a. Thermochemical Conversion
b. Biochemical transformation, as shown in (Figure 1.58):

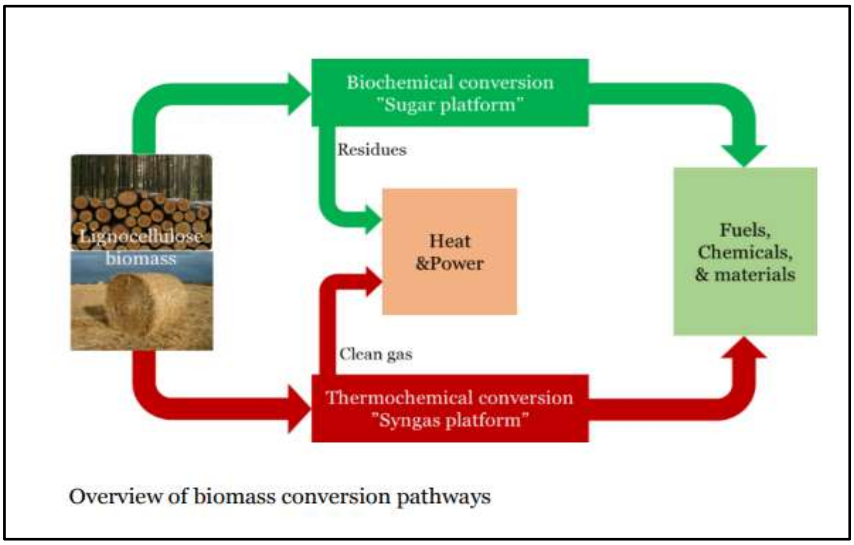
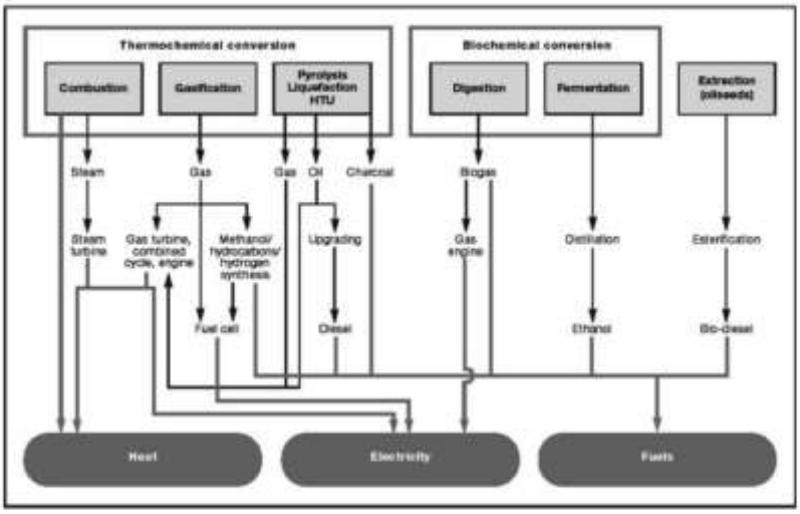


Figure 1.58: Overview of Biomass Conversion Pathways.

Bacteria and enzymes are by hydrolysis into small molecules, which are usually inefficient and slow and are usually used in biochemical conversion processes. In the case of thermochemical conversion, biomass is converted into small molecules by heat through physical and chemical reactions [42]. Biomass conversion as in (Figure 1.59) below:



Main conversion options for biomass to secondary energy carriers (Turkenburg 2000).

Figure 1.59: Biomass Conversion [43].

1.8.3.2 Production models

for biofuels, biomass was first used in the nineteenth century for fossil fuels, the use of biomass is equivalent to 10% of global energy use, and it is the most renewable energy sources The materials used in biomass to produce biofuels are wood fibers, grasses, primary and secondary crops, algae, and seaweed. Recent years have seen a high production of biofuels to reduce greenhouse gas emissions The increase in the use of biofuels is due to the increase and fluctuation in the prices of fossil fuels, as well as in response to the document signed to limit and reduce global warming [44]. The most crucial biomass products: -

a. Bio-alcohol (methanol, butanol, ethanol)
b. Biodiesel
c. Bio-hydrogen
d. Algae fuel
e. Biogas
f. Synthetic gas
g. Solid biofuels (fertilizers, wood panels)

The main advantages of biofuels:

a. Reduce greenhouse gas emissions.
b. Low production costs of ethanol and biodiesel.
c. High efficiency and high octane as in bioethanol.
d. It is highly effective in solubility and is considered cleaner in engines and tanks.
e. Biofuels are non-toxic, safe, biodegradable, and transportable.
f. Biofuels are considered medium and moderate in terms of prices, contributing to reducing poverty.

Disadvantages of Biofuels:

a. Biofuels require many materials to produce energy. It has not yet been confirmed that greenhouse gases are not being emitted.
b. The change, like the land and the exchange of products for other products, causes a change in the soil and the removal of forests, which leads to a reduction and lack of biological diversity.
c. The change in crops and their replacement with other crops to generate energy leads to an increase in the prices of food commodities.
d. The resulting energy density is low compared to gasoline.

1.8.4 Thermoelectric Energy

It is the energy produced from ambient and regular energy, which is converted into electrical energy. Balance is a prerequisite between the required and existing energy; these resources must be robust and highly efficient. The energy source from which this source is produced is the basis of a thermal gradient, electromagnetic radiation, light, motion, and chemical energy [45].

Combined energy sources: -

a. Natural or artificial source
b. The energy converter that converts environmental energy into electrical energy
c. An energy storage device such as rechargeable batteries or capacitors
d. Electronics

1.8.4.1 Thermal energy mechanism

The collection is widespread depending on the surroundings, which contain a temperature difference that can convert this heat into electricity. As the energy generation is efficient, this energy's efficiency depends on the source's efficiency and the amount of heat emitted. In the place, heat is collected from thermal wristwatch devices that generate electricity from body heat, as it produces 22 megawatts of energy, As in (Figure 1.60), which represents the heat generated by the electrical stations[51].

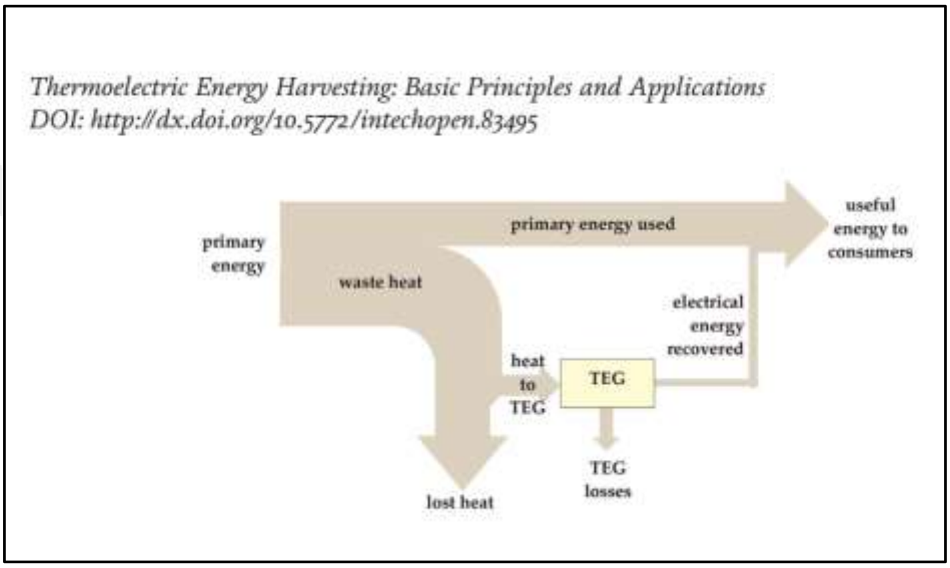


Figure 1.60: Thermoelectric Energy Harvesting: Basic Principles and Applications.

1.8.4.2 Thermal Generators

are characterized by generating reliable and static energy, and they can be developed to generate electric power, as they are cheap. Energy is produced from the occurrence of electro-thermal effects through the electrons in metals with semiconductors that are in active motion, and this process is similar to the movement of gas during load. The movement is from the hot to cold section, and the charge is negative in the end for the electrons and positive for the holes, and this generates an electric potential, generating a balance between chemical reactions and electrostatic repulsion as a result of the accumulation of charge.

This process is called the Seebeck phenomenon. Thermoelectric devices contain multiple pairs of thermoelectric consisting of free electrons and holes, any conductive elements, and thermal elements. This process needs a heat generator to contribute to the passage of heat from the difference between temperatures to produce electrical energy for the external circuit as in the equation[51].

There is a need to obtain the highest efficiency and distinction in the work of this field on batteries through the presence of energy density and in terms of low cost because the batteries need to be replaced and changed continuously. The process is based on charging the battery with high power (megawatts or watts) for a short period, a few seconds, and the devices used are sensors and communications. The remaining time is collected by the battery power, as in Carnot's law:

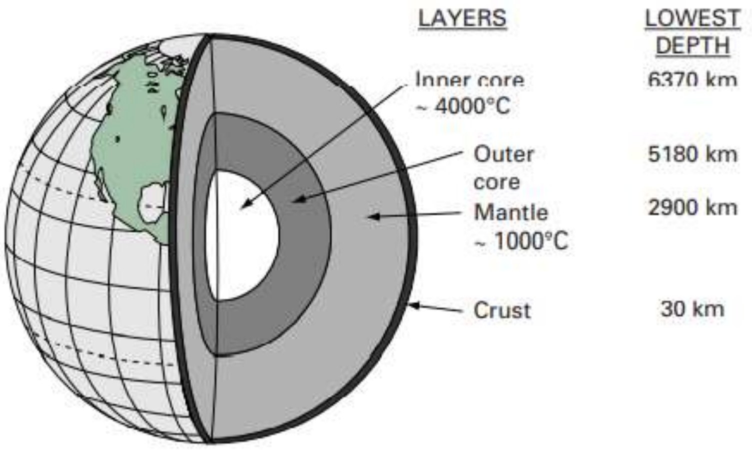
$$\eta_{carnot} = \frac{\Delta T}{T_h} \tag{1.30}$$

This is the temperature resulting from thermal energy. Here we see that this is insufficient compared to other energy sources because the energy generated is negligible compared to sunlight, which produces about 100 megawatts / cm2 in an office, higher than the wristwatch generated by thermal energy. The heat generator is what drives the conversion of heat into electricity. The converter's efficiency depends on the temperature[51].

1.8.5 Earth Energy

It is known as the heat in the earth's interior, as it is boiling, and the temperatures are high to bring us closer to the earth's center. The energy in the earth's interior produces raccoons and hot water springs.

This indicates that the earth's center is sweltering and produces heat continuously. The intensity of heat is constantly produced from Earth to space. From this, solar energy is absorbed from the soil and returned to space. Heat is formed over a very long range, estimated at 4.5 billion years, in addition to the source of heat from the radiation of radioactive isotopes. The center of the earth is about 4000 degrees Celsius. The following (Figure 1.61) shows the amount of Earth's heat in each part [46].



Geothermal structure of the Earth, showing average lower depths of named layers. The crust has significant variation in composition and thickness over a local scale of several kilometres.

Figure 1.61: Geothermal Structure of The Earth [47].

This energy is characterized by being a clean, emissions-free, safe, and cheap source compared to petroleum, as it is considered a non-renewable fuel because its use in an area we notice is less and not generated again in this region because it was millions of years ago due to numerical factors, it is subject to depletion. Work is characterized by this resource efficient and robust in the face of harsh environmental conditions [47].

Possible uses of ground energy in heating, agriculture, air conditioning, and electricity generation from this source depends on the heat of the Earth's interior and how the phenomena occur and exploit them. The earth is a mixture of multiple minerals and silicates. The base mineral is iron, water, and hydrocarbons [47].

Volcanoes represented by one of the geological phenomena are active in a certain number of countries, and these must be exploited to generate geo-ground energy. The number of countries that use this source is 25, and the energy production is approximately 11,000 megawatts, as shown in (Table 1.2).

Table 1.2: Capacity for Electricity Generation (MW) [46].

Countries with effective use of geothermal energy. The table shows the installed capacity for electricity generation (MW,), capacity factor Z for geothermal electricity, and installed capacity for direct heat use (excluding 'surface' ground- and air-source heat pumps) (MW_{th}). All data are for 2010.					
Country	Electricity capacity MW_e	% Of world geothermal total	Electricity capacity factor Z (%)	Direct heating capacity (excluding hear pumps) (MW_{th})	% of world total of direct heating
USA	3093	29	61	611	4
Philippines	1904	18	62	3	
Indonesia	1197	11	92	2	
Mexico	958	9	84	155	1
Italy	843	8	75	636	4
New Zealand	628	6	74	386	3
Iceland	575	5	91	1822	12
Japan	536	5	65	2093	14
El Salvador	204	2	79	2	
Kenya	167	2	98	16	
Costa Rica	166	2	78	1	
Nicaragua	88	1	40	0	
Turkey	82	1	68	1548	10
Russia	82	1	61	307	2
China	24		71	3690	24
Others	168	2		4075	27
WORLDTOTAL	10715	100%		15347	100%

The rate of use of ground energy has increased in recent decades, reaching $2,500 per installed electric capacity, as in nuclear and hydropower [46].

The total energy is estimated at 150 oxyjoules / year, or 4.5 million megawatts, according to the statistics of the International Energy Agency [47].

1.8.5.1 Forms of use of geothermal heat

a. Geothermal heat can generate electricity, as the ground heat reaches 150 degrees grilled for flowing water and rising vapours so that it can be used to produce electrical energy.
b. Hot water: Hot water is represented by springs and bathrooms with temperatures of about 50-70 degrees Celsius and is used for heating and drying crops and heating buildings.
c. Heat pumps can be exploited near surfaces of 3 m to generate heat for buildings.
d. It is used in electric power generation, reaching five terawatts, compared to hydropower generation, which amounts to 3.4 terawatts [46].

There are three geothermal zones:

a. Hydrothermal temperature is at 80°C.
b. Sub-thermal temperature between 40-80 degrees Celsius.
c. The average temperature is 40°C [46].

Methods of obtaining heat by:

a. Hydrothermal circulation.
b. Pyrotechnics.
c. Crushing igneous rocks [46].

Ground Energy must be obtained near the place of demand because it lacks an effective distribution mechanism in long-distance transportation, and there must be a population density. To exploit this energy, about 350 people generate 100 megawatts of geothermal heat in the region. It can also be used in greenhouses, fish, and drying food.

1.8.6 Distribution Generation Energy

Given climate change and the occurrence of global warming, and the demand to activate a role for sustainable development, a change in the strategy of using the current fuel in power generation must be resorted to, i.e., from sources with less or no carbon emissions, as the use of renewable energy will contribute to reducing the occurrence of this phenomenon, It is expected that there will be a focus in the field of electric power generation from renewable sources (solar energy, wind energy, biomass, water). Combining heat and energy is one of the essential goals in reducing the risk of emissions [48].

The following (Figure 1.62) shows the mechanism for the operation of a conventional fuel power plant and a renewable power plant.

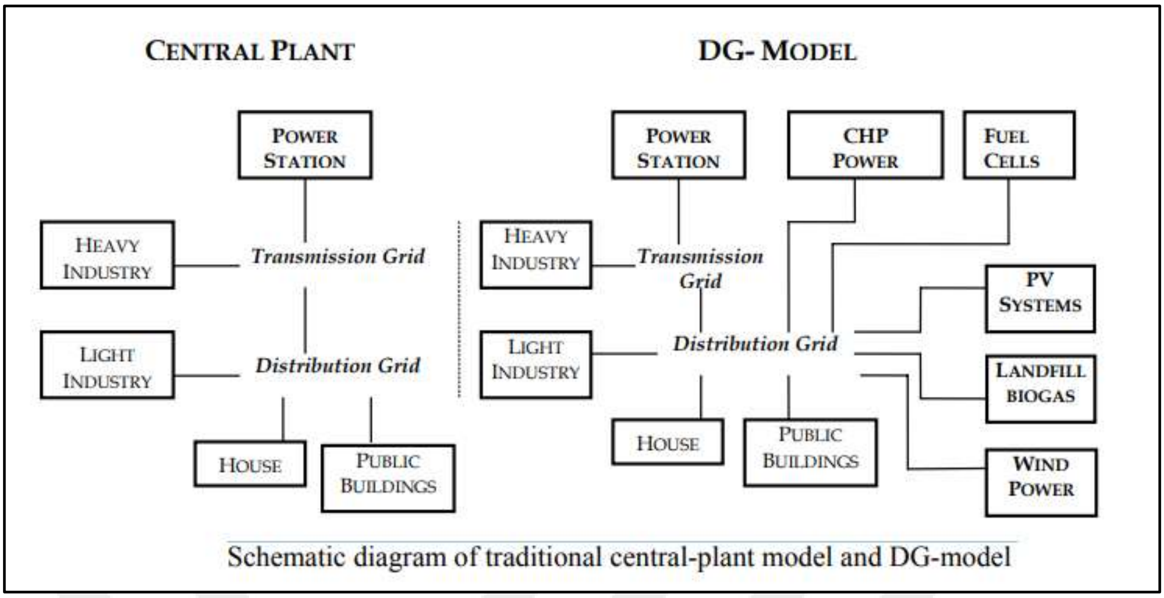


Figure 1.62: Traditional Central Plant and DG Models [49].

Different extensions characterize distributed generation as the energy source between the customer and the grid. The energy distribution system is complex, consisting of several suppliers, consumers, heating pipelines, storage facilities, and energy transmission lines. Electricity generation needs to be near power plants or resources, as the energy is transmitted by memorable high-pressure lines and then distributed to medium-voltage networks. The energy generation must be from different sources or hybrid, reliable, and safe. The goal is to reduce dependence on fossil fuels and add renewable energy sources. This transformation can contribute to growth, as in (Figure 1.63) below:

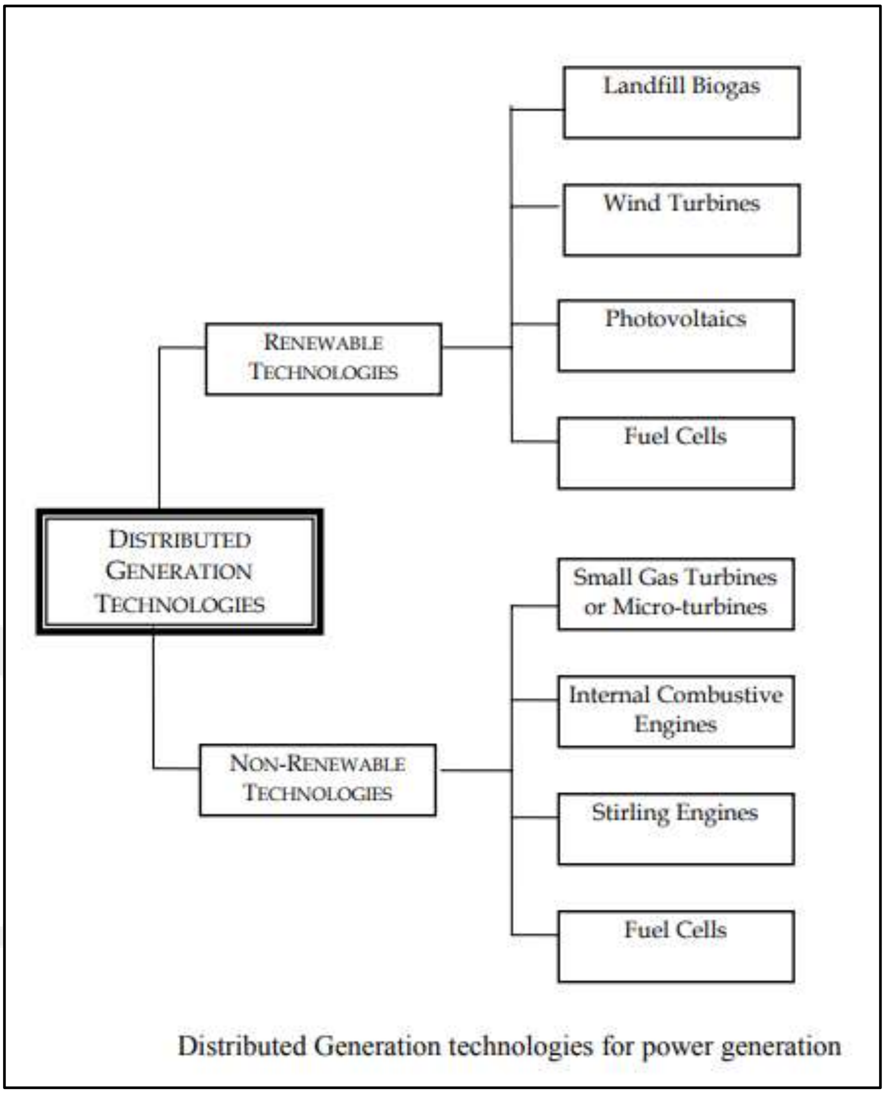


Figure 1.63: Distributed Generation Technologies for Power Generation [54].

The following figure shows the difference in the work of a power plant based on its operation. Conventional and renewable fuels following (Figure 1.64) show the mechanism for operating a conventional fuel power plant and a renewable power plant[55].

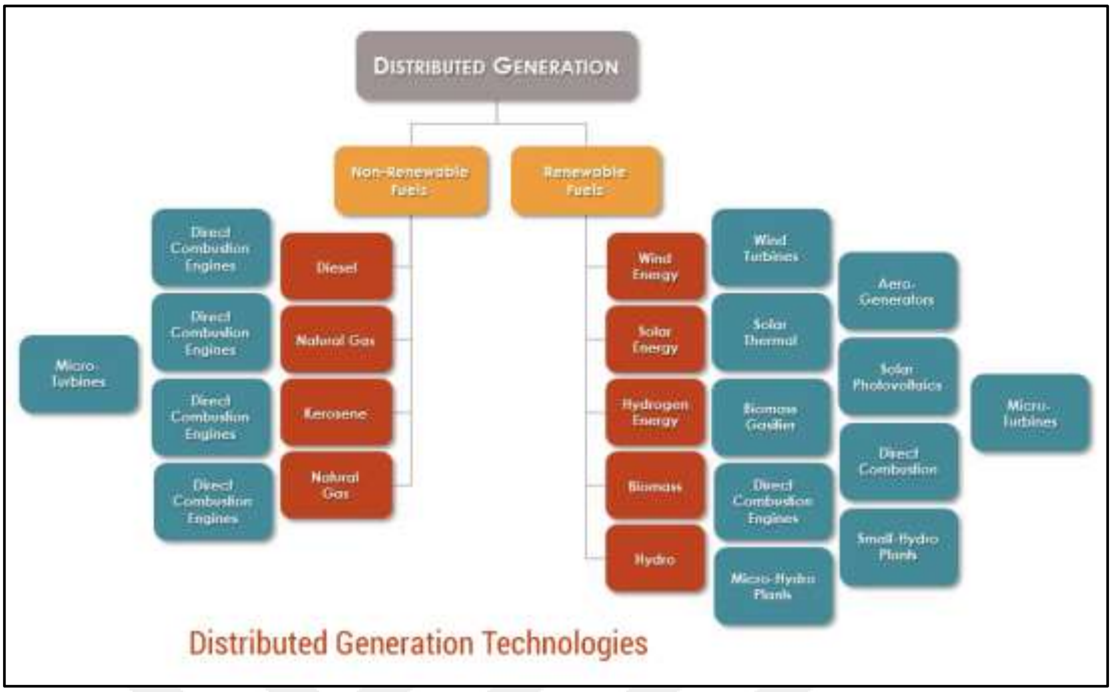


Figure 1.64: Distribution Generation Technologies [56].

The site shows the efficiency of the distribution of some energy sources according to (Table 1.3):

Table 1.3: The Efficiency of The Distribution of Some Energy Sources[54].

HNOLOGY	BENEFITS	DRAWBACKS	FUEL CHOICE	SIZE (KW)
Microturbines	Thermal recovery improves s efficiency	Insufficient thermal output for industrial apps	Natural gas, propane, diesel, multi-fuel	15–250
	Thermal output for residential or small commercial apps			
Efficiency is 28% to 33%	Operable as base, peaking, or back-up			
	Commercially available in limited quantities			
Small Gas Combustion Turbines	Highly efficient when used with thermal recovery	Potentially onerous siting and permitting requirements	Natural gas, distillate, methane	3,000–15,000
	Technology commercially available today—the most likely candidate for on-site needs >3 MW in DG applications	Environmental issues—emissions and noise		
Efficiency is 25% to 40%	Can operate base load, backup, or peaking	Possible on-site fuel storage needs		
	Several manufacturers			
	Relatively low installed costs			
Internal Combustion Engines	Bulk power is delivered when the utility is unavailable	Insurance policy effect: Capital is only being used when the backup generator is running	Diesel, natural gas, propane, biogas, and other petroleum distillates	<1–6,000
	The fast startup allows less sensitive processes to be served without the need for UPSs (emergency lighting, HVAC, elevators, and some manufacturing processes)	· Marginal cost of production generally favors the utility source in all but rare occasions		

Table 1.3: The Efficiency of The Distribution of Some Energy Sources[54]"Table Continued".

HNOLOGY	BENEFITS	DRAWBACKS	FUEL CHOICE	SIZE (KW)
Efficiency is 28% to 37%	Very mature, stable technology	Environmental issues—emissions and noise		
	It can be paralleled to the grid or other generators with a control package.	Possible on-site fuel storage needs		
	It can be very efficient when combined with heat recovery.			
Fuel Cells	Very high fuel efficiency from hydrogen to electricity	Few commercially available devices	Directly by hydrogen; natural gas, propane, methanol, or other hydrogen-rich sources through the reformer	MCFC (molten carbonate fuel cells): 250–2,850
	Potential to operate base load with utility back-up	Most research efforts are for automotive applications		PAFC (Phosphoric acid fuel cells): 200
High temp: Efficiency is 45% to 55%	Possible residential application—a no-moving-parts energy appliance	Need for fuel reformer in almost all applications (reduced fuel to electrical efficiency)		PEMFC (proton exchange membrane fuel cells): 3–250
	Very high efficiencies when combined with heat recovery	Not a zero-emission technology—the effect of that may vary by state		SOFC (solid oxide fuel cells): 225–2,240
Low temp: Efficiency is 30% to 40%	Green technology—water and heat are the only emissions from hydrogen fuel, with low emissions from other fuels.	Cold start is 1-2 days for MCFC, 3 hours for PAFC, 1 hour for PEMFC, and 2 minutes for SOFC.		
Photovoltaic	No variable costs for fuel	Giant footprint (600 ft^2/kW)	None	

Table 1.3: The Efficiency of The Distribution of Some Energy Sources[54]"Table Continued".

HNOLOGY	BENEFITS	DRAWBACKS	FUEL CHOICE	SIZE (KW)
	No moving parts—inexpensive maintenance and long life	High installed costs		Limited by the available area
	No emissions, no noise	Not suited for base load		
	It can be used for peak shaving	Not suited for backup except when accompanied by storage		
	Highly reliable, mature technology	Variable energy output		
Large Wind Turbines	No variable costs for fuel	Need to meet siting requirements	None—need winds of >12 mph or sometimes higher	<1–1,000
	In utility implementation, zero emissions may allow a green power price premium.	Generation is intermittent with wind, and the energy output can vary with wind speed squared or cubed over the operation range. Not appropriate as backup or off-grid applications		
	Mature technology	Needs utility source for energy purchases and sales		
	Multiple manufacturers	It can require a footprint of up to $100ft^2/kW$		

One of the biggest electrical energy problems is the loss and waste of energy with losses in the distribution networks. Avoid these losses by reducing waste and controlling the transmission and distribution networks. Among the most prominent of these solutions[54].

a. The electric power network needs more growth, safety, and reliability in technology, reducing emissions and being more organized.

b. The electricity supply goes through several obstacles, which are fluctuations in the electrical voltage and a reverse flow of energy to ensure that more energy flows, the stability of the network must be taken into account in terms of payment to increase the flow of energy.
c. Distributed generation is one of the new energy regulations by adding grid-connected renewable energy sources.
d. Electric energy, or the field of electric energy, is not regulated because the expenditures are large in exchange for a long-term period, which is not commensurate with global energy consumption.
e. They are increasing the capacity of the electrical network by adding new sources, which have received global attention because of their practical value in these sources of low costs, such as solar energy, wind energy, and biomass.
f. Several countries have achieved large profits in blending fuels, raising the percentage of renewable energy in fuel blends.
g. There must be parity and balance between supply and demand for energy, and loads and consumers must be monitored because using renewable energy resources improves the efficiency of electric stations' work—one strategy for consuming more energy.

There are three cases of low, medium, and high. This is based on the type of network problem that you can fix. Using renewable energy sources can cause fluctuations in the current with compatibility problems between devices and their control.

1.9 THE COST OF RENEWABLE ENERGY

In the past few years, the world has witnessed a demand for renewable energy sources, and the most widely used sources are solar energy and wind energy[50], [51].

From 2010 to 2020, there was a decrease in the costs of renewable sources, such as solar and wind energy. It was noted that using these sources in generating electric power was less expensive than traditional sources due to the leading cause of environmental pollution and global warming.

Where it was found that there was a decrease in solar energy costs by up to 85% for the period from 2010-2020, as it amounted to 0.381 US dollars/kilowatt hour to approximately 0.057 US dollars/kilowatt/hour. The total installed capacity decreased from 444,731 US dollars/kilowatt to about 883 US dollars/kilowatt, and the accumulated capacity of the solar panels increased the efficiency from 24 gigawatts in 2010 to 714 kilowatts, as shown in (Figure 1.65) below.

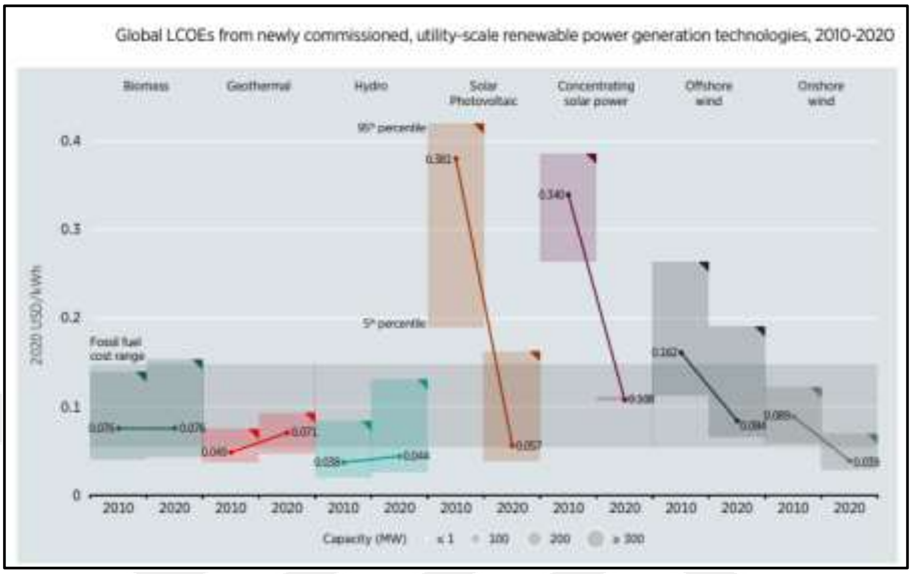


Figure 1.65: Renewable Power Generation Costs in 2020 Costs in 2020.

The cost of photovoltaic energy in residential areas decreased to 0.55 USD / kWh in 2020 compared to 2010, about 0,460 USD / kWh. The rate of decrease was about 82-49% yen.

Wind power fell to 0.039 USD/kWh in 2020 from 0.089 USD/kWh, and the rate of decline was 56%. Using this source also increased to 36% instead of 27%, and the construction cost decreased from 13,595 U.S. dollars /kWh to 971 U.S. dollars/kWh. The installed capacity increased to 699 kWh instead of 178 KWh. This decline indicates lower costs and contributes to lower prices for turbines and terminals. There was a decrease in offshore winds from $0.162 per kWh in 2010 to $0.084/kWh, with a reduction of 48%. Biomass increased the electricity supply by 60 kWh, costing about US$0.076/kWh, the lowest amount for electricity generation.

The addition of renewable sources generating capacity by 162 kWh in 2020 is cheap to cost, and the rate of increase in demand for electricity is about 62%, so these sources will contribute to reducing the costs of generating electricity by about $6 billion annually[57].

1.10 SUMMARY

The goal of energy sources and solar energy is to bring the best resources and references for energy production, find diverse ways to invest resources, and address the inequality in poor energy sources.

Energy is the foundation of life, but its consumption contributes significantly to demographic changes and daily human economic activities. It contributes to changes in environmental issues such as climate change and pollution, as well as changes that affect human health. The use of renewable energy sources significantly reduces carbon emissions. Governments are also attempting to implement alternative energy solutions to eliminate the risks of fossil fuels. Using solar energy to generate energy and producing green hydrogen has dramatically reduced carbon emissions.

The main goal is to provide an analysis of electricity generation in the energy system to find an analysis of the generation system based on diversity and a mixture of different generation technologies based on energy source diversity.

The system was created for energy by using MATLAB simulations that are quick to complete and provide easy access to mathematical solutions, as well as the MPPT algorithm with PID technology and an analysis cell in addition to the photovoltaic solar cell with a battery and a storage tank for the resulting hydrogen, as the resulting hydrogen is considered a sustainable fuel and it is possible to store it. It is stored and used in transportation, heating, and electricity generation.

The lower the battery voltage, the higher the hydrogen production rate, and the grid voltage ranged between 220-235 volts, while the battery voltage reached about 240 volts. The analyzer's power was about 200 kilowatts, a good percentage. The MPPT algorithm is used to get the most energy out of photovoltaic cells, and PID technology is a control unit that helps get the most hydrogen out of photovoltaic cells.

This study is ideal because solar energy is readily available and renewable but somewhat costly if implemented. It is recommended that new control units be found to increase system efficiency or that existing units be improved to ensure longevity with increased energy efficiency.

The first chapter discusses the global demand for energy and electricity. The first chapter discusses the global demand for both energy and electricity, the demand for energy in Iraq, and the various types of conventional and renewable energy.

The definition of energy, the concept of energy, and the types and methods of energy storage were discussed in the second chapter to study the demand for energy in Iraq, with a mention of both conventional and renewable energy.

The second chapter discussed the definition of energy, the concept of energy, and the various types and methods of energy storage.

2. GENERAL INFORMATION

Previous Studies

a. A DC-DC converter and solar cells created electrical power and MPPT technology. Using MATLAB's PID controller, a maximum power point tracking (MPPT) DC-DC converter was linked to a BUCK-BOOST converter Energy [52].

b. In this study, energy storage systems were discussed, which include hydrogen energy and the battery, in which a hybrid storage system was used that links the storage of the battery and hydrogen gas [53].

c. Energy storage systems were discussed, which include hydrogen energy and the battery, in which a hybrid storage system was used that links the storage of the battery and hydrogen gas [54].

d. Used MATLAB simulations with PID and FLC techniques to obtain the maximum energy value generated by the photovoltaic panel.

e. Because the PV system is linked to a buck converter with an FLC intelligent control unit, the maximum amount of energy possible is extracted under various environmental conditions [55].

f. A PSO tracker achieved maximum power with a MATLAB MPPT controller, comparing the resulting value between the photovoltaic panel's current, voltage, and potential capacity [56].

g. A MATLAB simulation with an MPPT console was used, but this algorithm suffers from some fluctuations and disturbance, so an optimization technique, PSO with PID, is used to improve the performance of this algorithm. To be more accurate in performance and faster in reaching the desired result, despite temperature and radiation differences The MPPT algorithm underpins PSO work. PID's MATLAB's role is to simulate the system to produce the best results.

h. Using the PSO-PID control system improves the power system procedure regarding response power and maximum power output [57].

It is well understood that the energy produced by the MPPT algorithm is primarily determined by differences in weather conditions, which are represented by both temperature and the amount of radiation. As a result, a non-linear type control unit must be used to obtain the maximum amount of energy possible from the photovoltaic system using a DC-Dc buck converter.

The simulation results presented here are based on the control unit's fast-tracking and effective performance, and it also compares the proposed control unit and the traditional perturbation and control (P&O) and FLBC console [58].

Many sources and power converters are used in this study, and they must be integrated by connecting each photovoltaic generator with fuel cells. Furthermore, electrolysis devices maintain the amount of energy demand. The hydrogen can then be produced and stored later due to photovoltaic energy in the FC system. The MATLAB sim power system is used to process the amount of reduction and absence of energy in order to obtain more effective results [59].

The process of studying, reviewing, and evaluating the process of producing and storing hydrogen and the mechanism used in its transfer is carried out in this study.

The electrolysis device in the hydrogen production process simulates an energy system consisting of a battery and a fuel cell. It should be noted that the fuel cell consumes all of the electricity entering the system rather than hydrogen. It is stored and reused in the system following the hydrogen production process.

In addition to the water tanks, a polymeric membrane electrolyzer with a MATLAB control unit was used. It emphasizes the system's modelling and simulation process to present the results and benefits and compare them with battery-powered loads [60].

2.1 ENERGY

Energy is defined as the ability to do specific work according to a unique mechanism and high efficiency, which is not technical and does not develop, but moves from one form to another, more like the process of transferring the content of the body from one object to another, such as heating and energy is considered one of the general terms in our daily lives because it enters all areas that everything around us represents energy and is the basis of the basics of the universe energy can be transferred or transformed from one form to another.

For Example

The human body is the energy for being able to do something. Fuel in a car engine is the energy that drives the car and the radio electricity generated by the work of generators. Energy is related to two fundamental factors, namely power and time, according to the following law:

$$\text{Energy} = \text{Power} * \text{time} \tag{2.1}$$

Determination is the use of force to move something. The torque depends on the force used and the distance the object is moved. The law of torque is the product of force *distance. It takes some height and strength to do the job, like lifting a box. One of the essential energy sources is objects and be of two types. One of the essential sources of energy is bodies, and it is of two types [61] :-

a. Vegetable or mineral sources.
b. Industrial resources

2.2 ENERGY FORMS

Energy Forms are classified into two categories.: -

2.2.1 Kinetic Energy

There are several types of kinetic energy.: -

a. Radiant Energy
b. Thermal Energy
c. Kinetic Energy
d. Sound Energy
e. Electricity Energy

2.2.2 Potential Energy

Potential energy is classified into several types: -

a. Chemical Energy
b. Mechanical Energy
c. Nuclear Energy
d. Gravitational Potential Energy

Energy produces many transformations: light, heat, motion, sound, growth, magnet, and rays [62].

Examples of different types of energy:

a. Kinetic is like the movement of a ball.
b. Gravitational height of an object.
c. Rubber compressed body.
d. Chemical Heating Molecules.
e. Nuclear fission of atoms.
f. Thermal warming.
g. Electrical current flow.
h. Radiative light and waves [62], [63].

2.3 FORMS OF ENERGY

2.3.1 Potential Energy

Potential energy which is either stored or the energy of putting any of the body's position in a specific state, for example, gravitational, electromagnetic, or chemical, resulting from burning fuel or radiation from electromagnetic waves.

Potential energy is the product of the difference between the body's position in one state and the energy in another. Energy in a state that is conserved, known as potential, is an example of this elastic potential fossil fuels contain potential energy

$$w = \quad u \tag{2.2}$$

Energy in bodies and irregular motion is energy F is the conservative force.

E U V Potential Energy

you are the change in potential energy.

The moving body is affected by force, and this produces a difference in energy force symbolizing f U, speed.

For each type of equation, as shown below [64] :

$$U = m \cdot g \cdot h \text{ (gravitational)} \tag{2.3}$$

$$U = ½ \cdot k \cdot x\ 2 \text{ (elastic)} \tag{2.4}$$

$$U = C \cdot V\ 2 / 2 \text{ (electric)} \tag{2.5}$$

$$U = -m \cdot B \text{ (magnetic)} \tag{2.6}$$

2.3.2 Kinetic Energy

Kinetic energy is the result of the movement of the body's molecules because it has energy and indicates the extent to which the bond between atoms and molecules depends on three theories?

Motor energy when it doubles, the mass doubles, it does not depend on direction, and it is always positive.

a. Each substance consists of atoms and molecules.
b. The amount of distance here indicates the area in which these molecules are located, i.e., the size they occupy, and does not depend on the space between the molecules.
c. The continuity of the movement of molecules results from collisions between atoms in the place where they are located.

Zero percentage represents the slow movement of atoms, and at 100°C, they are at the top of the activity. The distance in the solid phase is that the particles are close to each other. The liquid state is where atoms are in motion, which is irregular.

The gaseous phase of the molecules is in the state of continuous and active movement, the direction of movement is straight, and the nature of the molecules is large and spaced in the distance. The characteristics of atoms determine the strength of the energy in them, i.e., the more atomic number mass increases and the more kinetic energy can be converted into latent energy.

We note that hydrogen has an atomic number of 2 while gold is 197 atoms, and here gold is heavy heavier than hydrogen

According to the Kinetic Energy Act [65]

$$KE = 1/2\ mv2 \tag{2.7}$$

2.4 ENERGY CONCEPT

There are basic concepts of energy, the most important of which are the following:

a. Energy is related to the individual.
b. Everything around us has energy.
c. The things around us are the result of energy.
d. Energy is a part of things.
e. The production of energy by specific actions or reactions.
f. Fuel is the basis of energy.
g. Energy exists in liquid form.
h. The concept of transformation of energy from one form to another.
i. Everything in an active state is energy [66].

2.5 THE IMPORTANCE OF ENERGY

Energy is considered the backbone of life because it is present in all fields, and it is impossible to live without it if it is included in the industrial sector, transportation, electricity, housing units, and hospitals. It is a measure of the people's well-being, the country's development, and the economy's growth, as it is included in daily life. Energy is also linked to our body because every organ in the human body works with energy in a unique way plants are powered by photosynthesis from the sun, and machines and equipment are all powered by energy to produce clothes, paper, cars and other appliances because energy is the backbone of life when it is used optimally and rationally, it results in the following:

a. Generate more effective decisions.
b. Increase confidence in the safety of the product.
c. Effectiveness and efficiency of economic development.

d. I am resorting to sustainable development.

e. We are reducing pollution, emissions, and environmental disasters.

f. Development of the economy.

Therefore, there must be a special deal with energy according to specific mechanisms, including cost-efficiency and environmental preservation. The necessity of harmonizing and balancing natural resources and energy is achieved by finding new energy sources that are not currently being used.

Energy use is included in many fields today, as the demand for it has increased recently. The following (Figure 2.1) shows the demand for energy as it entered the industry, agriculture, buildings, and transportation [67].

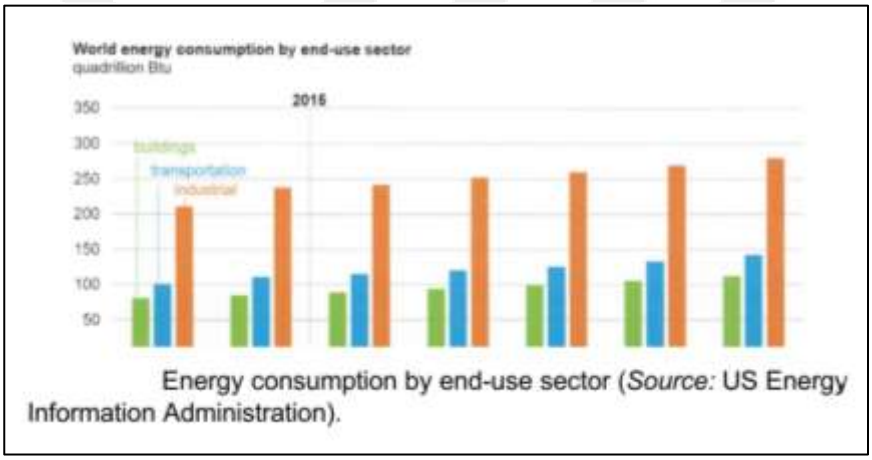


Figure 2.1: Energy Consumption by End-Use Sector.

In the following (Figure 2.2), which shows the increasing demand for energy sources, namely, natural gas and alternative energy, it is noted that gas is the fastest growing according[73].

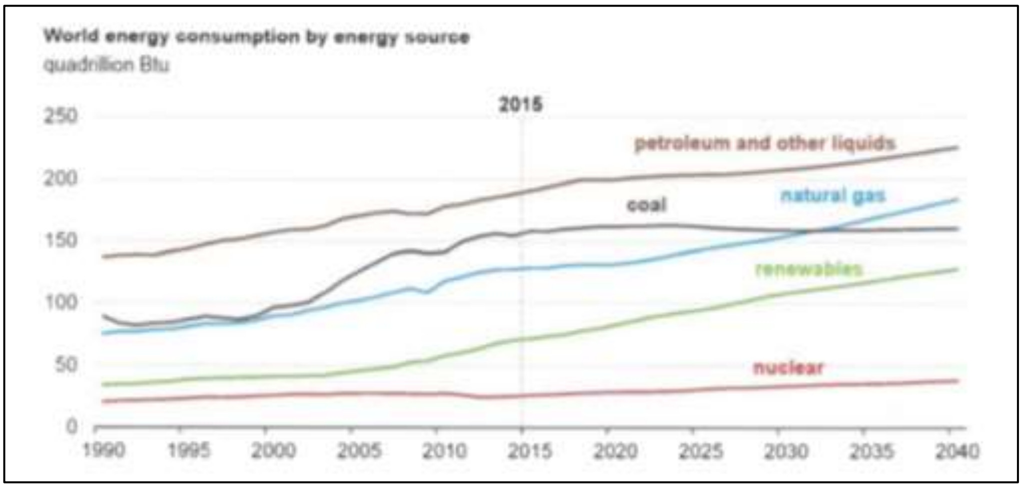


Figure 2.2: Energy Consumption Projections.

2.6 TYPES OF ENERGY

2.6.1 Chemical Energy

Chemical Energy is formed by the combustion of the material represents energy in materials such as oil, gas, and all fuels to generate electricity generated by electrons and chemical bonds that transport energy. The carrier must be excellent and efficient to get electrons and electric power, so the pressure on traditional energy sources must be relieved and moved to new sources, as in (Figure 2.3 below.

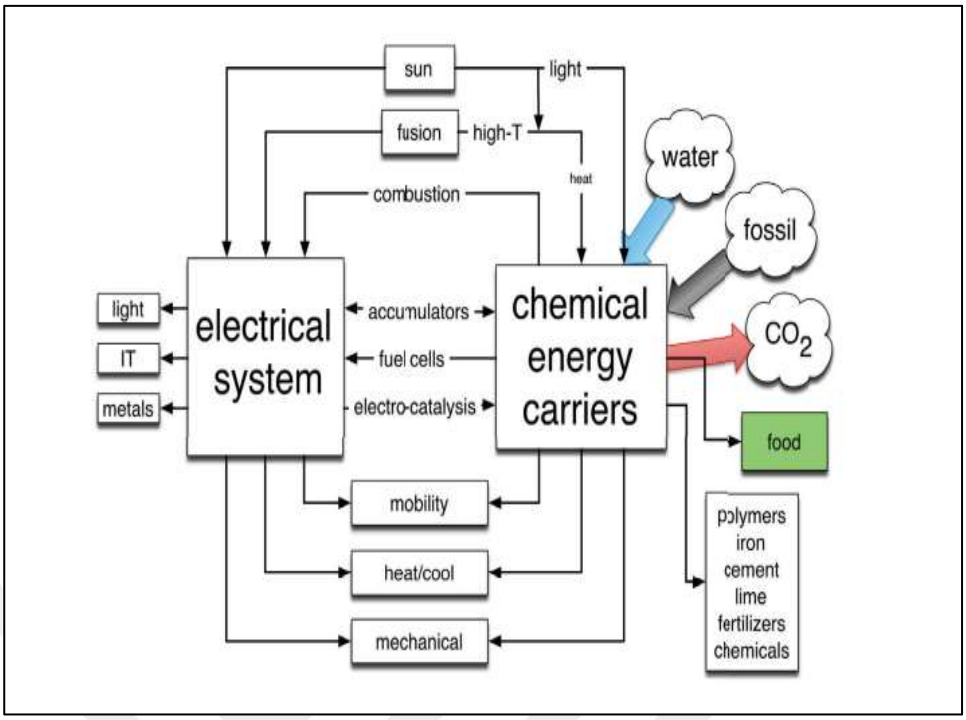


Figure 2.3: General Structure of energy systems [68].

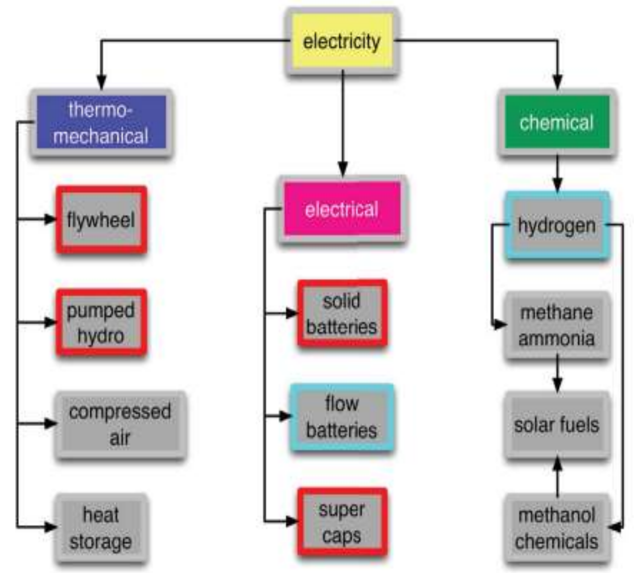
There must be a shift in two opposite directions, i.e., electricity conversion to chemical energy, due to the significant correlation between chemical elements subject to specific laws such as thermodynamics and tankers that provide for ease of chemical reactions if they include free energy and there is a highly efficient storage of chemical energy, in which case it depends on environmental stimuli, which can be used in batteries, electrical decomposition devices or solar radiation devices.

This mechanism can be changed by chemical catalysts that can change the way reactions and reactive substances work, and the process is as follows.

The catalyst is usually a solid material or enzyme that binds to reactive substances, and then the reaction occurs by the union and is a source of the electrons where the electrons are released from the source and returned to the catalysts that control chemical reactions and separate the union of these substances.

Here, the catalyst must be used more than once and in several interactions with multiple substances. In this case, the correlation between the catalyst and the reactive substances must be solid and close.

Energy is stored in carbon dioxide to form methanol by green hydrogen, as in (Figure 2.4).



Energy storage options with physical and chemical means. The red boxes denote solutions that are used in present energy systems, the light blue ones are options almost ready for grid scale use, the other options are in demonstration or research status.

Figure 2.4: Energy Storage Options with Physical and Chemical Means.

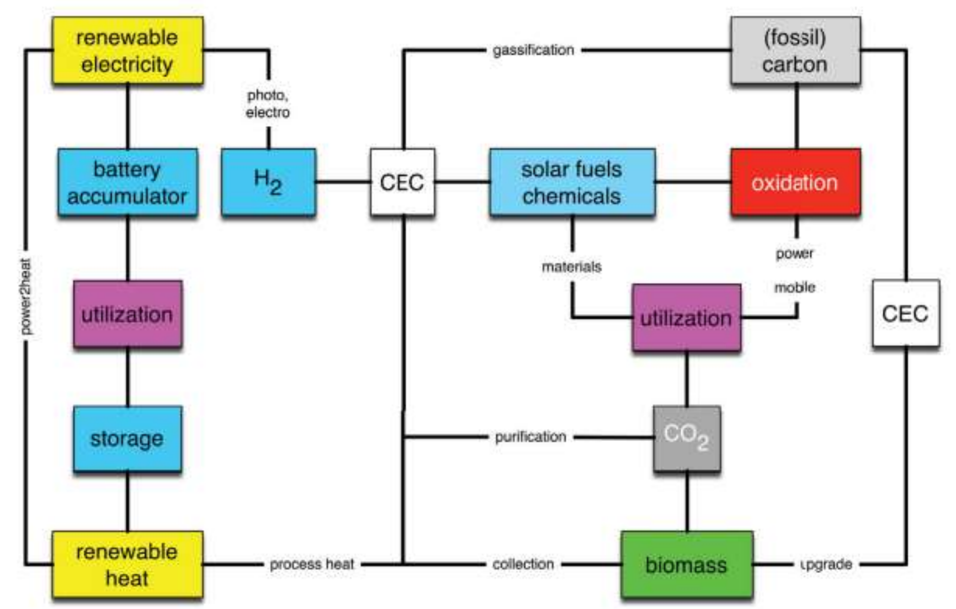


Figure 2.5: Generic Sustainable Energy System Design [74].

2.6.2 Thermal Energy

Thermal energy is generated by from the movement of molecules and atoms in different materials, such as water, so the more movement, the hotter the water. As in heating water in a vessel, we increase the movement of the atoms, as they are transformed into another form of energy by this process, from the state of water-to-water vapour. When exposed to high heat, water turns into steam, but if the temperature is reduced, it becomes solid. This indicates the activity of the movement of atoms and molecules between them.

It is in the form of stored energy and is transmitted in several states, temperature and pressure, which are closely related to energy measurement of the energy content based on pressure and temperature. Temperature measures the amount of energy generated by the movement of molecules and atoms or the amount of heat emitted, such as water at a freezing temperature of 0 degrees Celsius and 100 degrees Celsius in boiling. Pressures the amount of water rushing from the location in which it is located, such as air molecules that move due to the increase in pressure applied to them, as in a balloon [69].

Absolute pressure = Gauge pressure + prevailing atmospheric pressure

2.6.3 Radiant Energy

Radiant energy is light radiation, such as that seen in sunlight, and it contains X-rays, gamma rays, and other visible and invisible rays.

2.6.4 Mechanical Energy

Mechanical energy is the body’s possession of energy by the act of jogging or its position that the body has energy, enabling it to perform a specific task. It is kinetic or latent energy, which is represented by the energy contained in the body. Mechanical energy can be converted into thermal energy.

2.6.5 Nuclear Energy

Nuclear energy consists of the fission of atoms or their fusion. These atoms produce nuclear energy and can combine or fuse, as in the sun [70].

2.6.6 Electricity Energy

Electricity energy is the flow of electric current in electrical wires, electric energy needs a medium in which energy can be transmitted and depends on the principle of charges, and it is composed of two types, positive and negative, where these charges move from one body to another as a result of the body's friction with the body that gains negatively charged electrons and the body that loses electrons is positively charged., this electric charge is measured in coulombs. Charging electricity to objects is done by conduction, which brings a body free of charge to another charged body. Here the body that is free of charge acquires the charge it obtains from the charged body.

Extrapolation is the convergence process of an uncharged body with another charged without touching them, which is connected to the ground. Here the body without charge gets a charge opposite to the charge of the original body. Some objects conduct electricity and possess electrons called conductors, and they conduct heat and electricity and do not have any breakage like metals.

Materials that do not contain such electrons, called insulators not conduct electricity, and are brittle, such as wood [71].Electrical energy requires work and is symbolized by W, which is generated by an electrical force:

$$W_e = |q|Ed \cos(\square) \tag{2.8}$$

If it was electric, displacement and force are parallel, then $\square = 0$ and $we = |q|Ed$.

A charge q is equal to the productof the electrical force's strength (Fe), the magnitude of the displacement (d),

and the cosine of the angle ($\square$) between the force and the displacement.

The magnitude of the force is equal to the product of the absolute value of the charge and magnitude of the electric field (E) [77].

In general, an atom is made up of electrons, which are negatively charged, and protons are positively charged ,there is no force of attraction between electrons and protons of the same atom, but for other atoms of other bodies, there is an attraction, protons and electrons can separate between one atom and another to generate electricity, Electrical energy is measured in kilowatt-hours = 1000 watt-hours, there are sources of electrical energy as in (Figure 2.6).

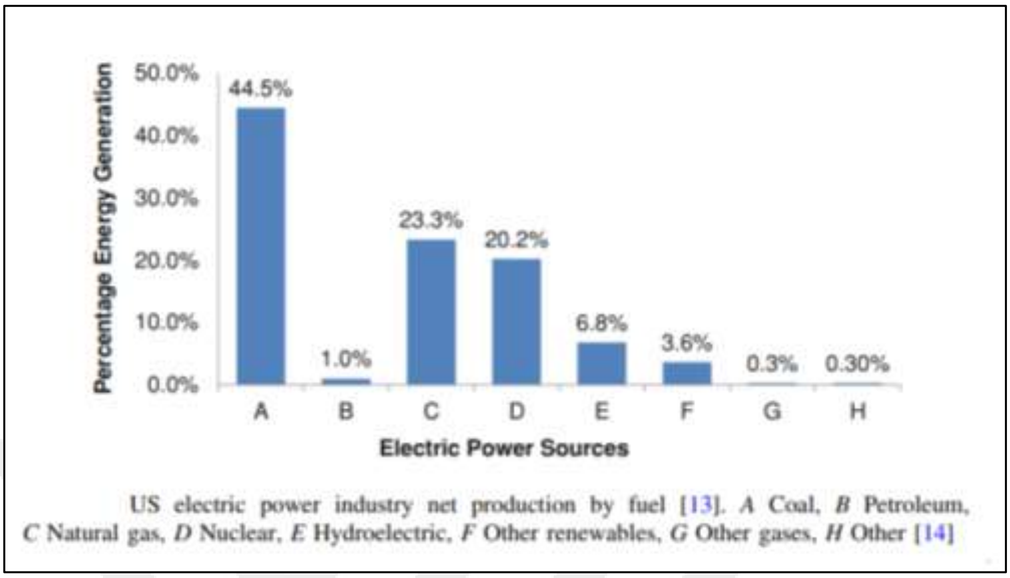


Figure 2.6: Sources of Electrical Energy [72].

Electrification is considered among the world's most developed shapes of energy due to the increased use of lighting, technical devices, and heating. Electrical power sources are Coal, natural gas, uranium, wind and sun [72], [73].

2.6.6 Magnetic Energy

Magnetic energy is known from rocks, and the giant magnet is the earth; each magnet pole produces a magnetic field flux and carries two positive and negative charges. The positive pole is finite, or the negative pole is of unlimited line if the magnetic field flux is zero [74].

2.6.6.1 The Magnetization Field

Is a charge moving with other charges, and it is parallel and under the influence of a perpendicular force as in the case of changing the path of the electron beam as explained in the following law:

$$F = qE + qV * B \tag{2.9}$$

F of charge depends on Lorentz's law. Eq is the force acting on the body [75].

Represents the power of magnetism and is based on the quantity present in the field. The magnetic material generates a magnetic field, which generates a magnetic force pressing on the material anywhere, as it is known as the force acting on a wire that has a current per unit length and the magnetic field is perpendicular to it. Magnetic field lines that are perpendicular to the size of the magnetic field. The median of a specific point with the line of the presence of the tangent to the charge represents the magnetic field line. The strength of the magnetic field depends on the velocity, the charge, and the angle between the field and the velocity of the charge, the magnet exists in a variety of forms, and specific locations represent the strength of these poles. According to the circular motion, it is known that similar poles repel. Different poles attract, so the direction of the magnet pole must be opposite to the direction of the earth because the earth is a giant magnet. The magnetic force is perpendicular depending on the speed and magnetic field, either in the plane or perpendicular to it [77].

2.6.7 Acoustic Energy

Acoustic energy can be generated as a result of doing a particular job, but it can fade at a time when the distance factor does. There are large amounts of acoustic energy from the essential concepts of sound. Sound depends mainly on the availability of energy, which can be heard, and sound energy is very available in many areas.

One of the areas of sound transmission is solid gas liquid and is caused by nitrogen and oxygen expansion in space as in (Figure 2.7):

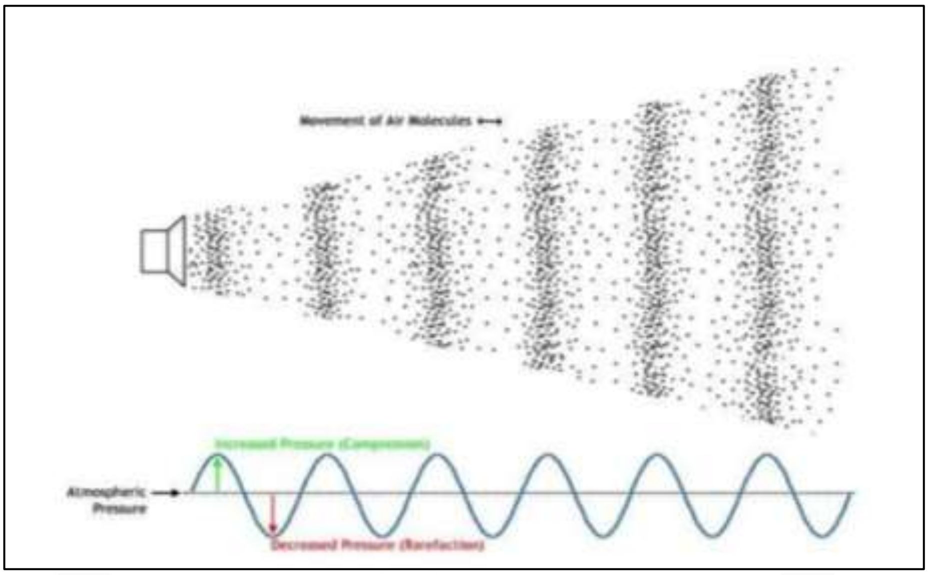


Figure 2.7: Propagation of Sound with its Impact Pressure on Air Molecules in Sinusoidal [76].

Sound is a wave, and it is of two types. A series of perturbations generate longitudinal waves and are parallel to the directions of the wave perturbations. In the same direction as a longitudinal wave, because the oscillations of molecules are constant and standing for two waves of equal length and amplitude and in opposite directions with the same speed in a fixed medium as in musical instruments, Transverse waves are a series of disturbances that travel through the medium in a vertical direction and consist of peaks and concavities, as the peaks are considered a transverse part. Sound consists of sound waves: -

2.6.7.1 Sound waves

The sound wave comprises a series of secretions in the middle within the frequency of the human ear that the human ear is determined by hearing frequencies within a specific and specific system. The acoustic wave is a vibrating particle in the middle that occurs due to collisions with other particles, which generates this energy to disturbances in the conveyor medium such as air or water. This effect is multiplied, and the sound wave is a mechanical wave that needs a conveyor medium to move from one place to another. Body reaction is the basis for transferring mechanical waves and is specific to where the conveyor molecules are.

The peak is above the dividing line or the equilibrium line, the concavity is below the line, and the wavelength is the distance from the beginning of the peak to the end is considered the distance from the highest point of the vertex to the lowest point of the concavity It is formed as a result of compression and decompression pressure is the basis of a longitudinal wave Longitudinal waves are the best waves [77]. As shown in the following (Figure 2.8)

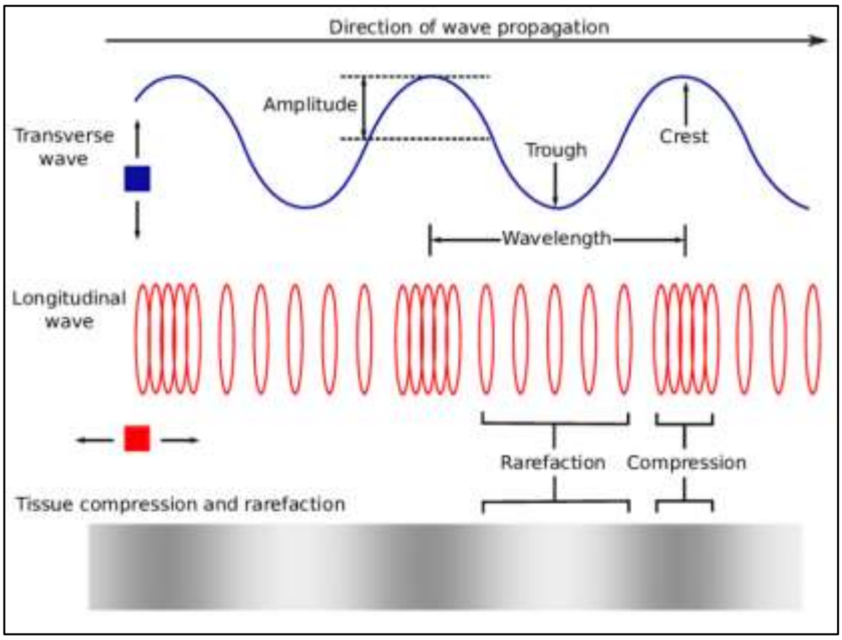


Figure 2.8: Sound [83].

2.7 ENERGY STORAGE

Energy storage is essential for energy conservation and utilization in the time of need or peak demand. The storage mechanism is from several systems and can be a combination of renewable energy that is intermittent according to the form that shows the percentage of energy generated from solar PV, which reached about 63 kilowatts and uses energy storage at a second time when there is an energy source or an increase in the energy demand the most commonly used type is chemical storage represented by batteries and storage is either long, medium or short-term and be either hours or weeks and the shape shows the balance between supply and demand [78].

Table 2.1: Examples of Energy Storage and Conversion Technologies and Their Applications.

Storage class	**Storage technology**	**Charging**	**Storing**			**Discharging**	**For the electricity sector**	**For the heating sector**	**For the transport sector**
			Sectoral						
Electric	Capacitors	Direct	Electric Field			Direct	Electricity storage, short – term	-	Recuperation short– term electricity storage
	Inductors	Direct	Magnetic Field			Direct	Electricity storage, short – term	-	-
Electrochemical	All batteries except redox flow	Integrated electrochemical conversion	Electrode or active material			Integrated electrochemical conversion	Electricity storage, short and long – term	-	-
	Redox flow battery	Pump, cell	Tank, chemical compounds			Pump, cell	Electricity storage, short and long – term	-	-
Chemical	Fuel storage tank	Pump, photosynthesis	Tank, fuel, cavern			Pump, burner, engine	-	Fuel storage tank	Fuel storage tank
Mechanical	Pump – storage Plant	Pump, engine	Upper Reservoir, water			Turbine, generator	Electricity storage, short and long – term	-	-
	Compressed air energy storage system	Compressor, engine	Cavern, Pipe heat storage system			Turbine, generator	Electricity storage, short – term	-	-
	Stored – energy storage system	Pump, engine	Movement of granite rock			Turbine, generator	Electricity storage, Short and long – term	-	-

Table 2.1: Examples of Energy Storage and Conversion Technologies and Their Applications. "Table Continued".

Storage class	Storage technology	Charging	Storing			Discharging	For the electricity sector	For the heating sector	For the transport sector
	Flywheel energy storage system	Engine	Rotational energy			Generator	Electricity storage, short–term	-	-
	Elastic – energy storage system	Mechanical work	Stored energy			Mechanical work	Electricity storage, short–term	-	Emergency brake in case of vehicle power failure
Thermal	Hot water tank	Heat exchange	Tank, water			Heat exchanger	-	heat storage	-
	Latent-heat storage	Heat exchange				Heat exchanger	-	heat storage	-
	Thermochemical storage	Chemical energy conversion				Chemical energy conversion	-	heat storage	-
			Cross-sectoral						
Electrochemical	Electric vehicle batteries	Power electronics, integrated electrochemical process	Electrode			Electric vehicles, hybrid	Load – management	-	Energy supplier
Chemical	PtG electricity	Electrolysis, methanation	Gas network, gas storage system			CCGT, gas turbine	Electricity storage, long-term	-	-
	PtG heating	Electrolysis, methanation	Gas network, gas storage system			Gas-fired boiler	Load – management	Heating supplier	-
	PtG mobility	Electrolysis, methanation	Gas network, gas storage system			Gas vehicle, car	Load – management	-	Fuel supplier

Table 2.1: Examples of Energy Storage and Conversion Technologies and Their Applications. "Table Continued".

Storage class	**Storage technology**	**Charging**	**Storing**			**Discharging**	**For the electricity sector**	**For the heating sector**	**For the transport sector**
	Hydrocarbon	Photosynthesis	Biomass, fossil energy gas storage system			Combustion technology	Electricity storage	Heating supplier	Fuel supplier
Thermal	PtH	Heating element, heat pump	Tank, water, heating network			Heat exchanger	Load – management	Heating supplier	-
	Absorption heat Storage	Heating element, heat pump	Zeolites, etc., tank			Heat exchanger	Load – management	Heating supplier	-
Mechanical	Drive system	Engine	Flywheel (kinetic energy)				Load – management	-	Drive
	Brake energy recovery		Flywheel (kinetic energy)			generator	Load – management	-	Brake

Renewable energy sources are volatile and prone to interruption[84].

There are many ways and mechanisms for storing energy, including electric, electrochemical, and magnetic, where each type has pros and cons of storage [79]. Energy storage is based on essential factors that determine the efficiency of storage:

a. Cost - Efficiency - Age of storage tool - storage capacity - changeability

b. Waste or loss when storage - measuring response and speed – interest factors [80].

Storage contributes to

c. Increasing the quality of the system and allowing the addition of new services

b. Increasing confidence in the system as it becomes more secure and reliable.

c. Ease of use allows the use of intelligent energy systems and improves production efficiency and network services' effectiveness, as shown in (Figure 2.9).

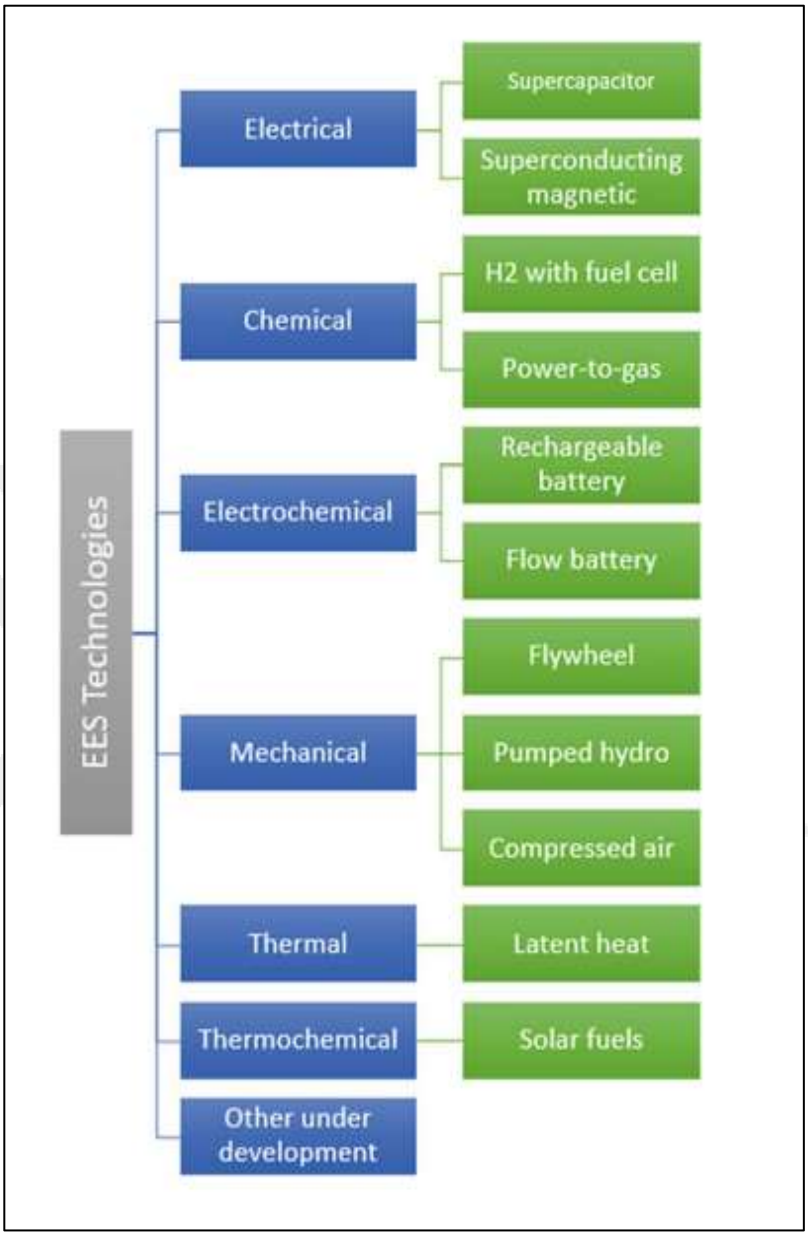


Figure 2.9: Types of Energy [86].

Types of Storage energy in (Figure 2.10) below:

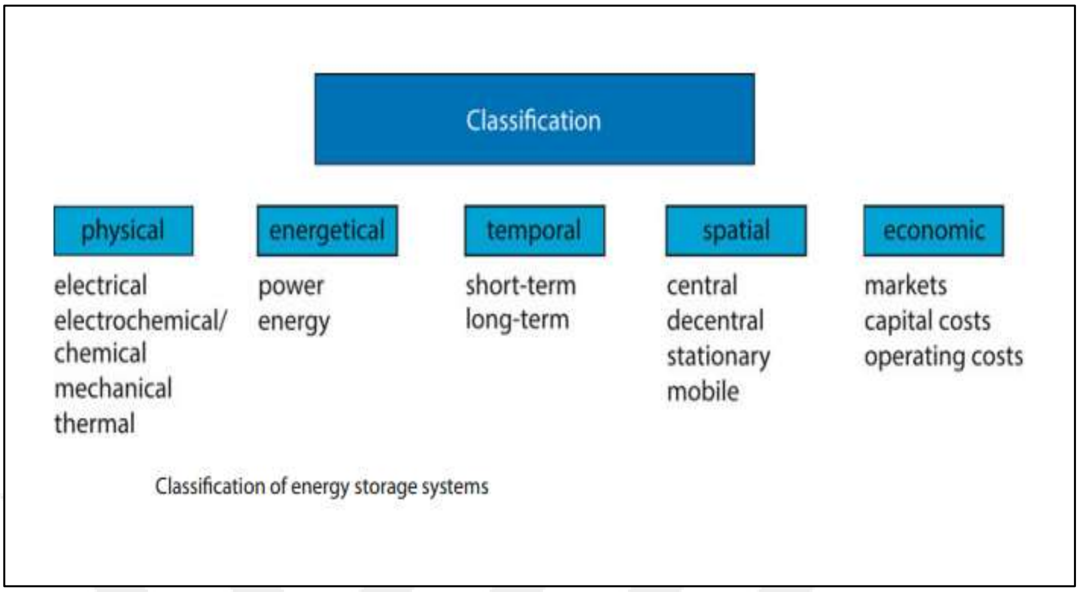


Figure 2.10: Types of Storage Energy [84].

Storage is Divided into: -

a. Physicist (electrical- electrochemical - mechanical - thermal)

b. As active as power and energy

c. Time includes long periods and short period

d. My Central place

e. Economic high-cost markets [84][81] .Energy Storage represents

Energy Storage classification is shown in (Figure 2.11) below:

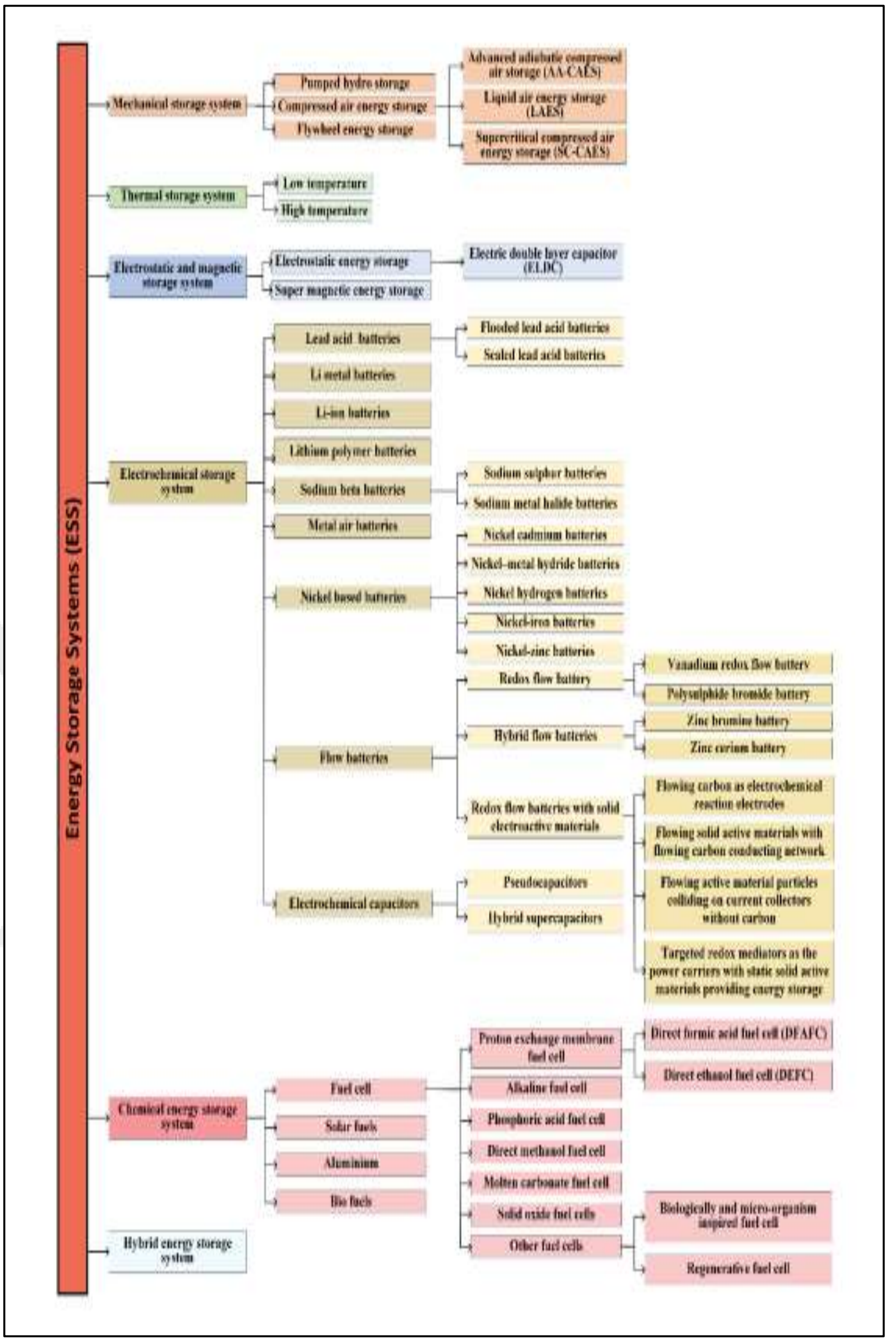


Figure 2.11: Energy Storage Classification [87].

2.7.1 The Storage of Thermal Energy

Using moderate and static temperatures where the storage is either higher or lower than the ocean temperature and is short or long life is one of the most accessible types of storage for electric power. Heat-powered stores are as energy-efficient as hot water, with 3.5 times the capacity of natural gas and mass and the storage is divided into: -

a. Physicist (electrical- electrochemical - mechanical - thermal).
b. As active as power and energy.
c. Time includes long periods and short periods.
d. My central place.
e. Economic high-cost markets.

The storage of thermal energy is by using moderate and static temperatures where the storage is either higher or lower than the ocean temperature is short or long life it is of the most accessible types of storage for electric power. Vitality, solar energy, geothermal storage and thermal energy can be produced from fossil fuels. [84]

Such as solar energy is stored in special tanks prepared for daily or seasonal use, as in Figure, which shows how to store energy as the material absorbs heat and stores heat below the melting point.

Solids and liquids are highly heat-storable, reaching fusion; in the case of fusion, they pull all the heat to be stored in a static form. A balance must be created between supply and demand for energy through storage methods such as solar energy, from which radiation can be stored in special tanks and used at other times, and this storage is considered short-term storage.

The storage inner is through large tanks or special docks or by creating holes in the ground that are padded and isolated. Large stores are considered one of the best types of stores due to the reverse relationship between the surface and size, where the more significant the size of the surface increases, it is associated with the amount of heat leaking or the waste of energy. There are large reservoirs that are solar-powered, as in Denmark.[84].

Advantages of thermal energy storage

a. Reducing pressure on energy through storage and mitigating global warming and climate change
b. Low maintenance of used equipment
c. Increasing the efficiency of equipment work
d. Resorting to the use of rechargeable technologies and the mobility system, the storage capacity is equal to the temperature.
e. Any source of energy, whether electrical or thermal, can be used.

2.7.2 Electric Storage

Electric storage It is by dams through which water is collected in large quantities, and then the turbine is used to generate electricity and store it by pumping, where the condenser stores the electric charges[78].There are two types of electrical storage methods, which are SMES, and SCES: -

SCES This type is characterized by a fast response, high energy density, long life, high efficiency and effectiveness, and the ability to adapt to all emergency conditions and environmental variables. It has a discharge rate of up to 40%. It is considered here as a short discharge in terms of cost. It is of high cost and low in energy density. It is used primarily for short-range systems such as UPS and pulse[85].Depending on the relationship between charge and voltage, capacitance is used to measure capacitors that store energy, and this capacitance is usually found in both cables and power transmission lines. [84]

The capacitor stores electrical energy and works by charging. Capacitors are characterized by being high energy and able to compensate for the shortfall in power supply and are used in the transportation and communication sector, such as railways and cars. [84]

As for the second type, SCES is characterized by having a long life, high-performance efficiency at work, and high response, but the storage cost is high. The need for cooling, the discharge energy is high daily, ranging from (10-15%) in addition to that, when using it, a magnetic field is generated, and this has an impact on the surrounding environment, as shown in the figure its use is in short-term areas and treats cases in which there is a weakness in energy efficiency that results from vacuum and fluctuation in the work of renewable energy sources in cases of interruption.

2.7.3 Chemical Storage Energy

Chemical storage energy in fossil fuels and bio-energy, which contain strong bonds saturated with energy, where energy can be stored, as in batteries and hydrogen. This type of storage depends mainly on three essential elements: oxygen, carbon, and nitrogen. Any substance containing one of these essential elements can combust and produce energy.

Water and carbon dioxide are the most essential materials that are a source of energy and adopted. Organic materials such as fossil fuels, coal, wood, and biomass produce sugar.

Hydrocarbon compounds such as methane, diesel, and gas., These compounds contain chains of hydrocarbons, as shown in (Figure 2.12) below:

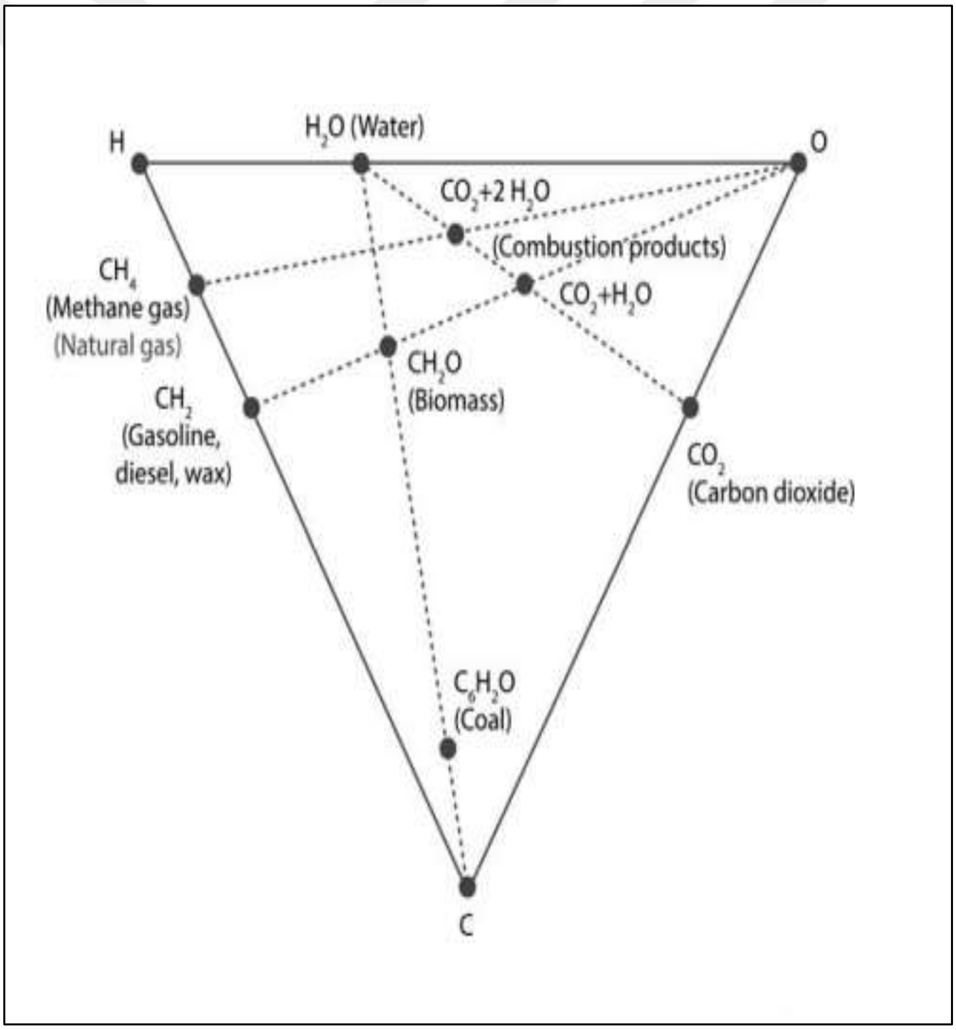


Figure 2.12: Conversion of Biomass [84].

The combustion mechanism is dependent on fossil fuels and biomass compounds, as it flows in one place, which is burning the compound to produce energy, which depends on the nature of the bonds between the material and is in one direction as in (Figure 2.13) [84]

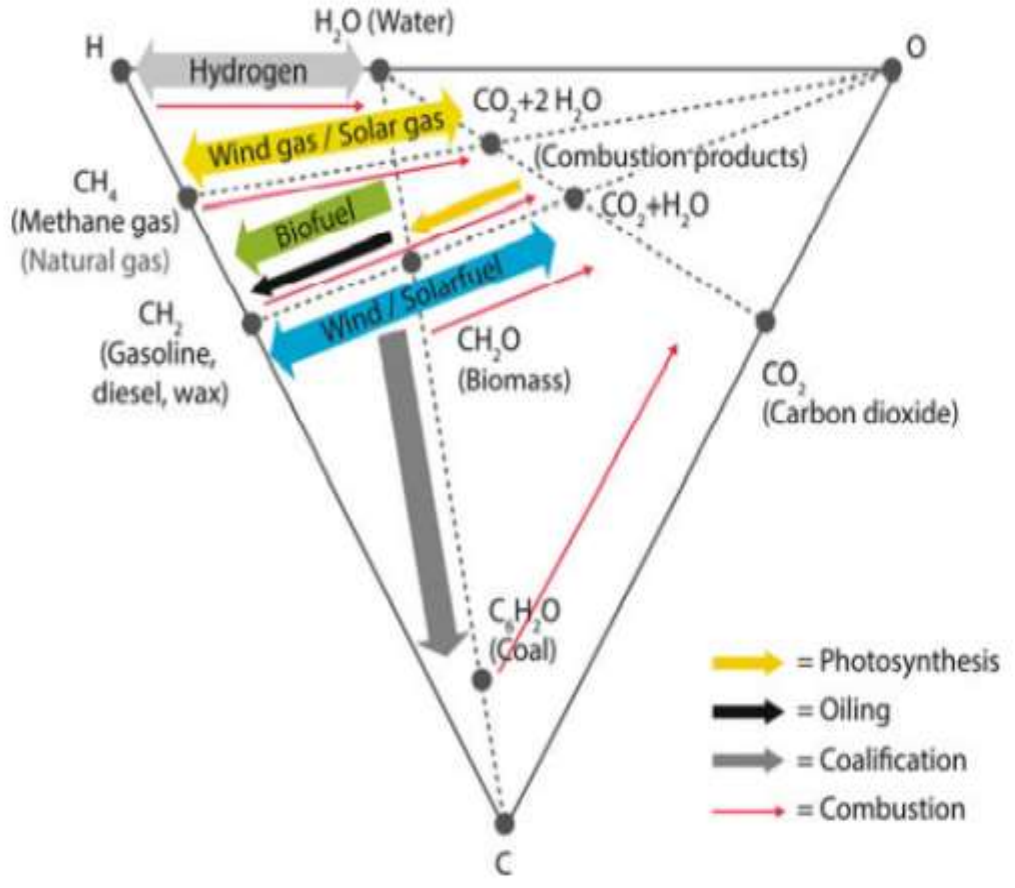


Figure 2.13: Conversion of Biomass.

Here, electrons are transferred from one substance to another to produce energy and a form of chemical storage.

a. Fuel cell storage
b. Biofuel storage
c. Aluminium storage
d. Hybrid energy storage [87].

2.7.4 Electrochemical Energy Storage

Electrochemical energy storge are divided into two types: -

ESTS is one of the highest storage capacities in the world, if it has a storage capacity of 9.6 KW. The advantages of battery storage are that it stores energy for a long time and is commonly used compared to other types. However, some batteries cost high cost and cause a waste of energy Lithium-ion batteries are the most widely used in the world with a working capacity of 8.5 KW and are advanced and highly efficient BESS such as Nickel Camedom and Lithium Ion batteries Sodium sulfur batteries are efficient 300-500 mAwatts and are used in multiple fields and are widely used in Japan Aluminum ion batteries, which are metal batteries and have a low cost and result in high energy and are used indirectly, the hybrid system is the system that is of the use of more than one type and is the most requested because it is fast responsive and has high power as in capacitors and is characterized by strength.[84].

Electrochemical energy is one of the best types of energy storage because it is old, cheap and goes into many uses[78].Here, electrons are transferred from one substance to another to produce energy and a form of chemical storage: -

a. Fuel cell storage
b. Biofuel storage
c. Aluminium storage
d. Hybrid energy storage

As shown in (Table 2.2) and the comparison between the types of storage.[84]**.** Types of batteries, the most famous of which are.

Table 2.2: Overview of Common Battery Systems [78].

Secondary batteries (accumulators)	negative	Positive	Cell reaction	Temp/ electrolyte	E[V]	g/Ah	Ah/kg
Lead-add	Pb	Pbo_2	$Pb+ Pbo_2+2H_2SO_4 \rightarrow 2PbSO_4+2H_2O$	RT, acidic	2.1	8.32	120
Edison (Nickel-iron)	Fe	NiOOH	$Fe+2NiOOH+2H_2O \rightarrow 2Ni\ (OH)_2+Fe\ (OH)_2$	RT, alka.	1.4	4.46	224
Nickel cadmium	Cd	NiOOH	$Cd+2NiOOH+2H_2O \rightarrow 2Ni\ (OH)_2+Cd\ (OH)_2$	RT, alka	1.35	5.52	181
Silver-zinc	Zn	AgO	$Zn+ AgO+H_2O \rightarrow Zn\ (OH)_2+Ag$	RT, alka	1.85	3.53	283
Nickel-zinc	Zn	NiOOH	$Zn+ 2NiOOH +2H_2O_2 \rightarrow 2Ni\ (OH)_2+ Zn\ (OH)_2$	RT, alka	1.73	4.64	215
Nickel hydrogen	H_2	NiOOH	$H_2+2NiOOH \rightarrow 2Ni\ (OH)_2$	RT, alka	1.5	3.46	289
Nickel metal hybrid	MH	NiOOH	MH+ NiOOH → M+2Ni (OH)2	RT, alka.	1.35	6.50	206
Silver/cadmium	Cd	AgO	$Cd + AgO+ H_2O \rightarrow Cd\ (OH)_2 +Ag$	RT, alka.	1.4	4.41	227
Zinc/ chlorine	Zn	cl_2	$Zn + cl_2 \rightarrow Zncl_2$	RT, acidic	2.12	2.54	394
Zinc bromine	Zn	Br_2	$Zn + Br_2 \rightarrow ZnBr_2$	RT, acidic	1.85	4.17	239
Li/manganes-dioxide	Li	MnO_2	$Li+MnIVO_2 \rightarrow MnIVO_2(Li+)$	RT, org.	3.5	3.50	286
Li/iron-disulfide	Li (Al)	FeS_2	$2Li(Al)+FeS_2 \rightarrow Li_2FeS_2+2Al$	HT, inorg	1.73	3.50	285
Li/iron-monosulfide	Li (Al)	FeS	$2Li(Al)+FeS \rightarrow Li_2S+Fe+2Al$	HT, Inorg	1.33	2.99	345
Sodium-sulfur	Na	S	$2Na+3S \rightarrow Na_2S_3$	HT, β-AL_2O_3	2.1	2.65	377
Sodium/nickel chloride	Na	$Nicl_2$	$2Na+NiCl_2 \rightarrow NaCl +Ni$	HT, β-AL_2O_3	2.58	3.28	305

2.7.5 Mechanical Storage

Mechanical storage the storage of energy in gaseous cylinders that are pressurized to be used in equipment, electric vehicles and aviation vehicles [78].

Mechanical storage is of two types and is generated by movement, such as rotation, as it is considered one of the best types of energy storage in the world and reaches 92.6%, or about 171.03 kilowatts. The energy here is either latent or kinetic, where kinetic energy stores energy in a particular body.

PHS: is flexible, reliable in use, and low-cost in terms of maintenance and operation, it is considered the most widely used in the world and is used in wind energy. The negatives of this type, slow response in changing and fluctuating unstable situations such as wind being associated with the impact of nature [85].

The CAEF type storage system in this type, in terms of cost, is low and enjoys high efficiency and speed of response and discharge is long-term and used in fossil fuels, but one of the drawbacks is that there is global warming that accompanies fossil fuels. However, this type can be used in the field of alternative energy and is characterized when used with high efficiency and high-speed response, high energy density, long life of use and short-term discharge at a rate of 20% per hour if it is in the start-up phase and used in spacecraft, army mechanisms and transportation Discharge is at a rate of 20%.Here it is not born for its use of toxic gases or harmful products as in fossil fuels [85].

This type of storage is used to store water and depends on water tanks that operate by pumping when a shortage occurs, as in Denmark, which built an artificial lake linked to an offshore wind farm that produces 150 megawatts per hour, which is based on the electricity that pumps water from the tank to the sea in the case of high demand, then the water returns to the tank by the turbine. The pumping mechanism depends on gravity, that is, raising the water against the force of gravity and not only is the water stored by this type of storage. Also, air can be stored by pressure in large tanks under the earth's surface to generate electricity through turbines to be compressed. The gas can be stored in the form of compressed air mechanically by electricity and through wind.

Gas is stored in gas turbines with low prices and medium size, provided that the place for storing energy is close to the place of demand for energy, which energy storage is close to the energy supply. There must be compatibility between generating and storing energy and considering energy transfer to consumers. Energy storage mechanisms usually witness a rise in prices per kilowatt hour, reaching 3000 US dollars for 7-kilowatt hours[84].

2.8 ENERGY CONVERSION

It is defined as energy that can be converted from one form to another, such as converting solar energy into chemical energy by carbon dioxide to water through photosynthesis and converting chemical energy into heat as in gasoline, as in (Figure 2.14) below[78]:

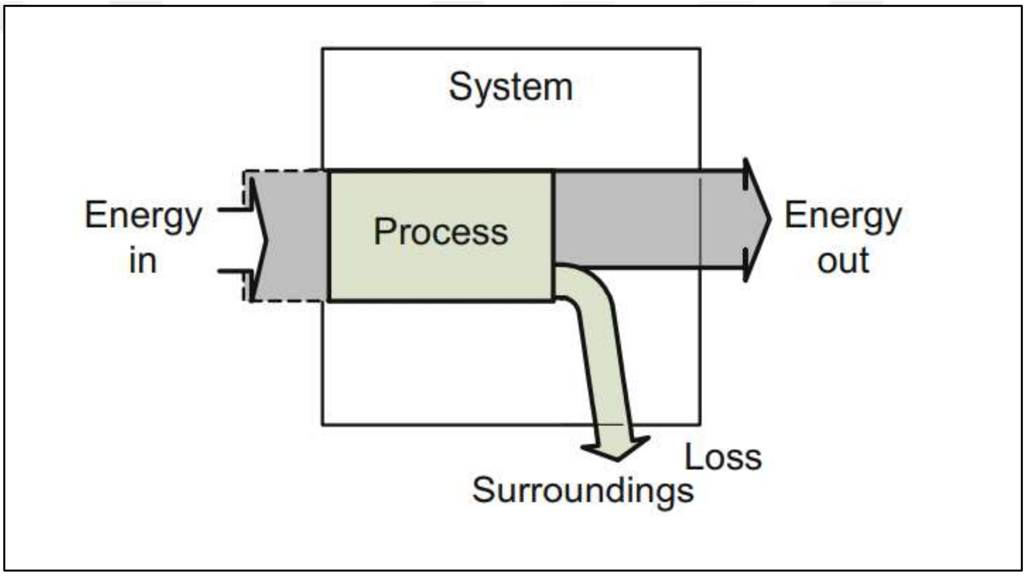


Figure 2.14: Converting Chemical Energy into Heat.

We should like to point out here that energy conservation should be done since, without energy conservation, it means doing nothing [72]. To absorb energy, there must be energy conservation similar to the Momentum Act [82].

The conversion of solar radiation into electricity, as in the lamp, subjects all kinds of previous forms to the (Energy Conservation Act). The bonds in sugar and gasoline can be transformed from chemical to heat, and the conversion of solar radiation into electricity, as in the lamp, subjects all kinds of previous forms to the Energy Conservation Act. The bonds in sugar and gasoline can be transformed from chemical to heat. Converting thermal energy into another form cannot be complete due to inefficiency and heat waste as it is less than

100% low 35-40% of thermal energy is converted into electricity and steam plants. 25% of the power turns into gasoline-powered engines, 10% of electric power is converted into light as the lamp, and the remaining turns into heat. This conversion results in a loss or waste of energy as a result of conversion and is not 100% efficient. Electric power is transformable into multiple forms, such as motion, sound, heat, and light. It is considered one of the most valuable types of energy. By converting it into multiple forms made by special equipment and equipment energy conversion efficiency, we note that the resulting energy is not equal to the energy before conversion, and these are known as efficiency varying efficiency according to the method of conversion sometimes reaches 90% like generators. 10-20% of solar energy or 35-40% are fossil fuel generators or wind [83].

There are Energy gradients: -

a. High-efficiency energy, such as chemical and electrical energy, is concentrated in a specific area, and thus it produces work effectively. This is because the nature of these materials, in which atoms and molecules are arranged and equivalent, produces high-efficiency energy, such as electricity and in the fusion of metals.
b. Low-efficiency energy, such as heat that heats water, is somewhat ineffective according to the irregular arrangement of particles such as coal (Figure 2.15).

- ****Oil burns to generate heat**
- **Heat boils water**
- **Water turns to steam**
- **Steam pressure turns a turbine**
- **The turbine turns an electric generator**
- **The generator produces electricity**
- **Electricity powers light bulbs**
- **Light bulbs give off light and heat****

Figure 2.15: Biomass Conversation to Electricity [69].

The most critical processes are subject to energy conversion, as shown in Table (Table2.3).

Table 2.3: Some of The Processes and Devices Convert Energy from One Form to Another.

Some of the processes and devices converting energy from one form to another		
Process and device	Energy in	Useful energy output
Steam engine	Heat	Mechanical energy
Photosynthesis	Solar energy	Chemical energy
Hydroelectric dams	Gravitational potential energy	Electric energy
Windmills	Mechanical energy	Electric energy
Electric generator	Mechanical energy	Electric energy
Diesel or petrol engine	Chemical energy	Mechanical energy
Electric motor	Electric energy	Mechanical energy
Fuel cells	Chemical energy	Electric energy
Battery	Chemical energy	Electric energy
Electric bulb	Electric energy	Heat & light
Resistance heater	Electric energy	Heat
Ocean thermal power	Heat	Electric energy
Bioluminescence	Chemical energy	Light energy
Nerve impulse	Chemical energy	Electrical energy
Muscular activity	Chemical energy	Mechanical energy
Geothermal power	Heat	Electric energy
Wave power	Mechanical energy	Electric energy
Friction	Kinetic energy	Heat
Thermoelectric	Heat	Electric energy
Piezoelectrics	Strain	Electric energy
Granet and Bluestein [13], Chih [4]		

The most important forms of energy, common transformations, and the essential products that result from energy transformation, as shown in (Table 2.4) [84].

Table 2.4: Different Forms of Energy and Various Methods with Which One Energy Form can be Converted into Another.

Different forms of energy and various methods by which one energy form can be converted into another energy form.					
To / Form	Thermal	Chemical	Electrical	Electromagnetic (light)	Kinetic
Thermal	-	Endothermic reactions	Thermo-ionic processes	Lamps (Tungsten wired)	Motor engines
Chemical	combustion		Batteries	Fireflies	Muscles
Electrical	Electrical resistances	Electrolysis	-	Electro-luminescence	Electric motors
Electromagnetic (light)	Solar collectors	Photosynthesis (chlorophyll)	Photovoltaic panels	-	Solar sails
Kinetic	Friction	Radiolytic reactions	Electrical alternators	Accelerated charges	-
Nuclear	Fission and fusion	Ionization	Nuclear batteries	Nuclear weapons	Radioactivity
Note: none of the energies in the first column can be transformed into nuclear energy.					

Energy undergoes many transformations through a series of processes and may be beneficial, as in coal containing chemical energy into heat when burned. Fuel consists of two main elements, hydrogen, and carbon. Some fuel types, such as wood and coal, contain water before the combustion process. Usually, this conversion is done by either oxidation of materials or burning to produce heat, as in the following reaction.

$$C_3H_{3(g)} + 5O_{2(g)} \longrightarrow 3Co_{2(g)} + 4H_2O_{(g)} + Heat \qquad (2.10)$$

The temperature depends on the amount of heat produced by the combustion process, measured in kilojoules/kg, representing the thermal unit. Thermal efficiency is one of the measures of the amount of heat produced by converting it, as in ovens, and the efficiency represents the amount of energy that was utilized that entered before the conversion, the thermal efficiency of burning fuel, the amount of chemical and kinetic energy converted into the fuel are calculated, the efficiency is calculated on the product of the amount of energy produced obtained from the fuel, as in the equation.

Qth=q(useful)/q in the electric generator converts mechanical energy into electrical energy using electrical lines and wires.

The efficiency of mechanical energy conversion is characterized by high efficiency, as it reaches 95% of the conversion to another form, and 5% is produced as heat, as in the turbine, which converts mechanical energy into liquid, as in the equations converting mechanical energy into electrical is done by using electric generators by electromagnetic induction Magnetic induction is the generation of electrical energy using a kinetic conductor that takes place in a magnetic field, as it converts the electrons in the circuit of the electrical circuit by its flow.

Running water in turbines and wind turbines can be converted from electrical energy to mechanical energy using electric motors. The efficiency of generators depends mainly on the amount of bearing and total output power [78].

3. METHODOLOGY

3.1 SOLAR ENERGY

Intelligent solar energy systems can track the change in the sun's rotation during the day, as these cells collect vast amounts of solar energy and then produce the highest amount of energy [85].Solar cells are known as photovoltaic cells, and the sunlight is converted into electricity, which is a direct current, that is, using photons in sunlight with a potential represented by electricity, known as PV [86].

Moreover, solar cells have a non-linear system, and the results cannot be guessed. Solar cells accurately deal with electrical energy by measuring the ratio of radiation and temperature, as both affect current and voltage, making them non-linear. Photovoltaic systems can reduce cost and size and increase maximum energy [87].The (Figure 3.1) below shows the configuration of the photovoltaic cell

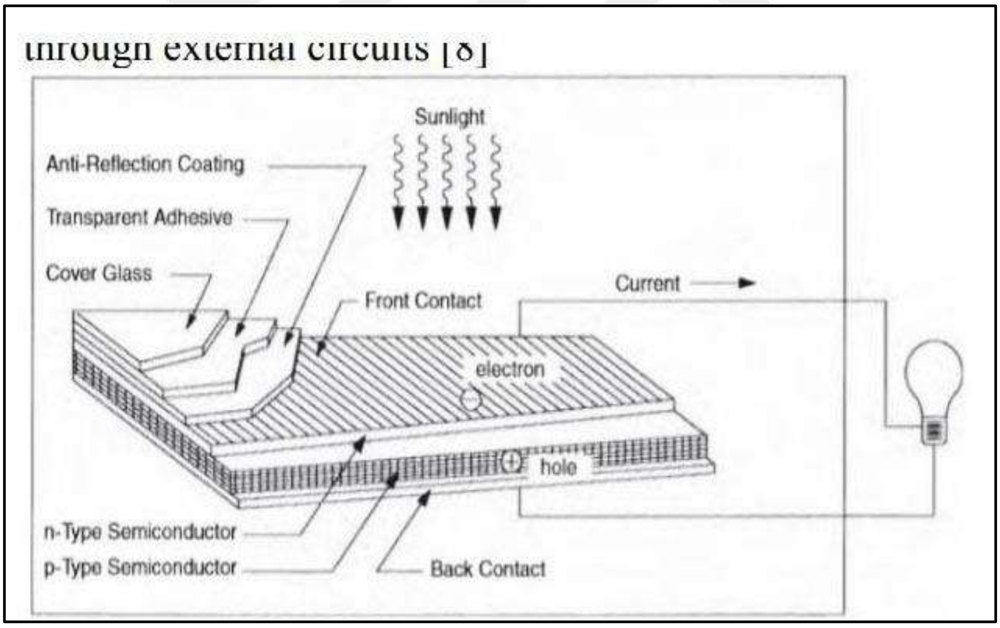


Figure 3.1: Photovoltaic Cell [88].

(Figure 3.2) below is the solar system consisting of the solar cell, solar panels, and the solar array.

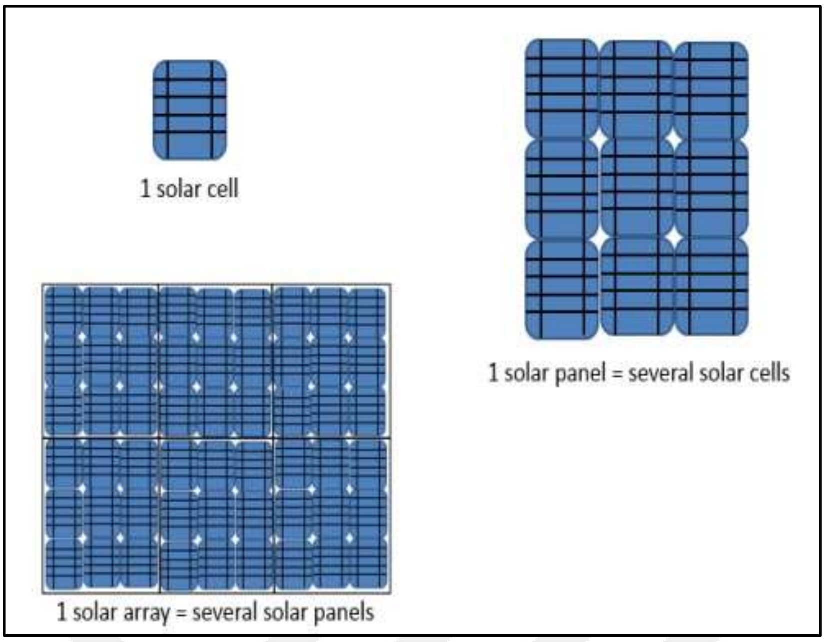


Figure 3.2: The Solar Cell, Solar Panel, and Solar Array Definitions.

The solar inverter is also known as the photovoltaic inverter. The function of this inverter is to convert the direct current in the solar cell, which is in the form of DC, into a current in an alternating state AC and in an electrical network (Figure 3.3) below shows the curves for IV, PV, and the extreme point.

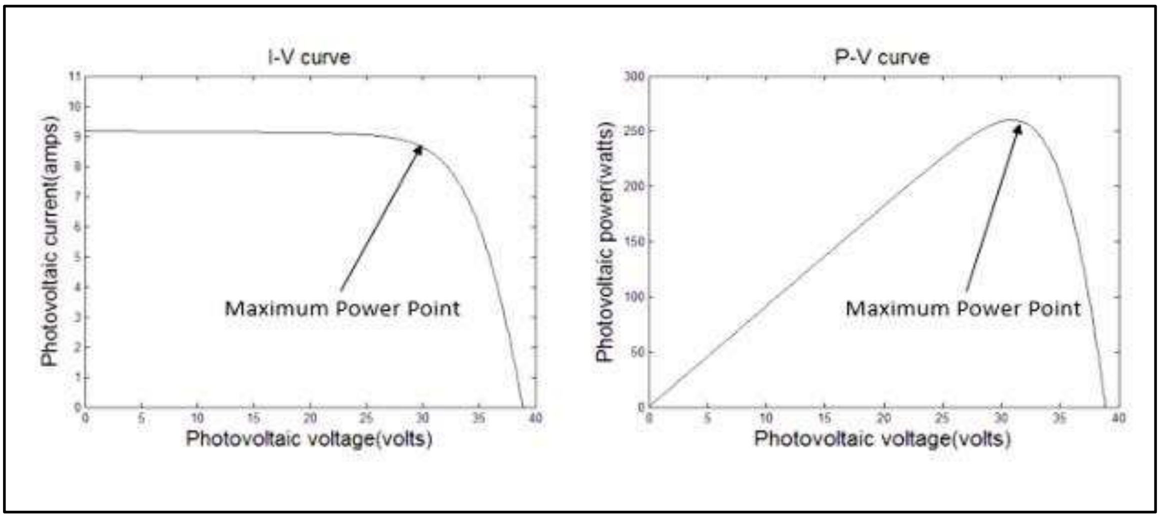


Figure 3.3: I-V Curve (left) and P-V Curve (right).

3.2 THE SOLAR ENERGY SYSTEMS

Are divided into the following: standalone system, Network-linked system, consisting of devices to store energy, which is to store excess energy. It produces photovoltaic energy for electrical networks and consists of the following: -

a. Solar cells/solar panels/solar arrays

b. A device to control the path of the maximum energy of the solar system

c. 3-cell voltage regulator

d. PWM generators

e. DC.DC converter

f. Electric load

g. AC adapter, if needed

(Figure 3.4) below illustrates the organizational structure of the system.

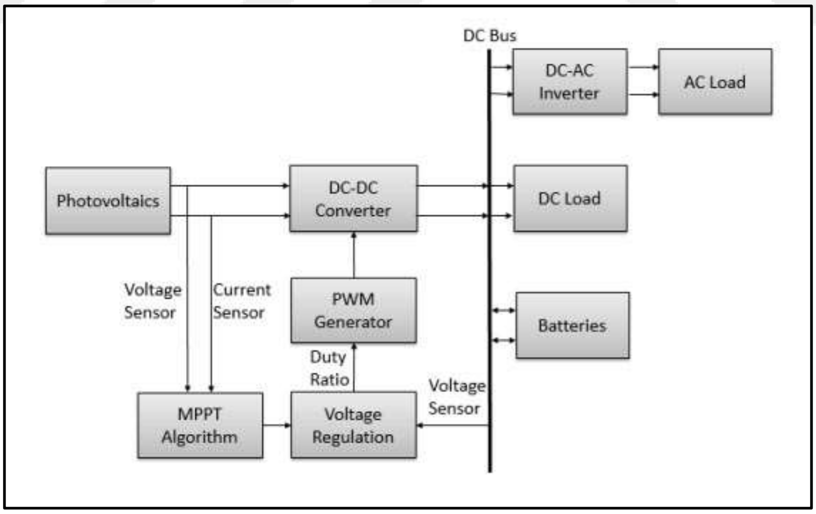


Figure 3.4: Stand-Alone Photovoltaic System [89].

3.3 SOLAR CELL SYSTEMS

a. The independent photovoltaic cell consists of an inverter to convert current to the photovoltaic panel with batteries that store energy, as shown in (Figure 3.5).

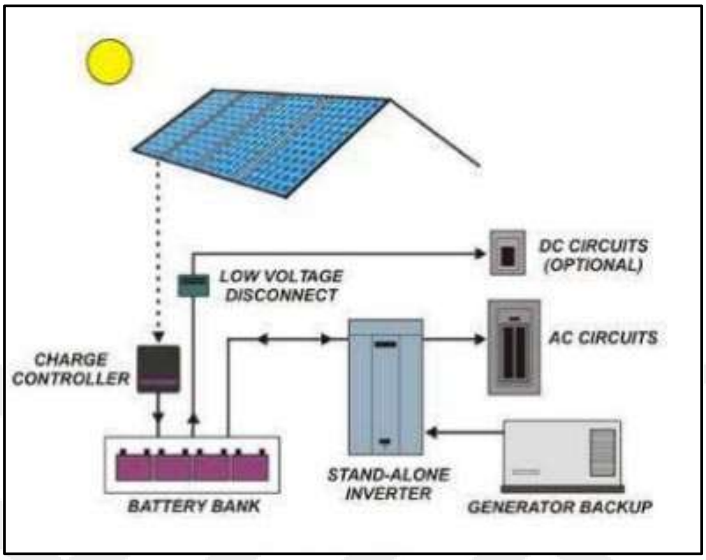


Figure 3.5: Stand-Alone PV System.

The (Figure 3.6) is below. Photovoltaic cells are the basis of work supplying electricity and use a high-efficiency and quality inverter, making it better than isolated systems. The photovoltaic system, which contains cells connected to the network, changes the direct current produced by converting the photovoltaic energy into an alternating current.

The system connected to the grid produces a large amount of power calculated on the grid's power. The work of the solar inverter in the grid-connected system is to convert the output from the DC system into alternating current.

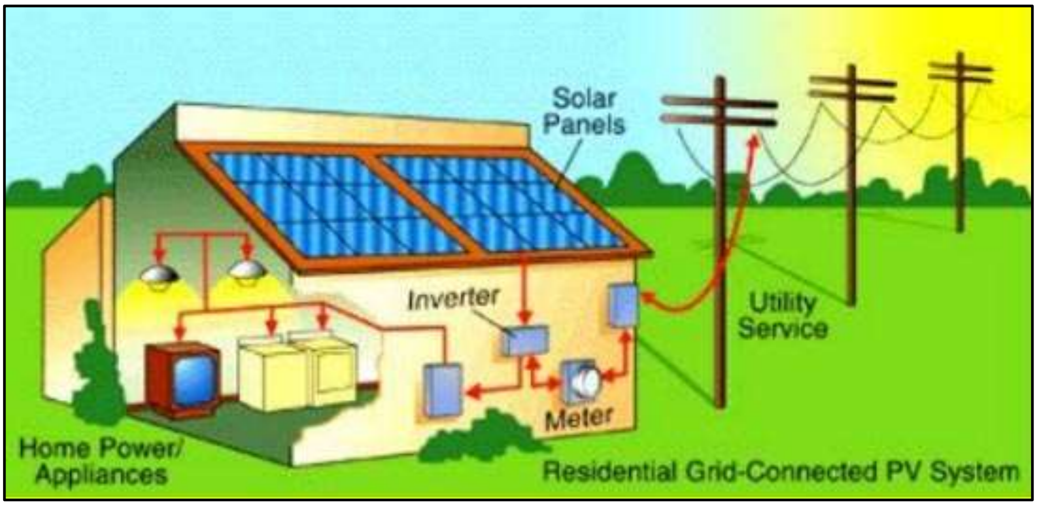


Figure 3.6: Grid-Connected PV System [95].

How to arrange the panels?

The arrangement of the solar panels is by installing solar cells in a sequential and parallel manner, the purpose of which is to obtain electrical energy as shown in (Figure 3.7) below:

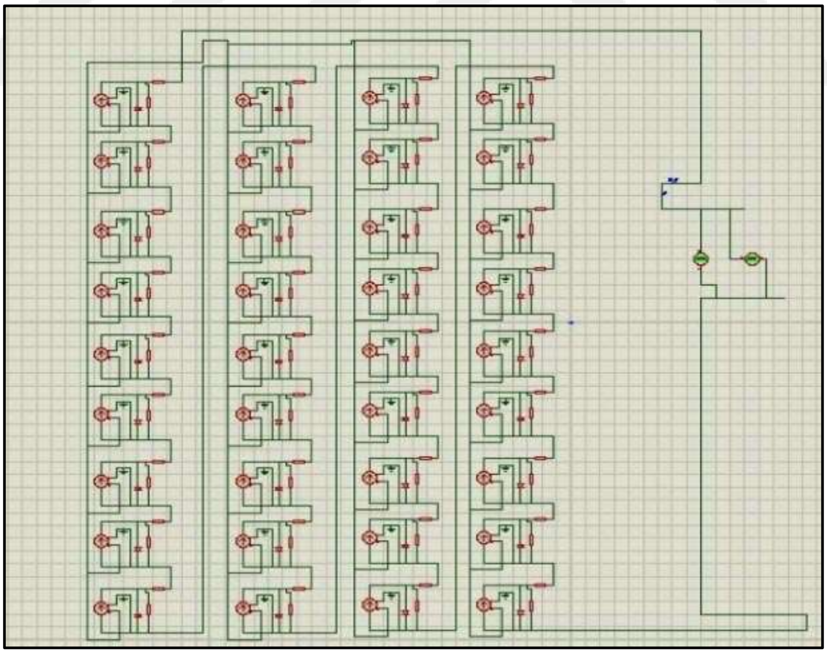


Figure 3.7: Panel Design with Proteus [91].

Configuration of the electrical circuit of the solar system as shown in (Figure 3.8) below and the following equations:

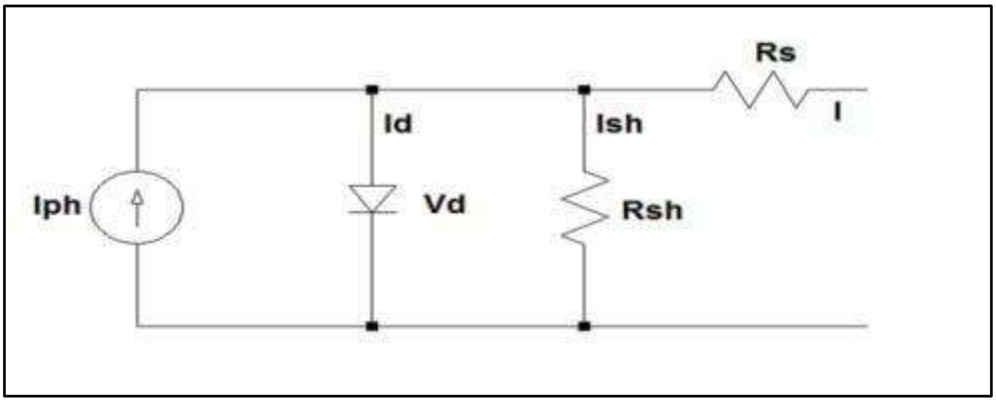


Figure 3.8: Equivalent Circuit Model of PV Cell.

$$Io\ = (Np\ *\ Iph) - (Np *\ Irs)\ *\ (exp((q/(k*T*A))*(Vo/\ Ns)) - 1) \tag{3.1}$$

Where: -

$$Iph = (Iscr + ki*(T - Tr))*\ ((s)/100); \tag{3.2}$$

$$Irs - Irr*\ ((T/Tr)\hat{}3)\ *\ exp(q*Eg/(k*A)\ *\ ((1/Tr) - (1/T)) \tag{3.3}$$

$$r - (Trl - 32) + 273 \tag{3.4}$$

lo& Vo: cell output current and voltage;

Irs: Cell reverse saturation current;

k: Boltzmann's constant:1.38* 10-19 J/K;

T: Cell temperature in Celsius;

The primary purpose is to obtain voltage and current, as shown in the following (Figure 3.9) (Figure 3.10).

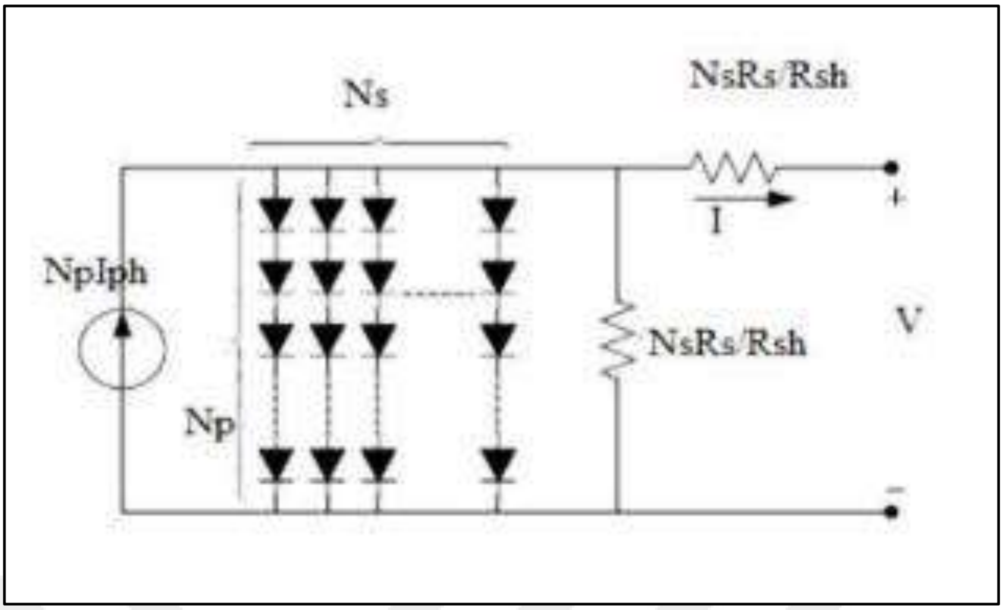


Figure 3.9: Equivalent Circuit of Solar Array.

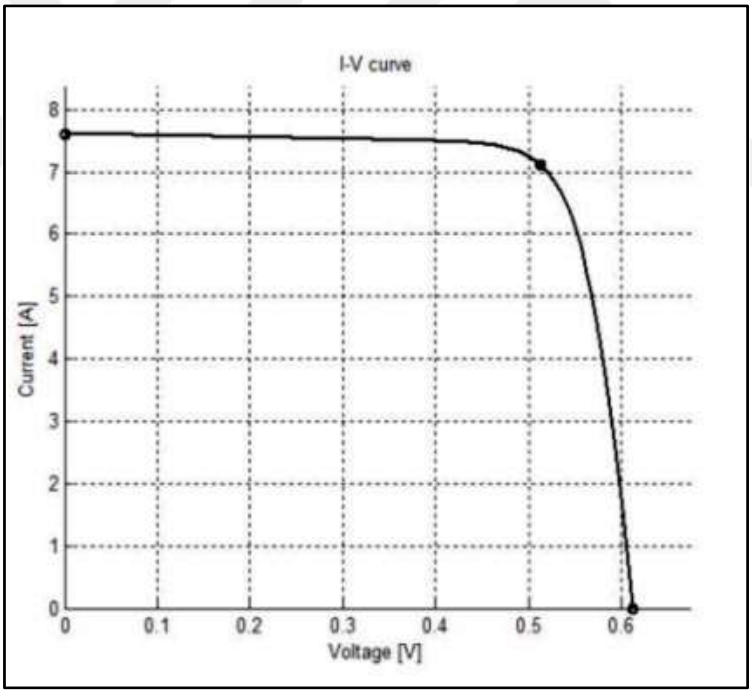


Figure 3.10: I-V Characteristics of a Single Solar Cell [90].

The circuit that is equivalent to a photovoltaic cell consists of the following:

a. Source of light
b. Diode (1)
c. Rsh

Type resistance' as shown in (Figure 3.11) shown below with the laws

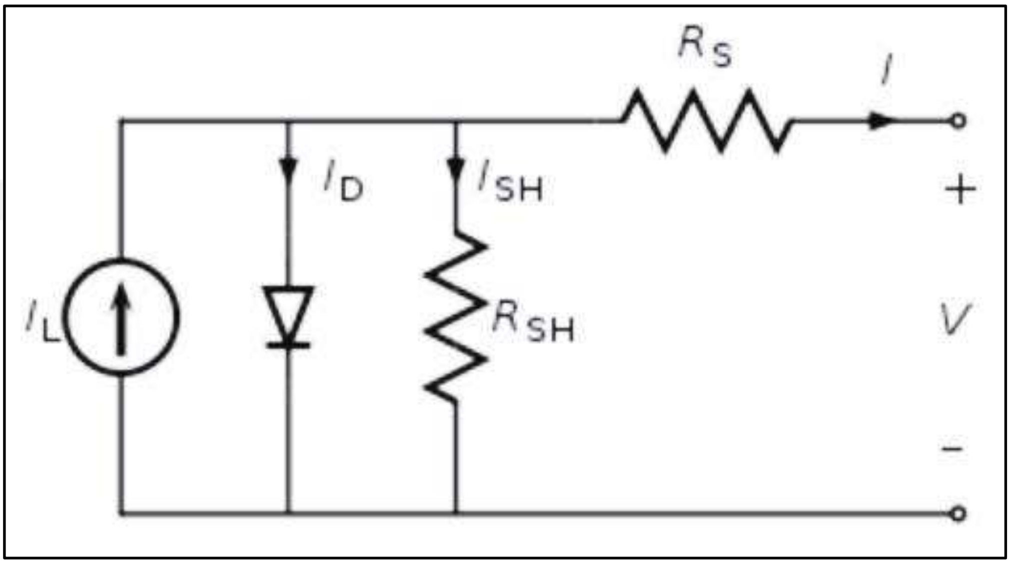


Figure 3.11: Circuit

The output current is provided for: -

I = I L − ID – ISH

Where I = Discharge current (amperes)

IL = Current created by a photo (amperes)

I D = Diode current (amperes)

I SH = Shunt current (amperes).

The voltage across them governs the current through these elements:

Vj = V + IRS

Where Vj = Voltage across both diode and resistor RSH (volts)

V = Voltage across the output terminal (volts)

I = Output current (amperes)

RS = Series resistance (Ω).

3.4 MAXIMUM POWER POINT TRACKING

One of the disadvantages of photovoltaic panels is the lack of the resulting efficiency, as it is less than 22%, in addition to the cost of power generation, which is high and depends mainly on weather conditions. The relationship between current and voltage is non-linear and fluctuates in all cases, and loads MPPT is designed to handle fluctuating weather conditions. The working efficiency of MPPT depends on the accuracy and speed of tracking the maximum power. Environmental conditions and misinformation play a role in the efficiency of the work of solar panels and energy [91].

MPPT is a control mechanism that tracks the maximum power in the system. If this mechanism is used, it increases the efficiency of the system as the system works at the highest amount of energy and also increases the work of the matrix in terms of efficiency and reduces the total cost, which is a practical, new and high accuracy system in controlling the charging process at a low cost [92].

It has the capability of maintaining the workflow, MPPT is a control mechanism that tracks the maximum power in the system, and if this mechanism is used, it increases the efficiency of the system as the system works at the highest amount of energy and also increases the work of the matrix in terms of efficiency and reduces the total cost It is an effective and new system with high accuracy in controlling the shipping process and at a low cost [93].

It is capped by moving the process towards obtaining maximum energy from the PV panel under fluctuating weather conditions such as varying temperatures, amount of solar radiation, total energy extraction in solar cells, and improved resistance under weather conditions.

In periods of daily or seasonal shade that hinder access to maximum energy, it also can change the operating points of the standard units to reach the maximum degree of energy saving.

The purpose of using the controller is to maintain the battery voltage in terms of charging, as it prevents excess charging from being wasted and continues to reach the maximum power of the PV system, i.e., regarding the voltage energy of the PV system. Towards obtaining maximum energy from the PV panel under fluctuating weather conditions such as varying temperatures, amount of solar radiation, complete extraction of energy in solar cells, and improved resistance under weather conditions. In periods of daily or seasonal shade that hinder access to maximum energy, it also can change the operating points of the standard units to reach the maximum degree of energy saving.

The purpose of using the controller is to maintain the battery voltage in terms of charging, as it prevents excess charging from being wasted and continues to reach the maximum power of the PV system, i.e., regarding the voltage energy of the PV system. This is considered one of the most successful systems because it saves shipping [94].

MPPT is an electronic system that changes the operating point of the electrical unit to generate the maximum amount of energy, and this energy is used to increase the battery charge., MPPT can be used with a mechanical system, but in the case of two different systems, the reason for the difference is that MPPT automatically searches for voltage or horizontal current.

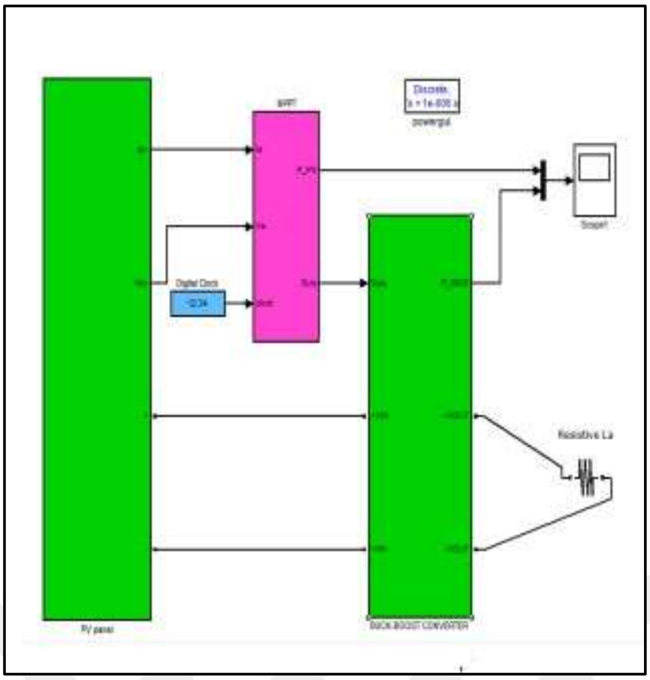


Figure 3.12: Model of System [101].

(Figure 3.12) above shows a photovoltaic system that works with MATLAB technology, one end is connected to the maximum power MPPT, and the other is connected to the transformer. P&O. algorithm

The P&O algorithm is an easy-to-apply technique to produce the maximum power from the photovoltaic panel. Considering that this algorithm is simple, it is more widespread in producing the maximum power, as shown in (Figure 3.13) below[101]:

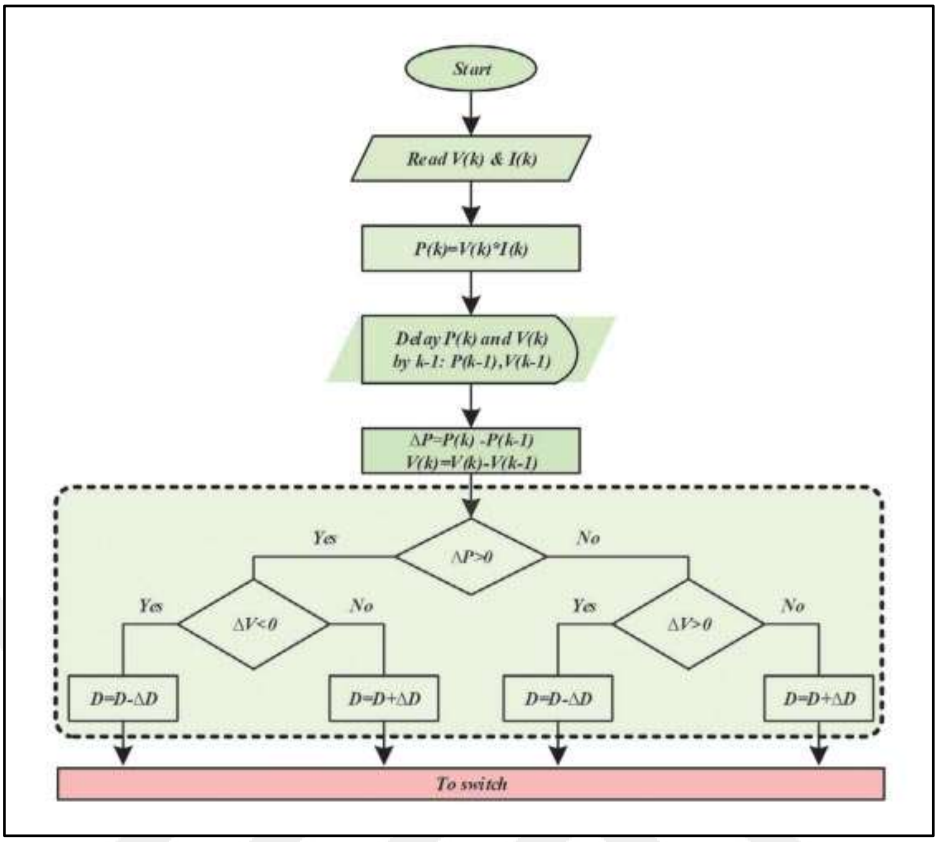


Figure 3.13: Algorithm to Implement P and O Algorithm [95].

The purpose of using the P&O is to know the extent of the disturbance, whether it is in a state of increase or decrease, and it depends on both current and voltage. The disturbance affects the work of the solar system, that is, the energy out.[94]**.**

The perturbation process of MPPT is generally of the photovoltaic at the end of each period Calculation of the new photovoltaic reference voltage is by using MPPT, where the voltage is sent to a voltage regulator of the photovoltaic cell. The use of this technology is well-known in commercial solar systems today [96].

The P&O tracking and monitoring method is one of the easiest methods used in the solar system and consists of one voltage sensor connected to an external voltage of the PV panel and 1 for you to do the sensor of the panel's voltage.

This model is characterized by its application in the MATLAB system as there is little time to get the maximum amount of energy, but this method is somewhat imperfect because it can assess the rapid change that occurs in the level of sunlight.

However, the P&O algorithm has a negative point, which is not to change the energy point due to wind and turbulence, and to overcome this point is to add a connection. The additional connection needs two sensors as it borrows current and voltage simultaneously, which increases the cost and complexity of the system[96].

There are several algorithms to monitor and track how the maximum power of solar cells flows. The P&O algorithm is one of the most used algorithms due to its low cost and ease of maintenance. Now there is a problem with the work of this algorithm, which is the inability to respond, and that's because of sudden changes in temperature and the amount of solar radiation. Modified P&O eliminates defects and can potentially improve the simulation process's efficiency, as shown in (Figure 3.14) below. [96] The work of this algorithm is based on interference and is either by increasing or decreasing the operating voltage of the photovoltaic unit and monitoring its effect on the output energy that results from the photovoltaic unit. The new method is based on the old method and works according to a flowchart with an additional calculation of the PV array capacity and is in the middle of the point of the MPPT. The maximum power varies according to the radiation levels since radiation levels can control the amount of energy by changing the rate of disturbance [96].

3.5 RATE OF DISTURBANCE.

The monitoring method is usually less than the known or traditional disturbance. This method can contribute to improving the efficiency of solar energy, as shown in (Figure 3.15) below. [96]

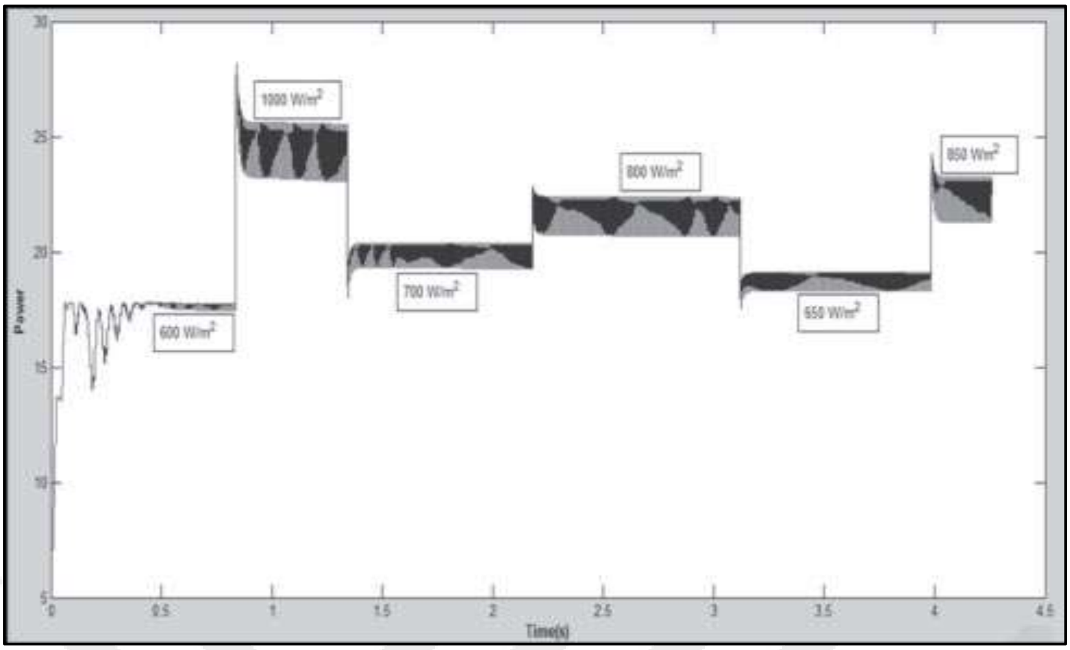


Figure 3.14: Characteristics of Power for Conventional P&O.

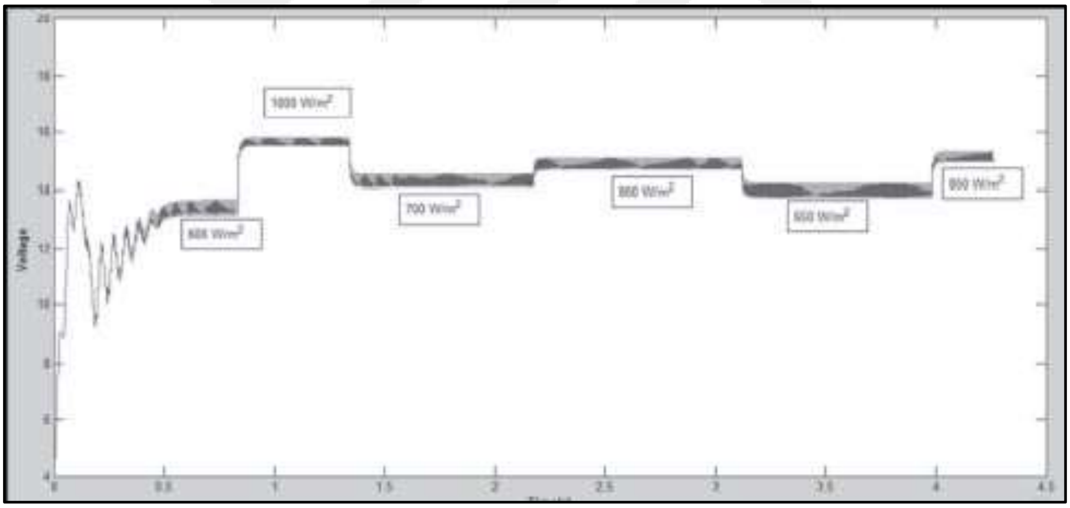


Figure 3.15: Characteristics of Voltage for Modified P&O.

The above figures show the value of the current at different levels of change in the amount of solar radiation, we note that the curves have little value under constant conditions, and a quick response can be obtained.

3.6 PID CONTROLLERS

Hybrid Fuzzy-PID Controller for Buck-Boost Converter in Solar Energy-Battery Systems. PID is a control unit used for control, and it is a proportional derivative that has a response according to the rate of change of the error that occurs in the process and has the ability and control to improve the work of the system and reduce the size of the overshoot. It is widely adopted worldwide and is widespread due to its low cost, which positively impacts the industry [97].

PID technology has played a role in technology for many years, as we notice continuous progress. The old consoles were used for single loops and one variable. Nowadays, it is possible to use units with multiple loops with multiple variables.

PID is the basis for control operations, and it includes a relative component, a fundamental component, and a derived component, As shown in (Figure 3.16) below [97].

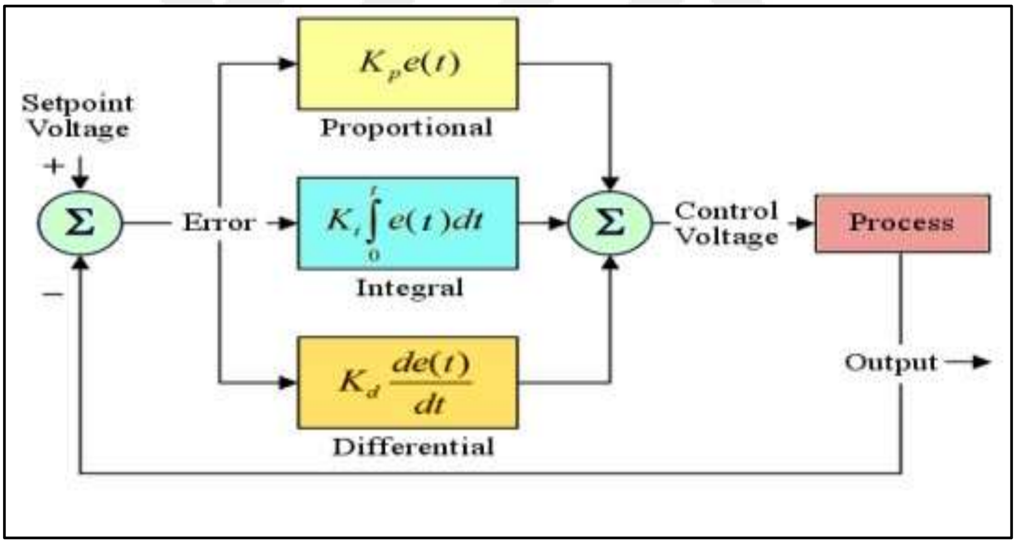


Figure 3.16: Functional Diagram of a PID Control Loop.

KP, KI, and Kd are relative, integrated, and derived elements and are, respectively.

The voltage of the set point is the required benchmark voltage.

(e) is the amount of difference between

Both the voltage of the set point and the resulting voltage

Systems are processes. and it is monitored.

The exterior is the amount of consumed power and voltage in the controller.

((t) is the linear time law.

$Kp\ (t)$is the proportional term.

$Ki \int e$ (τ) $d\tau\ t$ 0 is an integral term (I)

Kd $d\ dt\ (t)$ is the derivative term.

3.6.1 PID Properties

PID function performs proportional control, performs proportional control.

Kp reduces the height time, but it does not get rid of the error.

Ki gets rid of the error that occurs in the fixed value.

Kd is based on increasing system stability and reducing overflow.

As shown in (Table 3.1) below [104]:

Table 3.1: PID Properties.

Parameter	Rise Time	Overshoot	Settling Time	S-S Error
Kp	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	Small Change

3.5.2 PID's Mechanism of Action

To increase the efficiency of the work of solar panels, we need to make a control unit as shown in (Figure 3.17) below[92]:

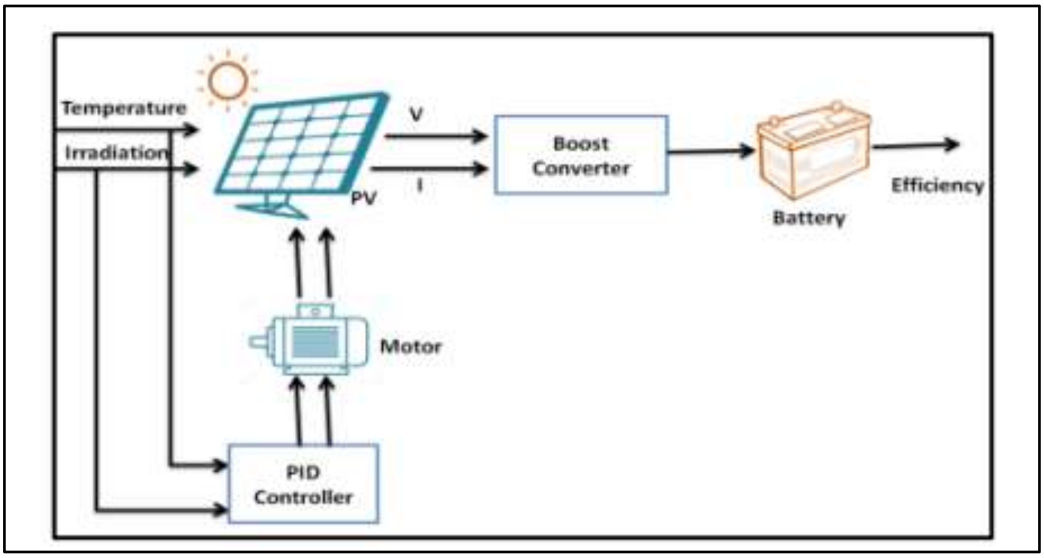


Figure 3.17: Architecture of PID Controller-Based Solar Panel Tracking System.

The work of PID is a structure to follow the mechanism of the work of solar panels, and cutting operations are used as a method for generating energy from sunlight during the day, and you need to increase the efficiency of this process, as shown in the (Figure 3.18) below:

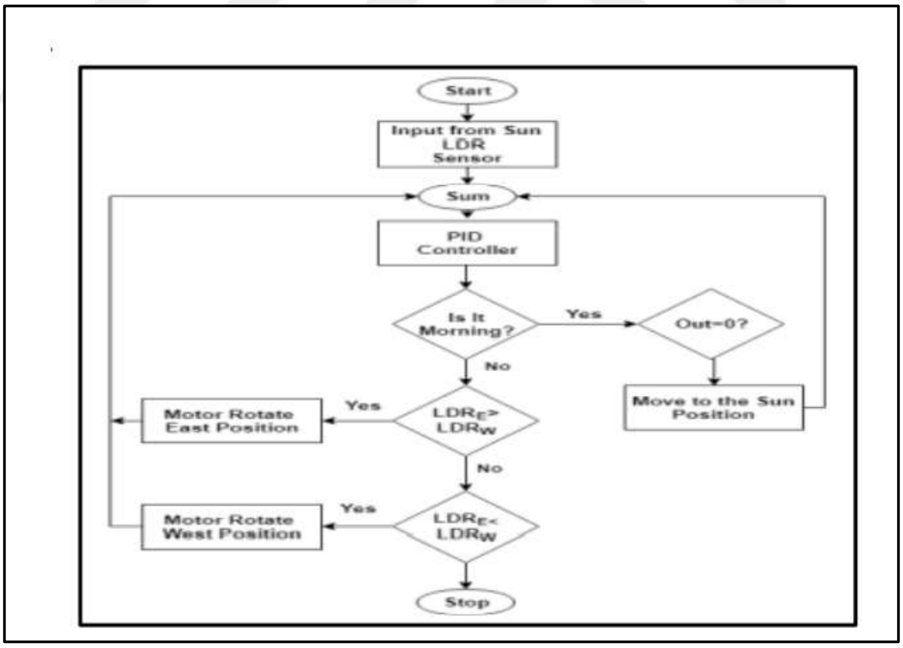


Figure 3.18: Algorithm of PID Controller-Based Solar Panel Tracking System.

It is known that intelligent solar energy systems can track what occurs in the sun's rotation throughout the day, and this technology produces a considerable amount of solar energy. Then the highest amount of energy is produced by PID control solar panel tracking, which is integrated into the design system. The result of the work is to obtain the maximum energy from the solar cells through the solar panels, which are in the upper direction, as the tracking system for the solar panels is highly dependent on the design and development mechanism that takes place in the PID control unit. As shown in the following (Figure 3.19) (Figure 3.20) [98]:

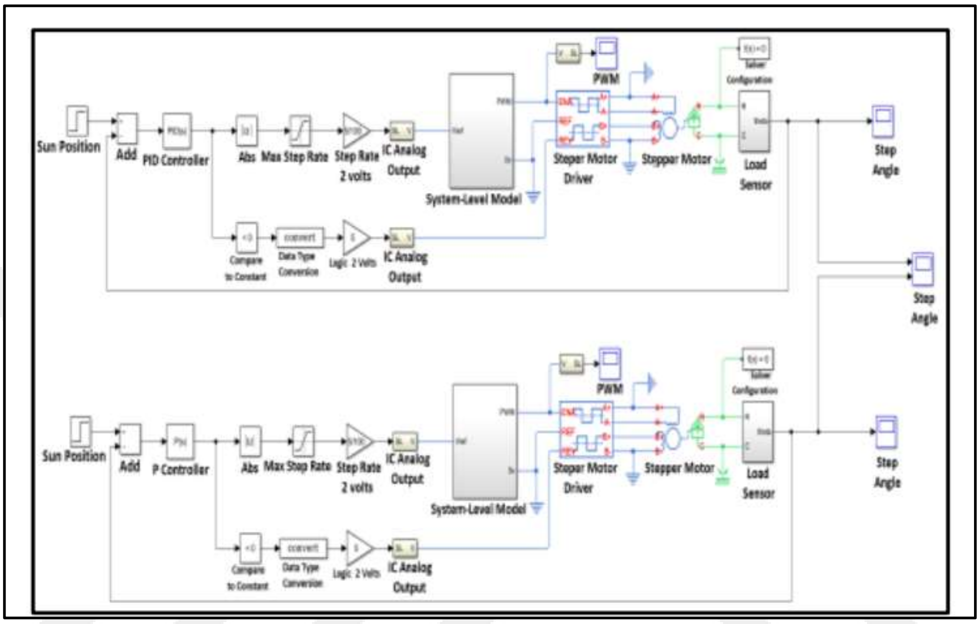


Figure 3.19: Design of The PID Controller System.

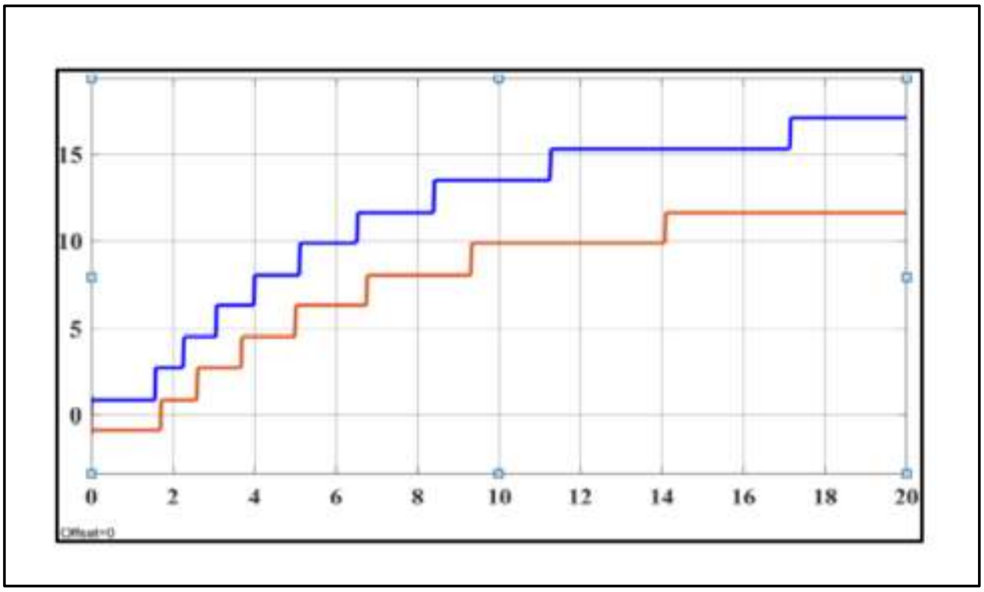


Figure 3.20: PID Controller and P Controller Simulation Results.

It is commonly used in mechanical systems, as shown in the treatment below.

$$\underbrace{u(t) = K_p e(t)}_{\text{proportional}} + \underbrace{K_i \int_0^1 e(\tau)\, d\tau}_{\text{Integral}} + \underbrace{K_d \frac{d}{d\tau}(\tau)}_{\text{Derivative}} \tag{3.5}$$

3.7 THE IMPORTANCE OF HYDROGEN

An evaluation on solar-powered hydrogen production. The importance of hydrogen lies in being a clean, renewable, sustainable fuel and a new energy source. The basis of the process is based on the use of a solar power plant and an electrolyzer for the production of hydrogen and its subsequent storage, As in (Figure 3.21) shown, which shows a solar energy system with hydrogen production[89].

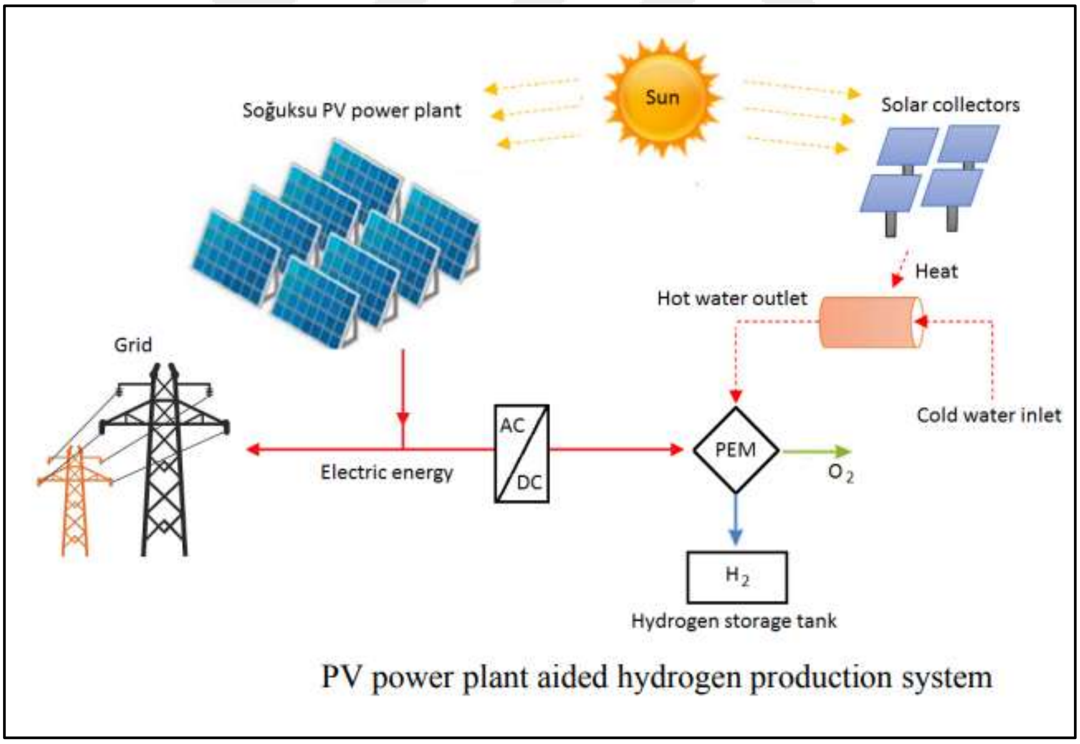


Figure 3.21: PV Power Plant Aided Hydrogen Production System.

The presence of hydrogen or how it is produced. It is known that hydrogen does not exist freely in nature, so you should resort to a method that is safe, environmentally friendly, and affordable. The production of hydrogen is either through fossil fuels or from renewable sources, As shown in (Figure 3.22) below [99]:

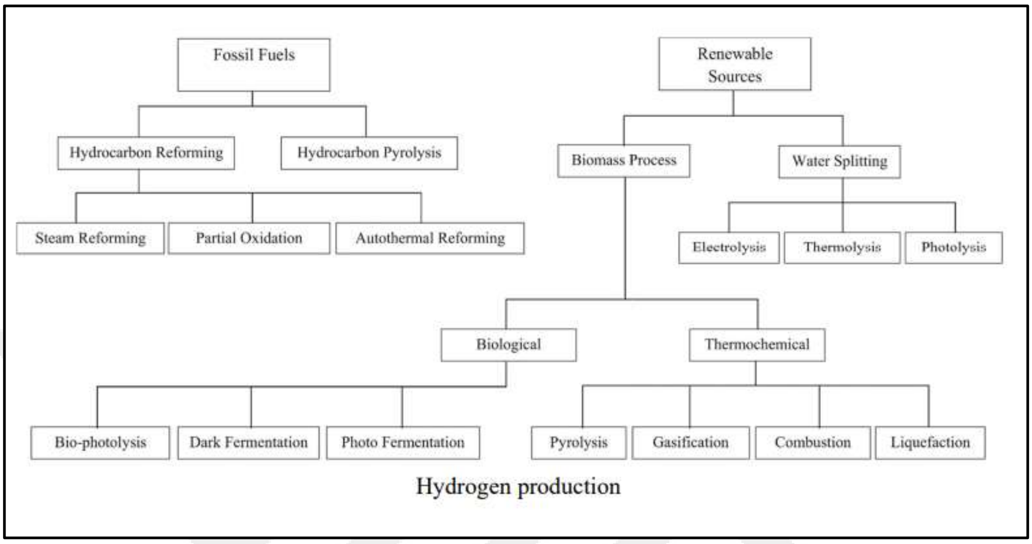


Figure 3.22: Hydrogen Production From Solar Energy [100].

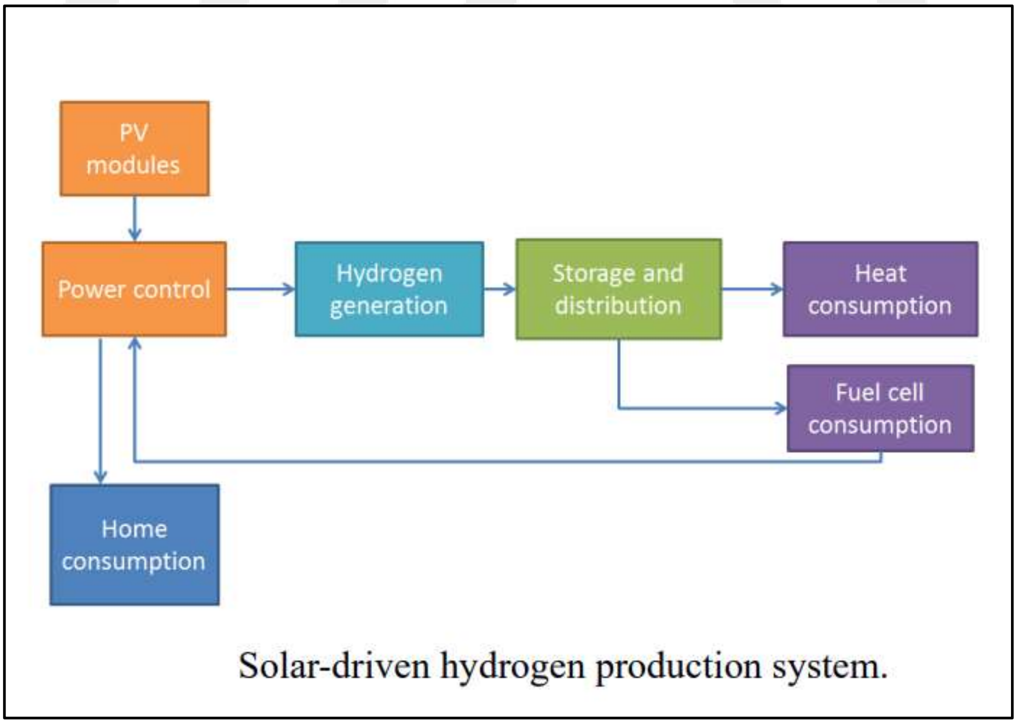


Figure 3.23: Stages of Hydrogen Production.

(Figure 3.22) above source shows the stages of hydrogen production. Hydrogen is produced from the photovoltaic system, and the resulting hydrogen is used to generate heat and electricity. Improve the performance of solar-based track systems by fuzzy logic controllers. [108]

One of the essential points in hydrogen production is photovoltaic cells and electrolysis devices. The PV system depends on solar radiation, temperature, and the extent of change in the maximum energy tracking points. In the case of grid-connected photovoltaic cells, there is a difference between the input and output value of the electrolysis device and the recipes IV, MPPT, and PV. To avoid this problem, there must be an electronic device to track the maximum power of MPPT, where it finds compatibility between PV and EL and Be responsive to radiation, but this process is expensive and complex in implementation. It must be done highly effectively and efficiently by doing MPPT tracking [101].

The generation of hydrogen from photovoltaic cells is based on electrolysis through the use of an electrolysis cell. The electric cell comprises the cathode and anode electrodes, and Hydrogen production is based on the generation of electricity from a solar plant connected to a photovoltaic network. The solar power plant is installed in a particular area and contains several photovoltaic panels of about 30 thousand units that can generate electricity of about 280 watts meeting the maximum load, so 1030 kg of hydrogen is produced in a net Day. One of the most essential techniques is electrolysis Alkaline Technique-Polymerization- Solid oxide electrolysis technology-

3.7.1 Hydrogen Production

The system used to produce hydrogen [102]:-

b. Solar energy.

c. Photovoltaic panels or cells.

d. Solar inverter.

e. Electrolysis.

f. Hydrogen production [103].

The following (Figure 3.24) shows how to produce hydrogen from a photovoltaic cell and system components.

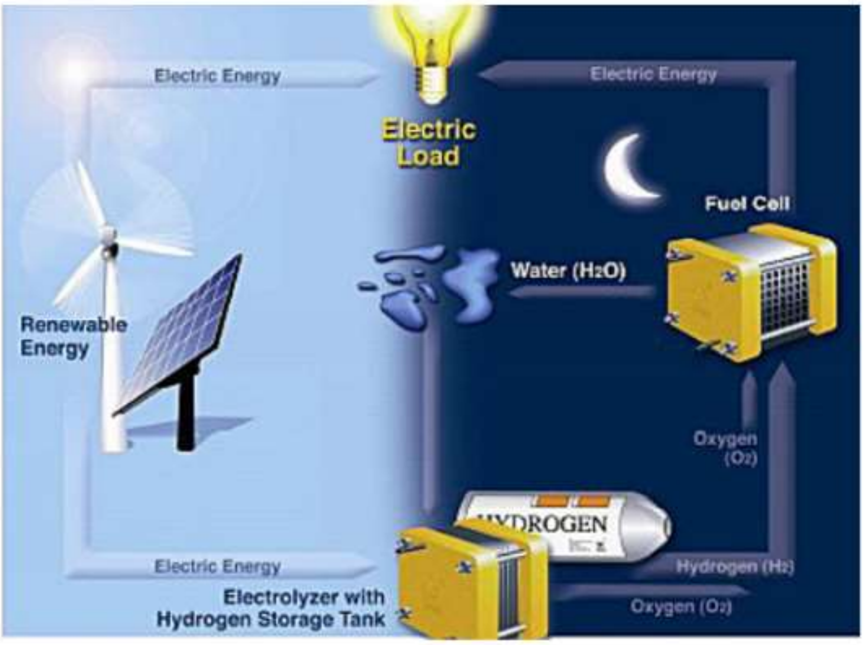


Figure 3.24: Solar Hydrogen Energy Cycle.

The (Figure 3.25) below shows the approved system for the production of hydrogen.

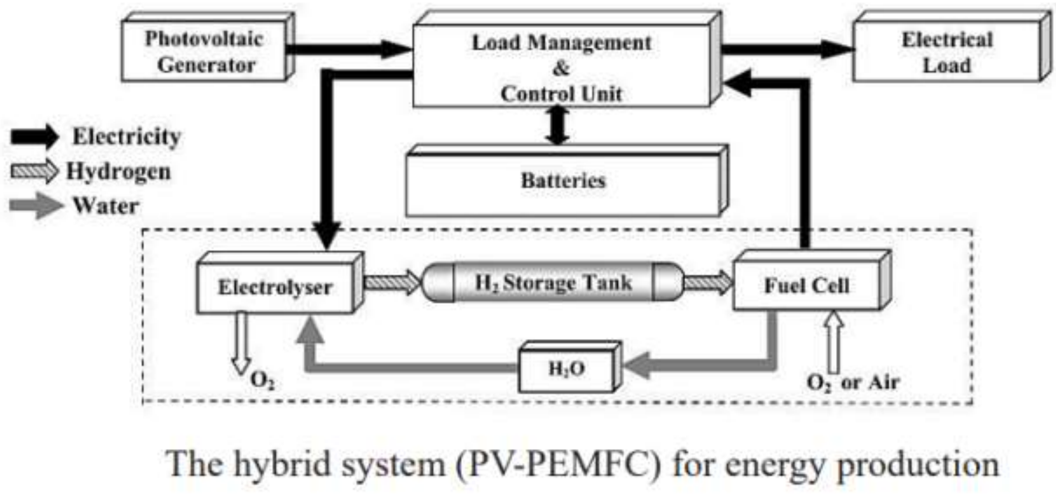


Figure 3.25: Approved System for The Production of Hydrogen [93].

The following (Figure 3.26) shows how the solar system works with electrolysis, which shows a photovoltaic panel with a water electrolysis cell, which results from solar radiation. The solution used in the cell is sodium hydroxide, an alkaline solution. The solar panels are connected to cables, which are connected to a voltmeter in addition to meters and meters for measuring solar radiation.

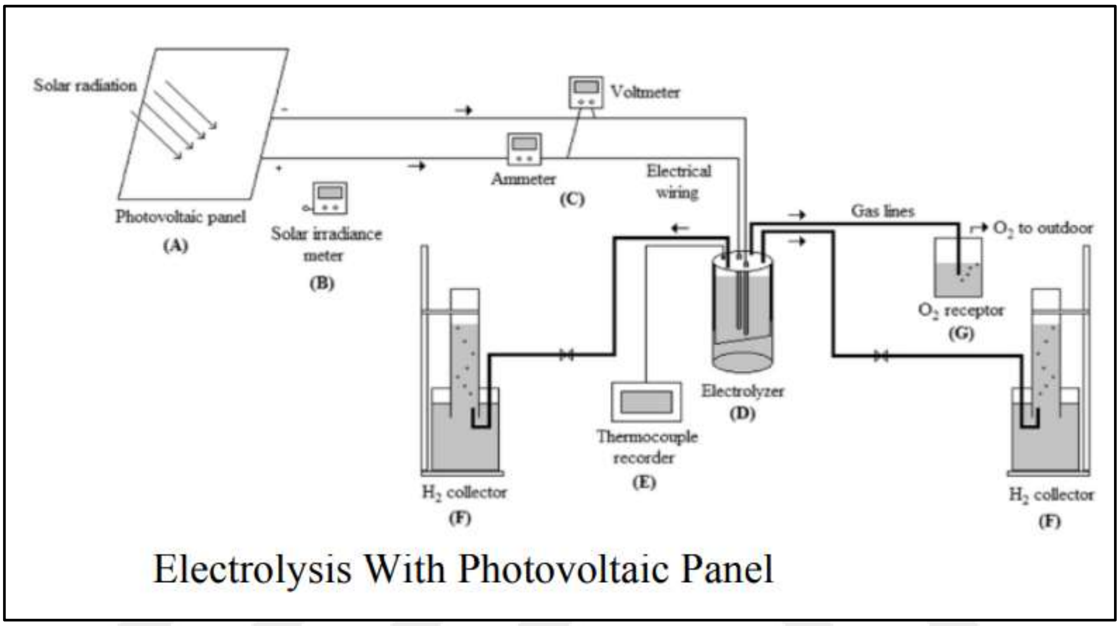


Figure 3.26: Electrolysis of Photovoltaic Panel.

3.7.2 Electrolysis

Electrolysis of water is one of the most common methods of producing hydrogen by solar energy. The use of an electrolysis device requires distilled water with salts and alkalis to obtain an electrolyte solution; sodium hydroxide and potassium are used as an aqueous solution [104], [105].

Electrolysis is based on electricity generated from solar energy, as water is decomposed by electrolysis into oxygen and hydrogen by direct current. This method is environmentally friendly and safe and does not emit greenhouse gases [111] [96].

The process of hydrogen production depends on the properties and condition of the electrode, surface, electricity, and distilled water to prevent impurities accumulation. The efficiency of the photovoltaic system is estimated at 20%, and the efficiency of electrolysis devices is about 80%. As for the efficiency of hydrogen production, it is about 16% of solar energy. The electrolysis device converts electrical energy into chemicals to produce hydrogen. The resulting hydrogen can be stored in pressure tanks or metal hydrates. The process of hydrogen production is carried out through the electrolysis of water by various methods, such as in the production of alkaline, acid, and solar images (Figure 3.27). [93], the mechanism of electrolysis is recommended.

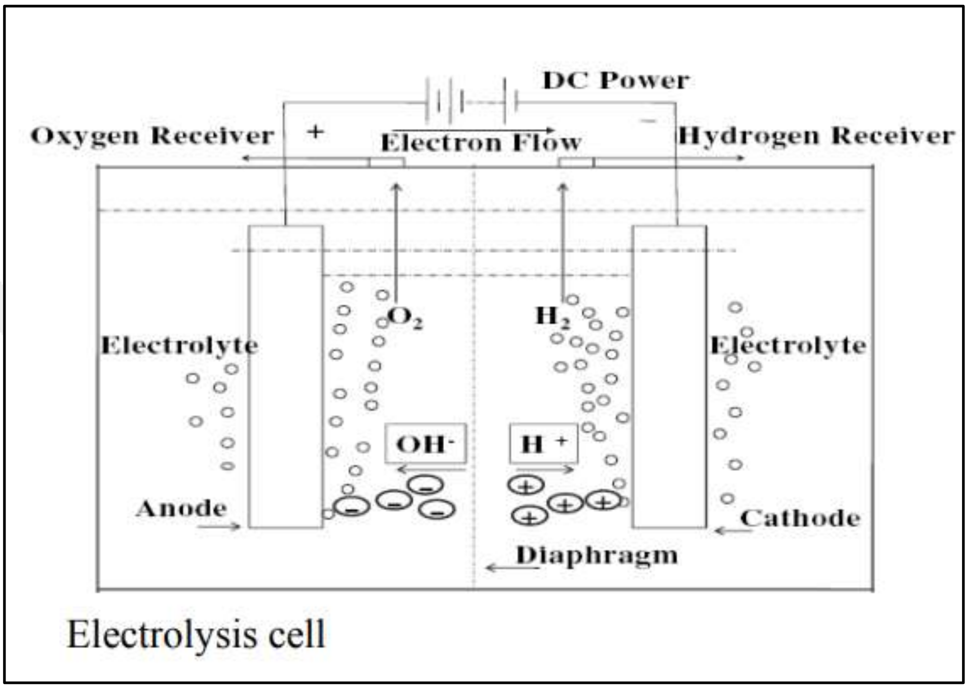


Figure 3.27: Electrolysis Cell [93].

Electrolysis consists of Cathode -anode-dissolved substance-current- The following equations explain the mechanism of hydrogen formation:

$$2OH^- \ H_2O + \frac{1}{2} O_2 + 2e^- \quad (3.6)$$

a. Reaction processes at the cathode

$$2H_2O + 2e^- \ 2OH^- + H_2 \quad (3.7)$$

b. Overall action

$$H_2O \ H_2 + \frac{1}{2} O_2 \quad (3.8)$$

Electrolysis results from splitting a water molecule into hydrogen and oxygen using a direct current. The production process is by releasing electrons by the ions on the surface of the electrodes in water electrolysis, which leads to the formation of gas–liquid–solid polyhedron. [93]The oxidation reaction is at the anode, the anode interaction of oxidation about the negative electrode, which is the cathode. The electrons move from the anode to the outer circuit, then to the cathode and the outer circuit. Oxygen is formed at the anode, and Hydrogen is formed from the negative electrode. As shown by the equations: The water electrolysis reaction formula is as follows:

Anode:

$$H_2O \rightarrow 1/2O_2 + 2H^+ + 2e^- \tag{3.9}$$

Cathode:

$$2H^+ + 2e^- \rightarrow H_2 \tag{3.10}$$

Overall:

$$H_2O \rightarrow H_2 + 1/2O_2 \tag{3.11}$$

In the electrolysis procedure, we note that the electrolyte does not interact with the electrodes or react with the chemical substance present. One of the essential conditions for this cell is that it is resistant to corrosion to have a more efficient and fast analysis process. The electrodes are electrically conductive and have catalytic properties, as well as the presence of a barrier to prevent the return of the union between oxygen and hydrogen produced by the cell, One of the essential advantages of electrolysis is that it is environmentally friendly, but its cost is considered relatively high, Its production capacity is considered low, the efficiency of the cell is less than 40%, and the production of electricity needs 30-40% as an average efficiency., As in (Figure 3.28) [106]].

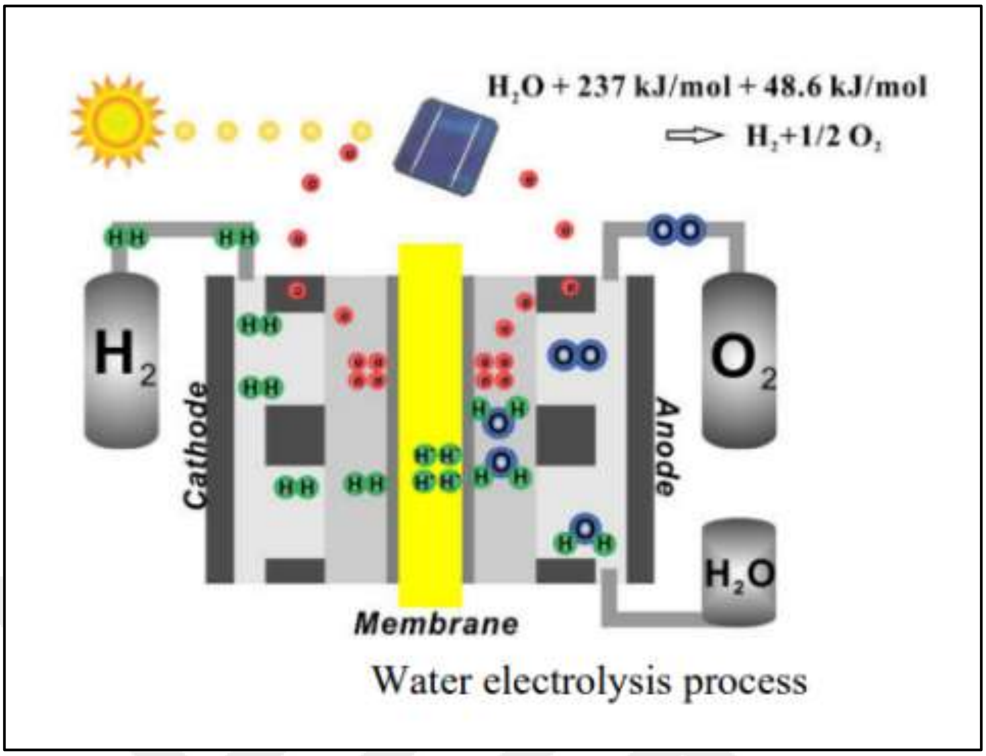


Figure 3.28: Water Electrolysis Process.

3.7.3 Storage Hydrogen

Improve performance of solar-based tank system by the fuzzy logic controller [108] Here, how to store energy and the techniques adopted are explained the working mechanism converts photovoltaic energy into electrical energy, where the output is transferred to an electrolysis device to separate hydrogen and oxygen from water in the form of ions. Hydrogen is stored in special tanks.

The hydrogen storage mechanism is somewhat complicated because it is a gas and occupies a large volume, which makes it difficult to move it from one place to another. The electrolysis device produces large quantities of hydrogen to obtain hydrogen. A large amount of energy must be used for the process to be completed entirely, obtain satisfactory results, and improve the performance of the solar-based track system by the fuzzy logic controller [107].

It is necessary to use storage technology for the resulting energy as storage systems increase economic and technical efficiency in addition to solar energy development. It can contribute to minimizing technical problems related to solar energy. The purpose of the storage is to minimize fluctuations in the power supply and to be available on demand. Solar energy can comply with electricity in terms of supply and demand.

4. RESULTS

Current energies can destabilize our ecological system; their availability is also limited. An energy system based on solar hydrogen is proposed as a non-polluting and renewable solution. The existence of crucial underground water combined with the highest insolation in the world make every country a place of choice for producing solar hydrogen. This production will offer countries clean energy and permit them to increase and diversify their energy resources.

Our work focuses on designing an islanded DC microgrid that powers an electrolyzer using a solar panel and an energy storage system. Our solar system will be based on a PID, i.e., we are trying to have MPPT based on a PID controller. Furthermore, its primary purpose and to have the maximum power and the best efficiency[105], [106].

Many experts posit that hydrogen has the potential to be a significant source of energy in the future. Hydrogen has the least detrimental effect on the environment compared to other forms of energy. This closed energy cycle is deployed for multiple purposes, including electricity generation, residential heating, and providing fuel for transportation [1].

Given the finite nature of fossil fuel reserves, hydrogen initially presents itself as an excellent alternative and eventually a viable substitute. It can assume a more prominent part than conventional energies. It is advantageous because it is non-polluting and can utilize the same means of transportation as traditional energies. It has the potential to satisfy regional energy requirements and can also serve as a significant exportable commodity.

It is of the utmost significance for our nation to develop and diversify its energy reserves and exports, for not only does this improve its energy exports, but it also helps to meet its growing energy requirements. There are multiple methods of generating hydrogen. Some of these techniques have achieved operational readiness for commercial deployment, while others remain at a developmental stage. Industrialization or industrialization is evident in the hydrogen production processes of catalytic decomposition of natural gas, partial oxidation of heavy oils, coal gasification, and water electrolysis.:

Thermochemical cycles of pure and hybrid varieties are currently undergoing research and development, whereas research into photochemical and photo-biological processes is still in its nascent stages.

The most employed and accepted method of hydrogen generation is through water electrolysis. Utilizing solar power for electrolytic procedures has the potential to be the most lucrative and ecologically sustainable practice. (Figure 4.1) shows the block diagrams of a hydrogen production process by electrolysis. We see, from this figure, that we can divide the system into three parts:

a. The energy support system for the decomposition of water. This system can be a field of photovoltaic panels or a hybrid system. The use of geothermal stations was also considered.
b. The water electrolysis system. The essential techniques commonly used for hydrogen production are alkaline electrolytes, polymer membranes, and ceramic oxides.

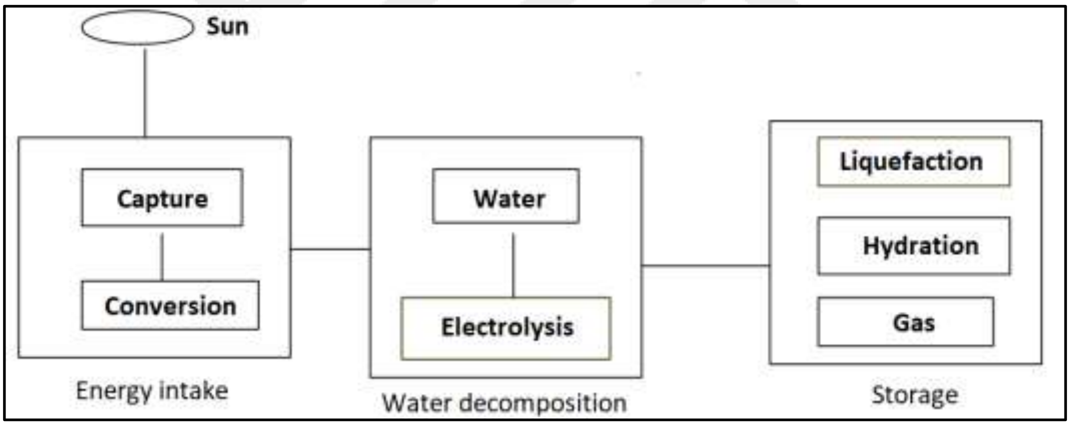


Figure 4.1: Synoptic Solar Hydrogen Production System.

c. Storage systems. The most used techniques are the liquefaction of hydrogen or its hydration. The choice of hybrids is significant. The emergence of quasicrystals and nanotubes as potential hydrogen storage metals has raised their importance. The storage system is sometimes replaced by a distribution system for use on-site for energy production, for example, or for evacuation to another place using transport or by pipeline (Figure 4.2).

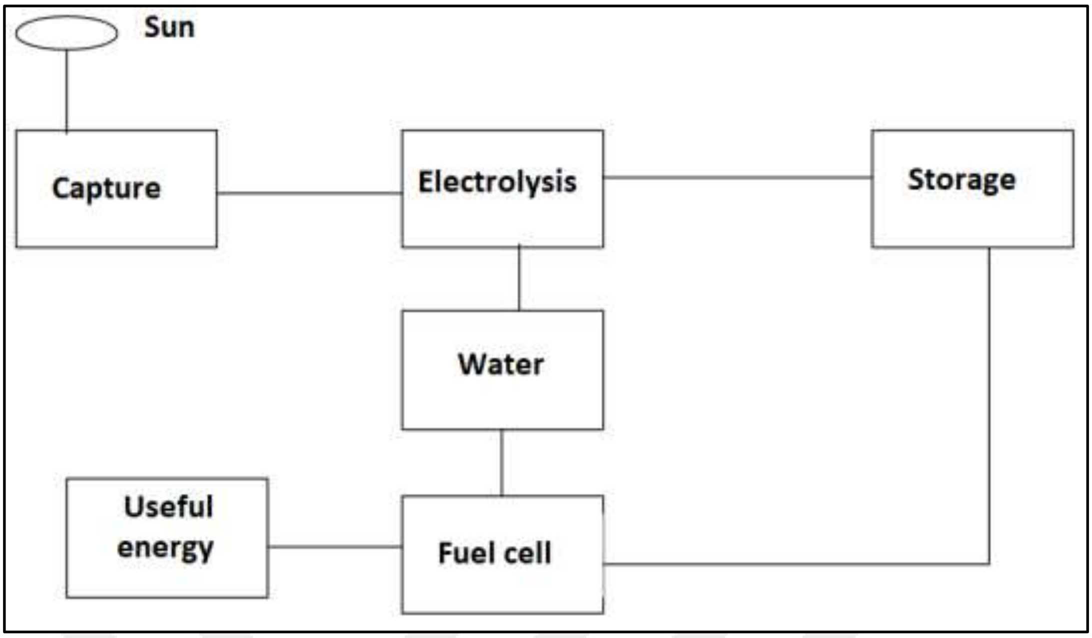


Figure 4.2: Solar Hydrogen Production Cycle by Electrolysis.

4.1 PHYSICAL AND ENERGETIC PROPERTIES OF HYDROGEN

From an energy point of view, hydrogen has several advantages: -

a. It has a very high energy mass density. As shown in (Table 4.1), the energy provided per unit mass of hydrogen is at least twice that provided by conventional energies. It is almost three times that of gasoline.
b. Hydrogen is the most versatile energy carrier. Indeed, conventional energies can only be converted into valuable energies (mechanical, thermal, or electrical) following a single combustion process. On the other hand, five different processes can convert hydrogen into helpful energy. In addition to combustion, hydrogen can be directly converted to steam, converted to heat by catalytic combustion, converted directly to electricity by electrochemical processes, and it can also act as a heat source and sink by chemical reaction.

Table 4.1: Comparison of Energy Densities.

Energy vector	Energy mass density (kWh/Kg)
Hydrogen (gas)	33.3
liquid hydrogen	33.3
Natural gas	13.9
Propane	12.9
Methanol	5.6
Essence	12.7
Diesel	11.6

Taking into account environmental impacts, solar hydrogen is a clean fuel. (Table 4.2) shows the pollutants produced by different fuels. It should be noted that the hydrogen combustion flame only produces NOx. Any other form of hydrogen use (hydration, vapor generation, catalytic combustion, etc.) does not produce it. We see that using hydrogen does not produce or produce very, very few elements harmful to the environment.

Table 4.2: Pollutants Emitted by Different Fuels.

Pollutant	**Hydrocarbure (Kg/GJ)**	**Coal (Kg/GJ)**	**Hydrogen (Kg/GJ)**
CO2	72.40	100.00	0.
CO	0.80	0.65	0.
SO2	0.38	0.50	0.
NOx	0.34	0.32	0.10

4.2 HYDROGEN PRODUCTION TECHNIQUES

In any hydrogen production, three aspects must be considered, namely:

a. The raw material: the extraction of hydrogen is generally done from water, hydrocarbons (such as methane, methanol, etc.), or both at the same time;
b. The energy required for production: this energy can be conventional, nuclear, or renewable (solar, wind, geothermal, etc.);
c. The production process: several processes exist using quantum energy, such as photolysis. Electrical energy, such as electrolysis, or thermal energy, such as the thermochemical process. For most processes, there are several types, and the number is relatively large.

The most widespread methods in hydrogen production, using renewable energies, are schematically summarized. It is important to note that the wind and the spas can play a dual role. The wind can be used as an energy vector for powering the electrolyzer and pumping the water supplying the electrolyzer. Similarly, spas can generate electricity and be a source of hot water for the electrolyzer. It has been shown that the hotter the water, the greater the efficiency of the electrolyzer.

Besides gas reforming, water electrolysis is the most developed and widely used process in the hydrogen production industry. Hydrogen is generated by the dissociation of the water molecule by an electric current flowing through two electrodes. In the case of solar hydrogen, this current is generated by the photovoltaic cells. The most critical technologies in the water electrolysis process are alkaline electrolytes, polymer membranes, and ceramic oxide electrolytes. The yields commonly obtained by the electrolytic process are around 65%.

However, yields of up to 85% are possible, and current work focuses on improving the electrocatalytic performance of electrodes, the corrosion resistance of materials, and the optimization of process conditions. Unlike electrolysis, which must go through the stage of generating an electric current (in our case, photovoltaic cells), hydrogen production by photolysis or photo conversion uses sunlight directly to produce hydrogen. However, this process uses a sensitizer to absorb light and stimulate the photochemical reaction and a catalyst to accelerate the reaction. This technique can therefore be divided into two processes:

a. A photovoltaic process where the chlorophyll present in microorganisms is the component of light absorption and catalyst enzymes.
b. The photoelectrochemical process is where the material absorbs light, and the metal is the catalyst. Depending on the nature of the sensitizer, there are two categories of photo-electrochemical processes.
c. The process uses molecules (metal complexes) in the solution as light absorbers. This type is often known as the photochemical process.
d. The photobiological process where the chlorophyll contained in the microorganisms is the light absorbing element and the enzymes are the catalysts.

In the photoelectrochemical process, one material is the light absorber, and one metal is the catalyst. Depending on the nature of the sensitizer, there are two classes of photoelectrochemical processes. There is the process of using molecules (metal complexes) in solution as light absorbers. This type is often known as the photochemical process. The other type of process uses a semiconductor as a light absorber, either suspended in solution or as a unit.

Photobiological processes use sunlight to generate hydrogen from certain algae and bacteria. Algae pigments absorb light, while cell enzymes act as a catalyst. Producing hydrogen from water with cyanobacteria as a catalyst is also possible. Yields are around 5%, 10% at best. In addition to this low yield, the process suffers from the double inhibition problem in the presence of oxygen and saturation. In semiconductor electrochemical processes, photoelectrochemical cells are used as light absorbers. The yield of these cells does not exceed 10% for CdS or $SrTiO_3$ type cells and 13% for p-InP. These cells also face corrosion problems which greatly limit their lifespan.

The second type of photoelectrochemical process, i.e., the photochemical process, is even less advanced than the first. In this case, a dissolved metal complex absorbs light and generates a charge separation which triggers the dissociation reaction of the water molecule. However, it is possible to combine two or all of the processes already described to produce hydrogen. This hybrid process is sometimes more powerful. For example, it is possible to widen the range of light-absorbed wavelengths, thereby increasing efficiency, by adsorbing molecules onto semiconductor surfaces.

Another option for hydrogen production is the thermochemical process. In this process, it is the thermal energy that is used for the dissociation of the water molecule. This process comprises several coupled reactions or cycles. Many of these cycles are postponed, but most remain in the state of experimentation and testing. The KIER-3 cycle uses copper oxide and copper sulfate, and the UT-3 cycle with ZrO3-Y2O3, ZrSiO3 + ZrO2 ceramics, and redox systems are the most prominent thermochemical processes. The pyrolysis of sulfuric acid also represents an exciting way of dissociating the water molecule. The thermochemical process can also be used for the gasification and pyrolysis of biomass and solid waste to produce hydrogen.

4.3 DESIGN OF PID CONTROLLER WITH P&O MPPT ALGORITHM FOR SOLAR SYSTEM

Different Maximum Power Point Tracking (MPPT) algorithms have been created to get the most power out of a photovoltaic (PV) panel, with the Perturb and Observe (P&O) MPPT method being the most popular. Either voltage reference control or direct duty ratio can be used to run the P&O algorithm. Tracking time and fluctuation around MPP are two flaws shared by both. In the latter scenario, a controller (PID) is fed the reference voltage produced by the algorithm to produce the correct duty ratio. The gains of a PID controller are computed using the PV panel's standard test circumstances, and the same values are utilized for other operating settings. This does not give good performance while operating under other conditions [106].

Using the power from a solar array alone or in conjunction with an energy storage device, our model can be used to assess the operational features of manufacturing green hydrogen over seven days. The electrical, thermal liquid and thermal gas domains are all present in the model. This conceptual model illustrates electrolysis, the process by which water and solar energy are combined to produce hydrogen gas. In our model, we place a much greater focus on electric power conversion.

The electrolyzer comprises a water tank that can be continuously filled as needed (conductivity increase in the solution may be accounted for). The diverted current that passes through a thermal resistor controls the water's temperature. The generated hydrogen is collected and stored in a tank with a gas chamber model at a constant temperature.

4.3.1 P&O MPPT Algorithm

The reference PV voltage is varied by controlling the perturbation step size (ΔVref) for the direction of slope variation. For the three-level operation of the P&O algorithm, the perturbation time Tα should be higher than the system's settling time. Similarly, ΔVref is decided for minimum tracking oscillation in the steady state of MPP. Therefore, ΔVref and Tα are two essential parameters in this MPPT algorithm. [116]

4.3.2 Fixed Gain PID Controller Design

The gains of the PID controller are calculated for the parameters of the PV panel at STC, which then generates the required duty ratio for the boost converter to operate in the MPP region. The continuous-time equivalent expression for PID control is,

$$G_c(s) = K_p + \frac{K_I}{s} + K_d s \tag{4.1}$$

Where K_P, K_I, and K_D are proportional, integral, and derivative gains of the controller, respectively.

We can express:

$$K_I = \frac{K_p}{T_I}, \qquad K_D = K_P * T_d, \tag{4.2}$$

5. DISCUSSION AND CONCLUSION

5.1 SYSTEM ARCHITECTURE AND CONTROL SYSTEM

This section provides a qualitative description of the hybrid energy system, its component functions, and the control procedure. The essential components of the energy system model consist of an electrolyzer, a lithium-ion battery, a hydrogen storage tank, and a PV system. The architecture of the proposed energy system is illustrated in Figure 5-1. The PV system functions as the primary energy source. Lithium-ion batteries store energy using a DC/DC converter as a charge controller.

If the lithium-ion battery is fully charged and the solar energy exceeds the amount of electricity required, then the electrolyzer is activated, producing hydrogen from the surplus energy. After a compression process, the hydrogen is retained in the hydrogen tank.

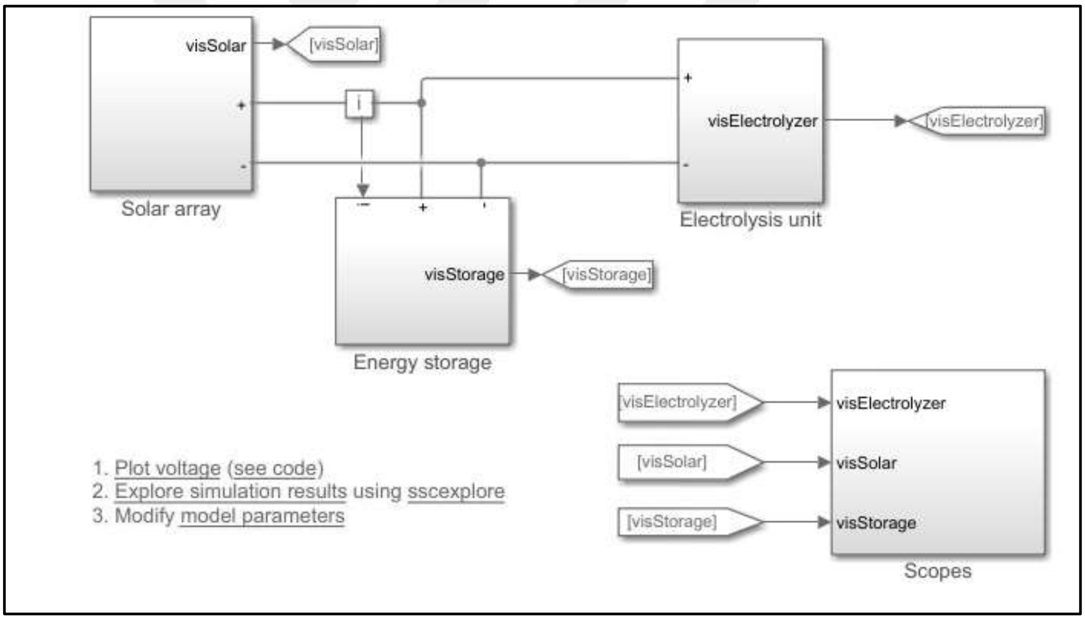


Figure 5.1: System Architecture.

5.2 DESCRIPTION OF THE PARTIAL MODELS

5.2.1 System Model

This chapter delineates the mathematical models and their realisation in MATLAB/Simulink. The MATLAB/Simulink version R2022a was employed. Hence, the components are examined singly.

5.2.2 Simulink Model of PV System

The simulation of the hydrogen production system begins with the modelling of the solar system. The Simulink system model shown in Figure 5-2 represents the solar cell as a buck boost converter. A buck-boost converter is a type of DC-DC converter that can step up or step down the voltage of the input power supply to match the required voltage of the load.

The buck-boost converter is a popular choice for solar systems as it allows for efficient power conversion and can work with input voltages that are higher or lower than the required output voltage. The buck-boost converter block is connected to the solar cell block and allows for the conversion of the solar cell's DC output to a suitable voltage for the load.

In addition, the model also contains a block for Maximum Power Point Tracking (MPPT), which is a technique used to optimize the power output of a solar system. The MPPT block is responsible for adjusting the operating voltage and current of the solar cell to maximize its power output. By tracking the maximum power point of the solar cell, the MPPT block can ensure that the solar system is operating at peak efficiency and generating the maximum amount of power possible.

Overall, the modelling of the solar system is a critical component of the hydrogen production system, as it provides the source of energy that is used to power the electrolyzer and produce hydrogen. By accurately modelling the attitude of the solar system and implementing MPPT techniques, the system can operate at maximum efficiency and generate a steady supply of clean energy.

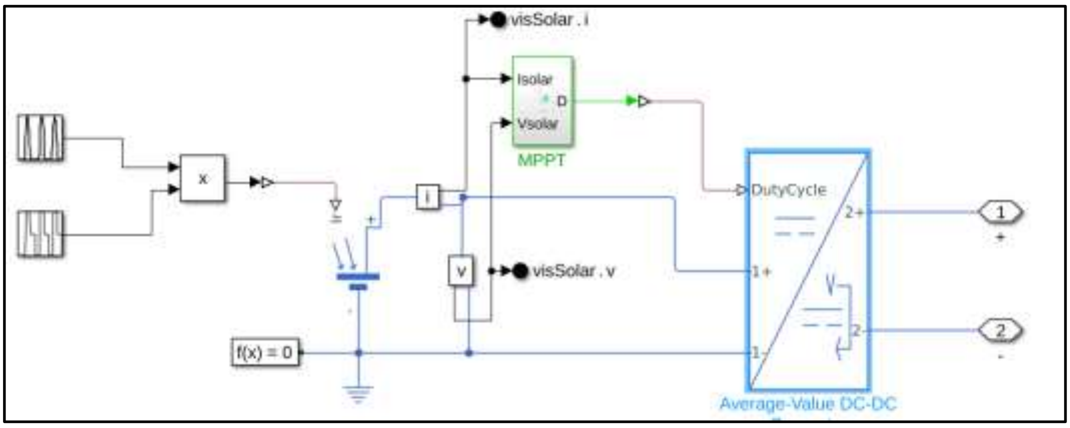


Figure 5.2: Modeling of Solar System.

The MPPT block is an essential component of the solar system model, as it is responsible for ensuring that the solar cell operates at maximum efficiency and generates the maximum possible power output. The figure below represents the MPPT block, which is based on two primary components: the P&O algorithm and the PID regulator.

The P&O algorithm, or Perturb and Observe algorithm, is a commonly used MPPT technique that works by perturbing the operating point of the solar cell and observing the effect on its power output. The algorithm continually adjusts the operating voltage and current of the solar cell and tracks the power output, allowing it to find the maximum power point of the solar cell. The P&O algorithm is simple and effective, making it a popular choice for MPPT applications.

The PID regulator is a type of control system that uses three primary components: proportional (P), integral (I), and derivative (D) terms to regulate a system's output. In the context of the MPPT block, the PID regulator is responsible for adjusting the output of the P&O algorithm to maintain a stable operating point for the solar cell. The P term responds to the current error between the desired and actual output, the I term integrates the error over time to provide a steady-state correction, and the D term accounts for the rate of change of the error to prevent overshoot.

By combining the P&O algorithm and the PID regulator in the MPPT block, the solar system can operate at maximum efficiency and generate the maximum possible power output. The MPPT block continuously adjusts the operating voltage and current of the solar cell, ensuring that it is always operating at the maximum power point. This allows the system to generate a steady supply of clean energy, which can be used to power the electrolyzer and produce hydrogen. (Figure 5.3) below represents the MPPT block based on the P&O algorithm and the PID regulator.

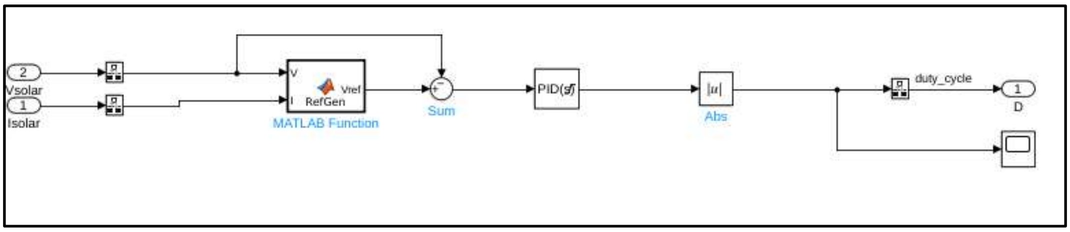


Figure 5.3: MPPT Block.

The "Average-Value DC-DC Converter" block in Simulink is a simulation block that models a DC-DC converter circuit operating in continuous conduction mode. This block is commonly used in power electronics and control system design.

The DC-DC converter circuit takes an input voltage and produces an output voltage that is either higher or lower than the input voltage. The average-value model of the converter provides a simplified representation of the converter's attitude, which is useful for simulation and control system design.

The block parameters for the "Average-Value DC-DC Converter" block include the input voltage, output voltage, switching frequency, duty cycle, and other parameters that are specific to the converter being modelled. These parameters can be set by the user based on the requirements of the system being designed. (Figure 5.4) shows the buck-boost converter parameters.

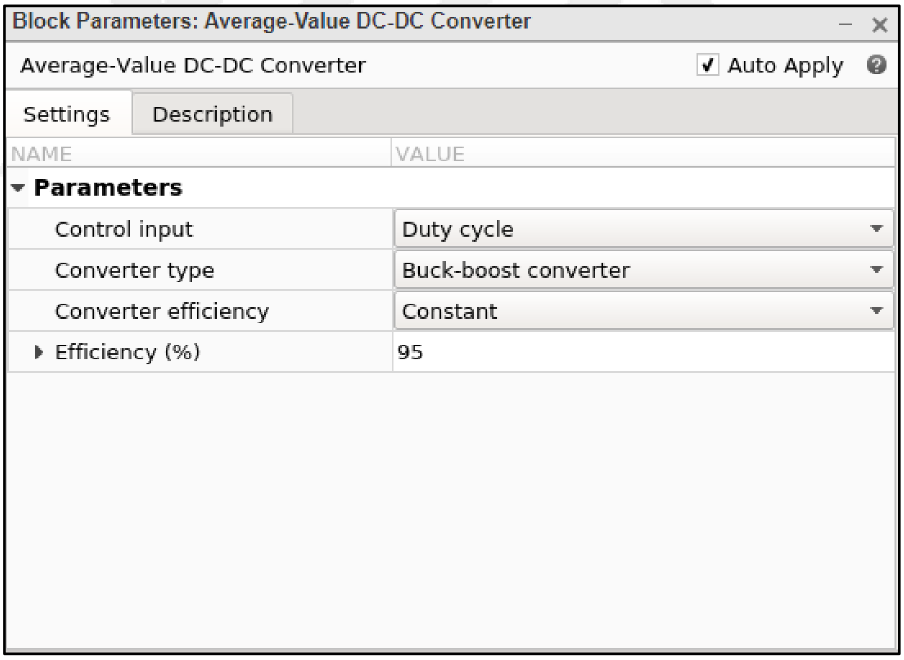


Figure 5.4: Buck-Boost Converter Parameters.

The "Solar Cell" block in Simulink is a simulation block that models the attitude of a solar cell. It is commonly used in the design and simulation of solar power systems.

The block parameters for the "Solar Cell" block include the solar cell's area, efficiency, and temperature coefficient. The area parameter represents the surface area of the solar cell, while the efficiency parameter represents the ratio of the electrical power produced by the solar cell to the amount of solar radiation incident upon it. The temperature coefficient parameter represents the change in the solar cell's efficiency due to changes in temperature.

The block also has an input port for the solar radiation intensity and a second input port for the cell temperature. These inputs can be used to model the effect of changes in solar radiation or temperature on the solar cell's electrical output.

The output of the "Solar Cell" block is the electrical current produced by the solar cell. This output can be connected to other simulation blocks in the model to simulate the attitude of a complete solar power system.

Overall, the "Solar Cell" block is a useful tool for simulating the behavior of a solar cell and for designing and optimizing solar power systems The (Figure 5.5) (Figure 5.6) below represents the solar cell parameters:

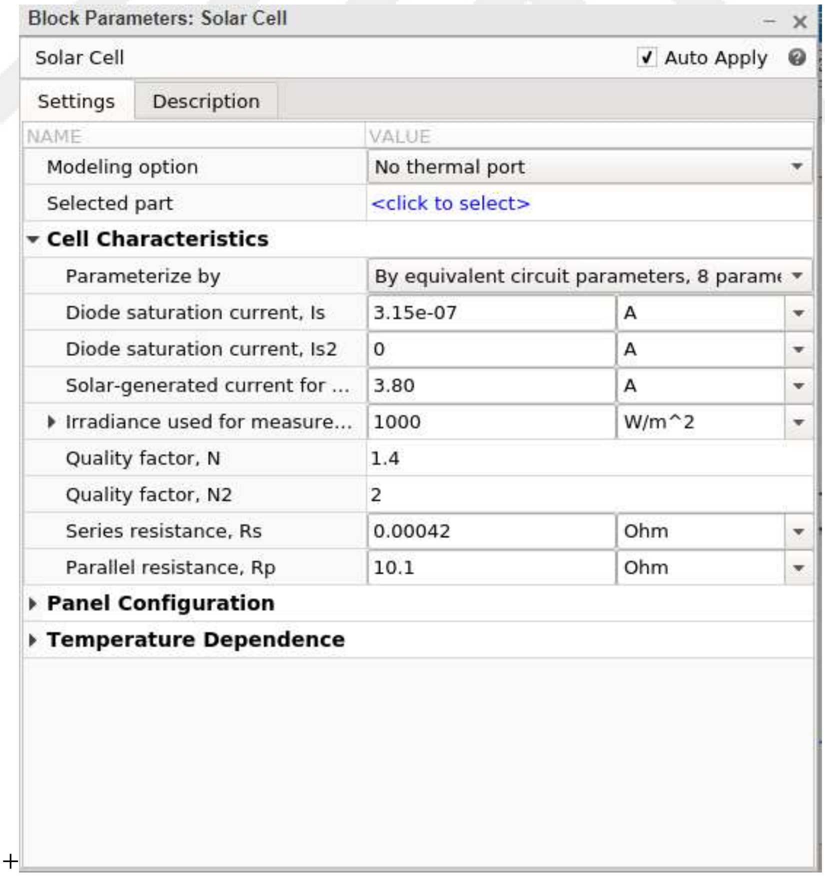


Figure 5.5: Solar Cell Parameters.

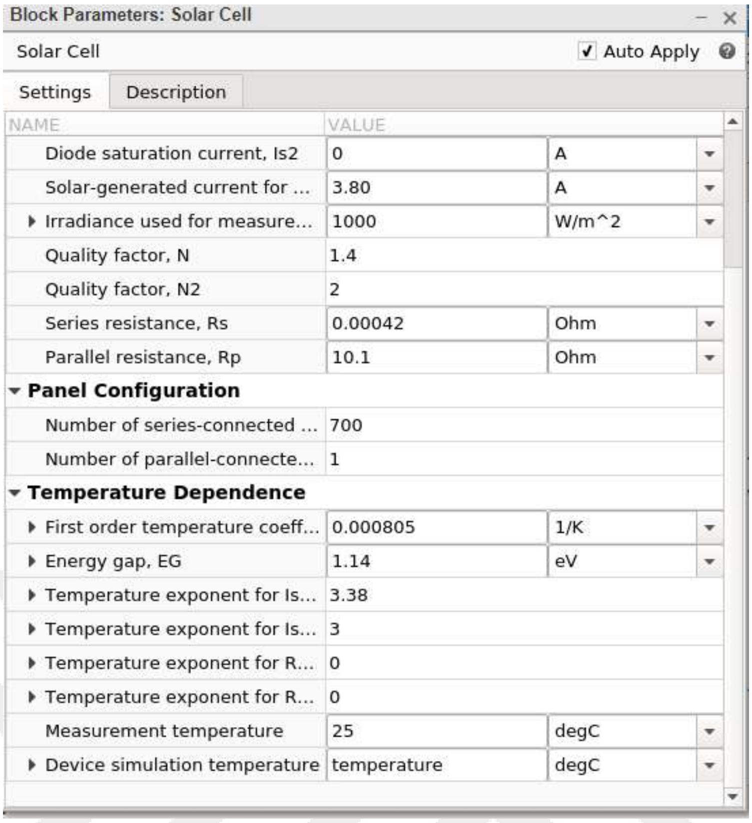


Figure 5.6: Solar Cell Parameters.

5.2.3 Modelling an Energy Storage System

Now we move on to modelling an energy storage system. This block contains a battery to store electrical energy and à DC-DC converter.

This is the primary depository for short-term electrical energy requirements. The surplus energy generated from the photovoltaic system is retained until the upper charging limit is reached. If the upper limit for energy charge is attained, the excess energy from the Photovoltaic (PV) system is then utilized to produce hydrogen. Excess energy is retained in the lithium-ion battery. The stored energy is utilized to meet the energy requirements during times of inadequate photovoltaic supply (e.g., at night, when cloud cover is present, or when energy demand is exceptionally high), as well as to respond to rapid load fluctuations occurring over a period. Due to the lower storage capacity of lithium-ion batteries in comparison to hydrogen tanks, these are only implemented for immediate energy requirements. When looking at energy-autonomous operation, the primary element is the amount of energy available over the specified period. (Figure 5.7).

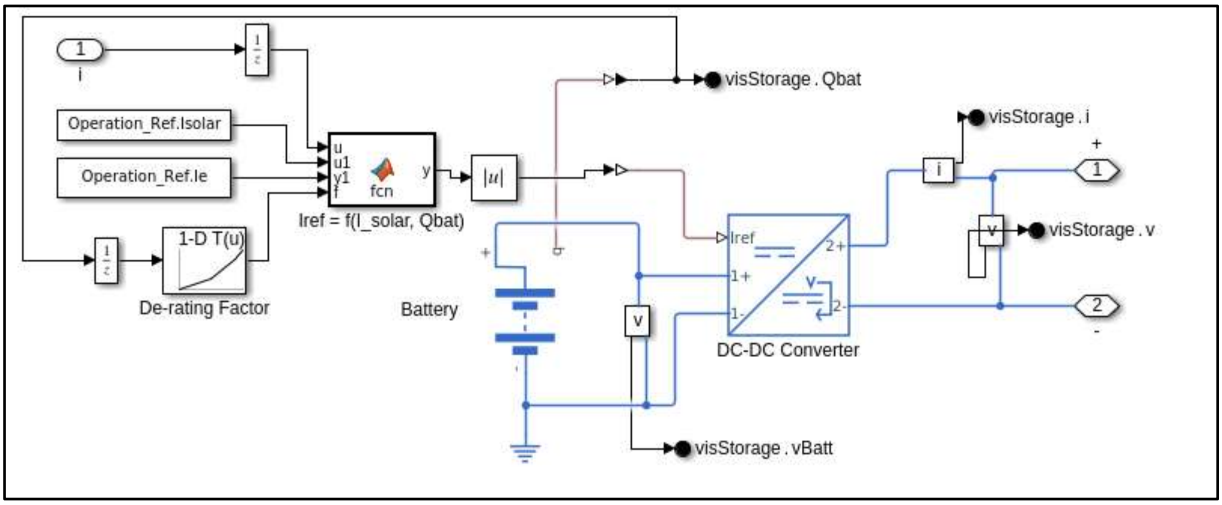


Figure 5.7: Energy Storage System Model.

The (Figure 5.8) below represents the DC-DC converter parameters:

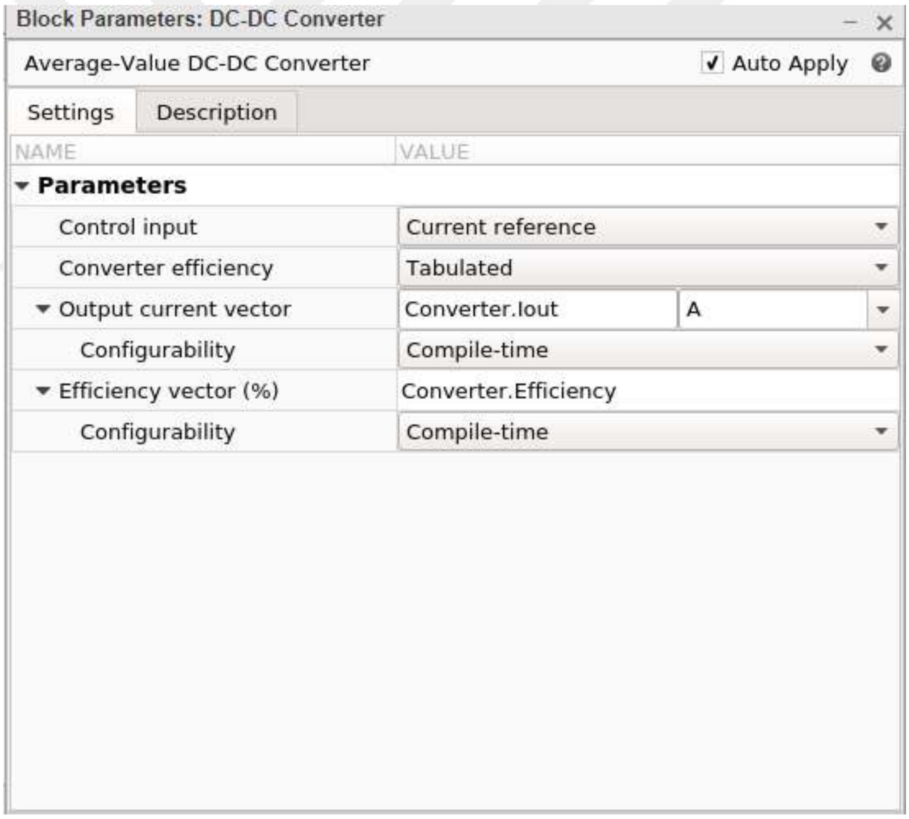


Figure 5.8: DC-DC Converter Parameters.

The "DC-DC Converter" block in Simulink models the attitude of a DC-DC converter circuit, with parameters including input/output voltage, switching frequency, and duty cycle. It also has an input port for a control signal and outputs the electrical current produced by the circuit.

The "Battery" block in Simulink is a simulation block that models the attitude of a battery. It is commonly used in the design and simulation of battery-powered systems.

The block parameters for the "Battery" block include the battery's capacity, voltage, and internal resistance. The capacity parameter represents the amount of energy that the battery can store, while the voltage parameter represents the nominal voltage of the battery. The internal resistance parameter represents the resistance of the battery's internal components, which affects the battery's performance and attitude.

The block also has input ports for the battery's charging and discharging currents. These inputs can be used to model the effect of charging and discharging the battery on its voltage and capacity.

The output of the "Battery" block is the voltage of the battery. This output can be connected to other simulation blocks in the model to simulate the attitude of a complete battery-powered system.

Overall, the "Battery" block is a useful tool for simulating the attitude of a battery and for designing and optimizing battery-powered systems. From (Figure 5.9) represents the Battery parameters.

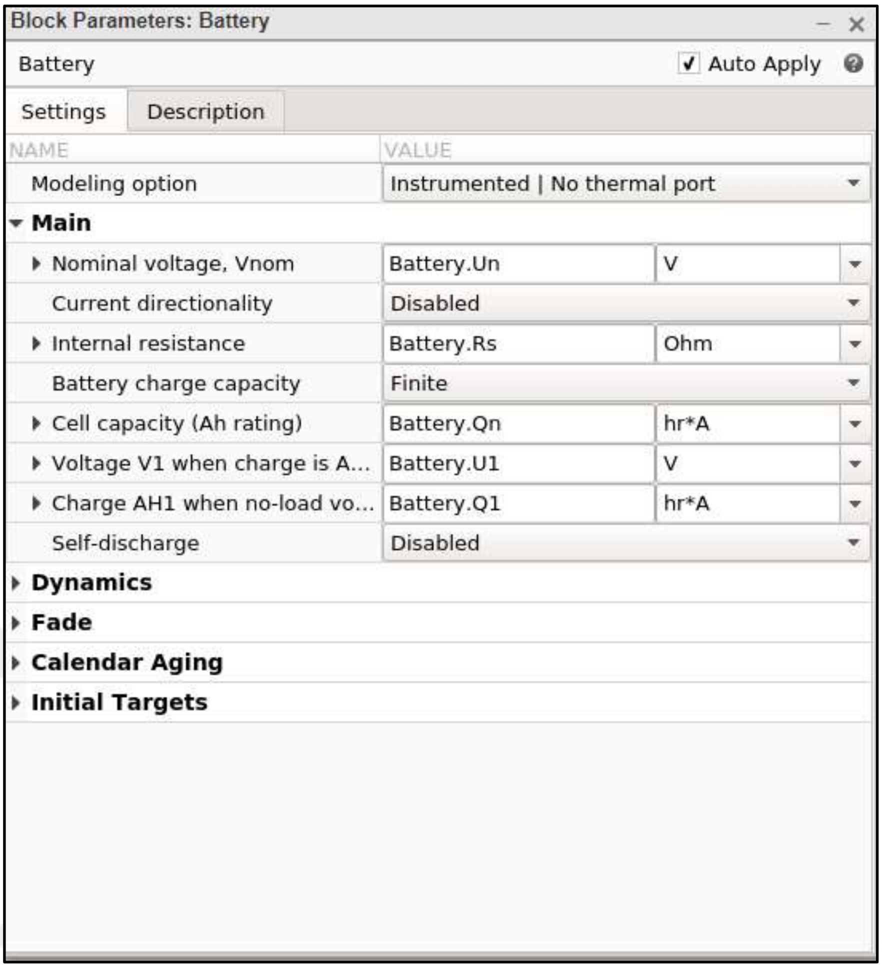


Figure 5.9: Battery Parameters.

5.2.4 The Electrolyzer Unit

The third block represents the electrolyzer unit, this block contains a water tank and a H2 storage tank, also an electrolyzer.

The "Electrolyzer Unit" block in Simulink models a system that converts water into hydrogen gas and oxygen gas using an electrolysis process. The block contains a water tank, an H2 storage tank, and an electrolyzer.

The water tank is the source of water for the electrolysis process. The H2 storage tank is where the produced hydrogen gas is stored. The electrolyzer is the component that carries out the electrolysis process, which involves splitting water molecules into hydrogen and oxygen gas using an electrical current.

The block parameters for the "Electrolyzer Unit" block include the water tank volume, the H2 storage tank volume, and the electrolyzer efficiency. The efficiency parameter represents the ratio of the electrical energy used for electrolysis to the amount of hydrogen gas produced.

The output of the "Electrolyzer Unit" block is the flow rate of hydrogen gas produced by the electrolysis process. This output can be connected to other simulation blocks in the model to simulate the behavior of a complete hydrogen production system.

Overall, the "Electrolyzer Unit" block is a useful tool for simulating the behavior of an electrolysis system and for designing and optimizing hydrogen production systems.

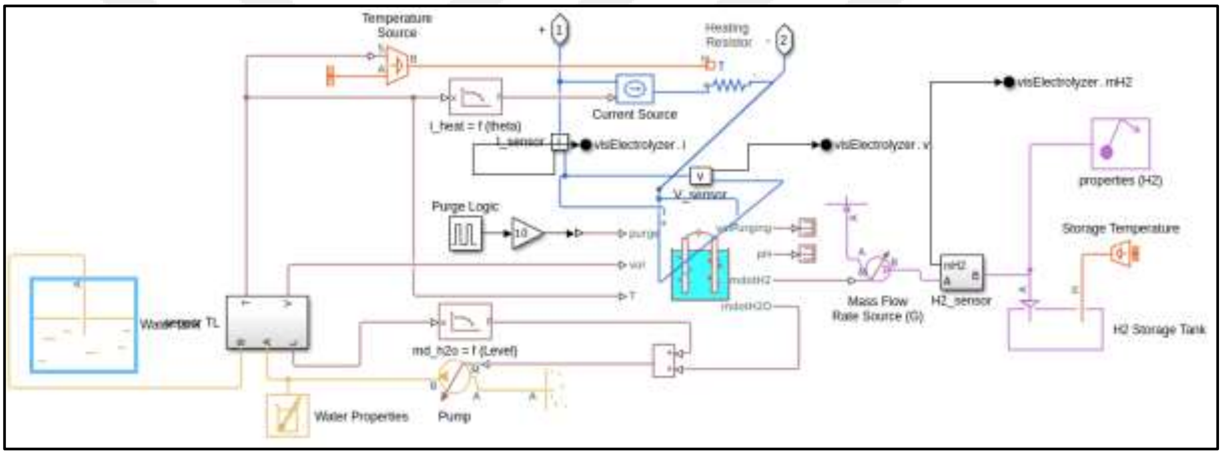


Figure 5.10: Electrolyzer Unit Block.

The "Electrolyzer" block in Simulink models the attitude of an electrolyzer device used for electrolysis. It is commonly used in the simulation and design of hydrogen production systems.

The block parameters for the "Electrolyzer" block include the efficiency of the electrolyzer, the current density, and the operating temperature. The efficiency parameter represents the ratio of the electrical energy used for electrolysis to the amount of hydrogen gas produced. The current density parameter represents the electrical current density in the electrolyzer, while the operating temperature parameter represents the temperature at which the electrolysis process occurs.

The block also has input ports for the current and voltage applied to the electrolyzer. These inputs can be used to model the effect of changes in current and voltage on the electrolyser's attitude.

The output of the "Electrolyzer" block is the flow rate of hydrogen gas produced by the electrolysis process. This output can be connected to other simulation blocks in the model to simulate the attitude of a complete hydrogen production system.

Overall, the "Electrolyzer" block is a useful tool for simulating the attitude of an electrolyzer and for designing and optimizing hydrogen production systems. (Figure 5.11) below represents the Electrolyzer parameters:

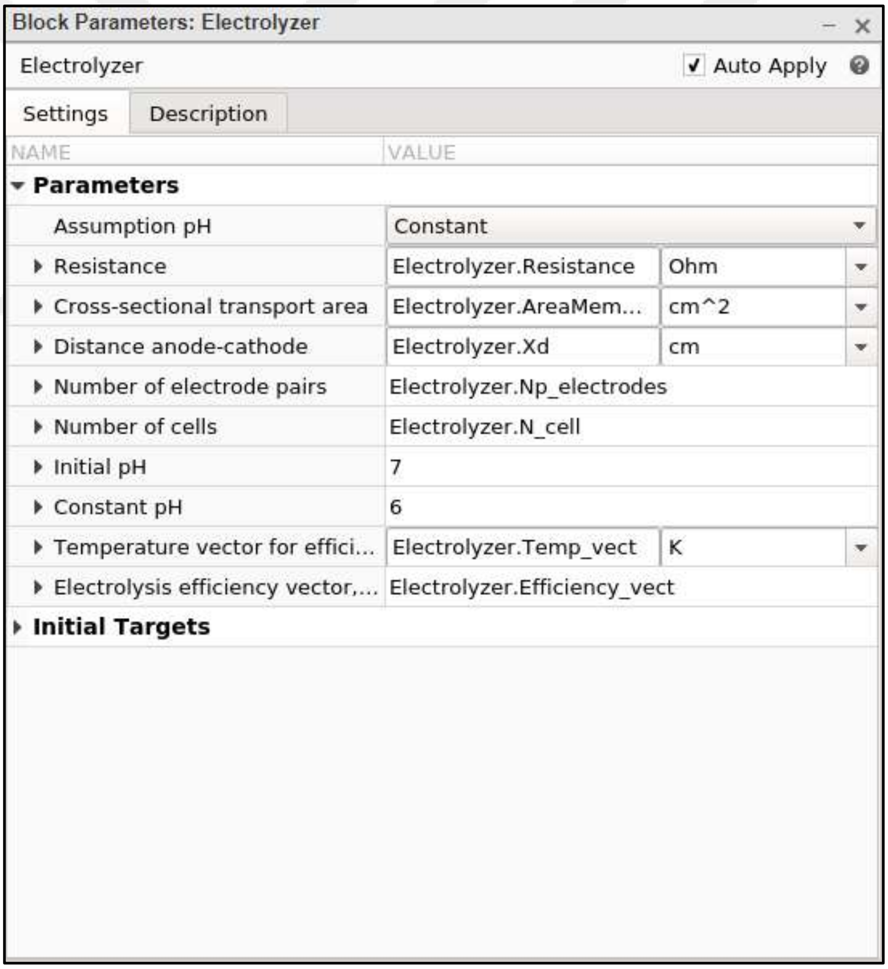


Figure 5.11: Electrolyzer Parameters.

The "H2 Storage Tank" block in Simulink models the attitude of a tank used for storing hydrogen gas. It is commonly used in the simulation and design of hydrogen storage systems.

The block parameters for the "H2 Storage Tank" block include the tank volume, the tank pressure, and the initial amount of hydrogen gas in the tank. The volume parameter represents the volume of the tank, while the pressure parameter represents the pressure of the hydrogen gas in the tank. The initial amount of hydrogen gas parameter represents the initial amount of hydrogen gas in the tank at the start of the simulation.

The block also has input ports for the flow rate of hydrogen gas into and out of the tank. These inputs can be used to model the effect of charging and discharging the tank on its pressure and amount of hydrogen gas stored.

The output of the "H2 Storage Tank" block is the pressure and amount of hydrogen gas in the tank. This output can be connected to other simulation blocks in the model to simulate the attitude of a complete hydrogen storage system.

Overall, the "H2 Storage Tank" block is a useful tool for simulating the attitude of a hydrogen storage tank and for designing and optimizing hydrogen storage systems. The (Figure 5.12) represents the Battery parameters.

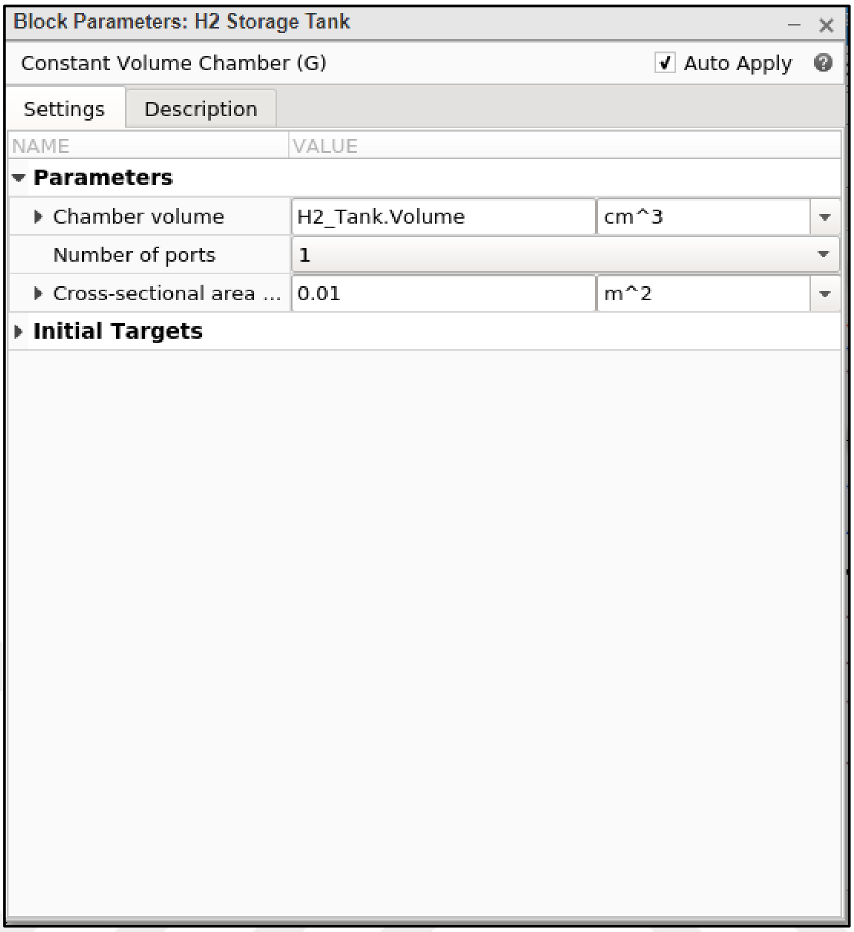


Figure 5.12: Represents the Battery Parameters.

The "Water Tank" block in Simulink models the attitude of a tank used for storing water. It is commonly used in the simulation and design of systems that require water as a resource.

The block parameters for the "Water Tank" block include the tank volume and the initial water level in the tank. The volume parameter represents the volume of the tank, while the initial water level parameter represents the initial amount of water in the tank at the start of the simulation.

The block also has input ports for the flow rate of water into and out of the tank. These inputs can be used to model the effect of filling and draining the tank on its water level.

The output of the "Water Tank" block is the water level in the tank. This output can be connected to other simulation blocks in the model to simulate the attitude of a complete system that requires water as a resource.

Overall, the "Water Tank" block is a useful tool for simulating the attitude of a water storage tank and for designing and optimizing systems that require water as a resource. The figure (5.13) represents the water tank parameters.

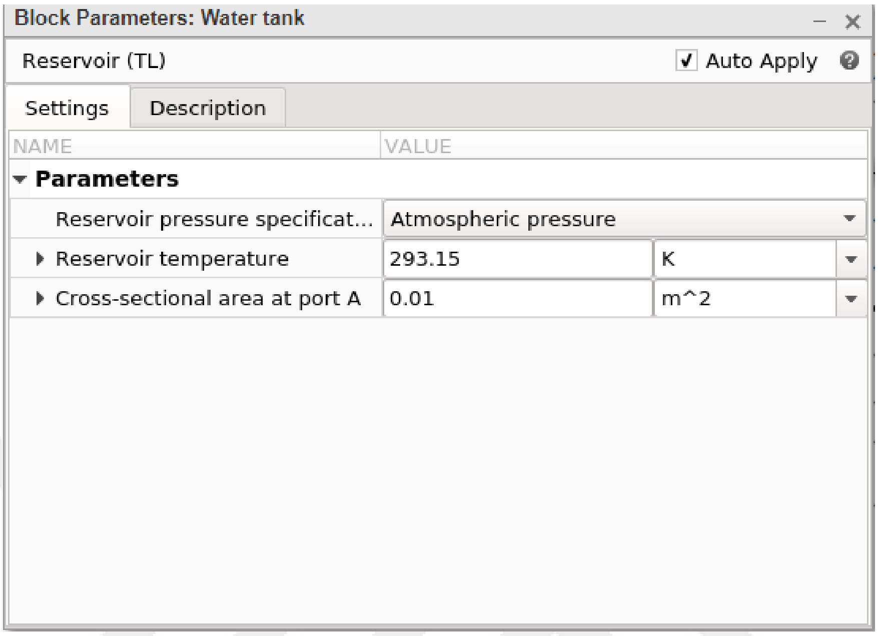


Figure 5.13: Water Tank Parameters.

5.2.5 System Parameters

The system parameters are critical inputs that determine the attitude and performance of the simulated system. The parameters used for simulating the system depend on the specific components and processes involved in the system. In this section, the system parameters that are used to simulate the system are listed and defined.

```
%% Parameters for Green Hydrogen Microgrid
%
% This example shows a DC islanded microgrid that provides power to an
% electrolyzer using a solar array and an energy storage system. we can
% use this model to evaluate the operational characteristics of producing
% green hydrogen over a 7-day period by power from a solar array, or from
% a combination of a solar array and an energy storage system. The model
% includes electrical, thermal liquid, and thermal gas domains.



%% Hydrogen Properties

T_vect = [-75 -50 -25 0 25 50 75 100]+273.15;                   %K
h_vect = [2532 2875 3224 3578 3936 4295 4655 5017];             %kJ/kg
nu_vect = [6.77 7.34 7.88 8.42 8.94 9.44 9.93 10.41];           %s*uPa
cond_vect = [132.4 146.8 160.5 173.4 185.6 197.5 210.1 222.0]; %mW/kg/K
cp_vect = [13.57 13.87 14.08 14.23 14.33 14.4 14.45 14.47];     %kJ/kg/K

R_h2 = 4.12; %kJ/kg/K

```

```
%% Solar Data
% Time vector for solar profile
t_solar_profile = [0, 3600, 7200, 10800, 14400, 18000, 21600, 25200,...
        28800, 32400, 36000, 39600, 43200, 46800, 50400, 54000,...
        57600, 61200, 64800, 68400, 72000, 75600, 79200, 82800]';
% Solar profile
solar_profile = [4, 4, 4, 4, 4, 4, 1204, 27604, 94404, 156804, 202804,...
        210404, 205204, 188404, 138404, 71604, 16004, 4, 4, 4, 4, 4, 4, 4]';

temperature = 25; % Solar cell simulation temperature [degC]

%% Electrolyzer Unit

Plate.X = 50;  % cm
Plate.Y = 100; % cm
Plate.Z = 100; % cm
Electrolyzer.Np_electrodes = 3; % Number of electrode pairs
Electrolyzer.N_cell = 50;       % Number of cells
Electrolyzer.Temp_vect = linspace(273.15, 353.15, 5); % Temperature vector for efficiency [k]
Electrolyzer.Efficiency_vect = linspace(0.55,0.9,5);  % Efficiency vector [pu]
Electrolyzer.AreaMembrane = (Plate.Y*Plate.Z)*Electrolyzer.Np_electrodes; % Membrane area [cm^2]
Electrolyzer.Xd = 2.0;          % Membrane tickness [cm]
Electrolyzer.Resistance = 0.25; % Resistance [Ohm]
Heat.Resistance = 25; % Heating resistor [Ohm]
```

```
Tank.Area = (Plate.X*Plate.Y)*Electrolyzer.Np_electrodes; % Area of water tank [cm^2]
H2_Tank.Volume = 100*100*100;  % Volume of hydrogen tank [cm^3]
H2_Tank.T_storage = 273.15;    % Temperature of hydrogen tank [K]

Temp_vect_heat = [0 50 75 100]+273.15;
I_vect_heat = [100 75 0 0];

%% Ennergy Storage

Battery.Qn = 50000;
Battery.Qinit = 50000;
Battery.Q1 = Battery.Qn*0.5;
Battery.Rs = 0.2;
Battery.Un = 240;
Battery.U1 = 210;

Operation_Ref.Ie = [100 95 75 12.5 12.5];
Operation_Ref.Isolar = [0 500 700 750 1000];
Converter.Iout = [40 80 120];
Converter.Efficiency = [95 98 100];

%% Control Parameters

Ts         = 10; % Sample time [s]
Ts_Control = 1;  % MPPT sample time [s]
```

5.3 RESULT

The plot below displays several important parameters related to the performance of the hydrogen production system, including the power consumption of the electrolyzer, the power output of the solar and storage system, the charge level of the battery, and the amount of hydrogen gas produced. By analysing these parameters, one can gain insights into the efficiency and effectiveness of the system, and identify areas for improvement. The plot serves as a valuable tool for optimizing the system's design and operation, and for ensuring that it operates at maximum efficiency while meeting the desired performance targets.

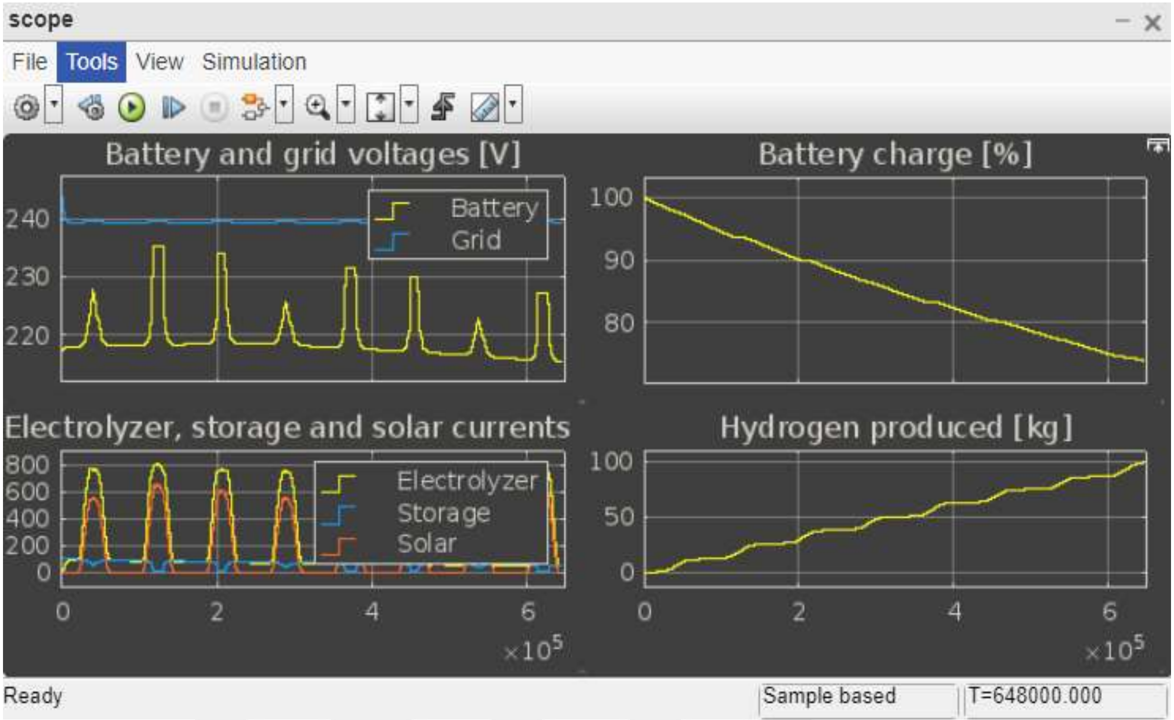


Figure 5.14: Chart 5-1 Shows Battery and Grid Voltage, Battery Change, Electrolyzer, Storage and Solar Currents, Hydrogen Produced.

The plot below shows the power of the electrolyzer, solar and storage in [KW], Energy electrolyzer and solar and storage in [KWh].

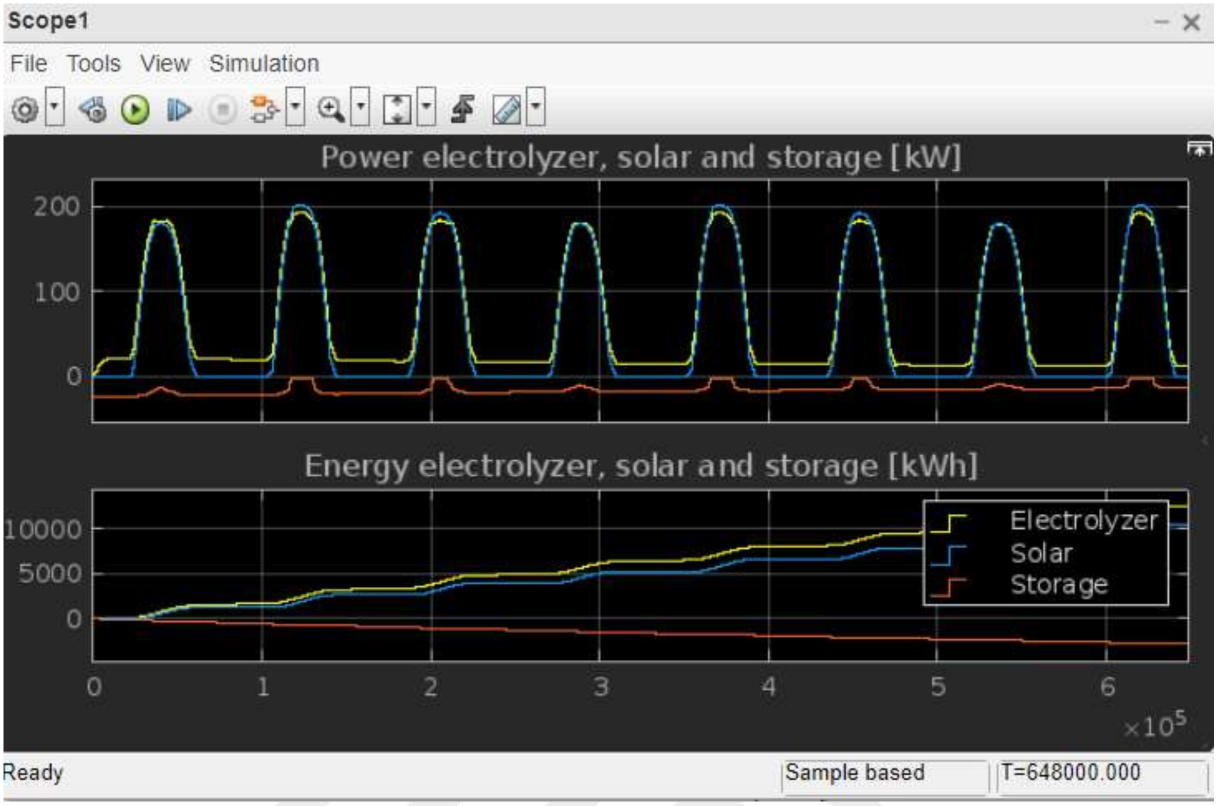


Figure 5.15: Chart 5-2: The Power of The Electrolyzer and Solar and Storage in [KW], Energy Electrolyzer and Solar and Storage in [KWh].

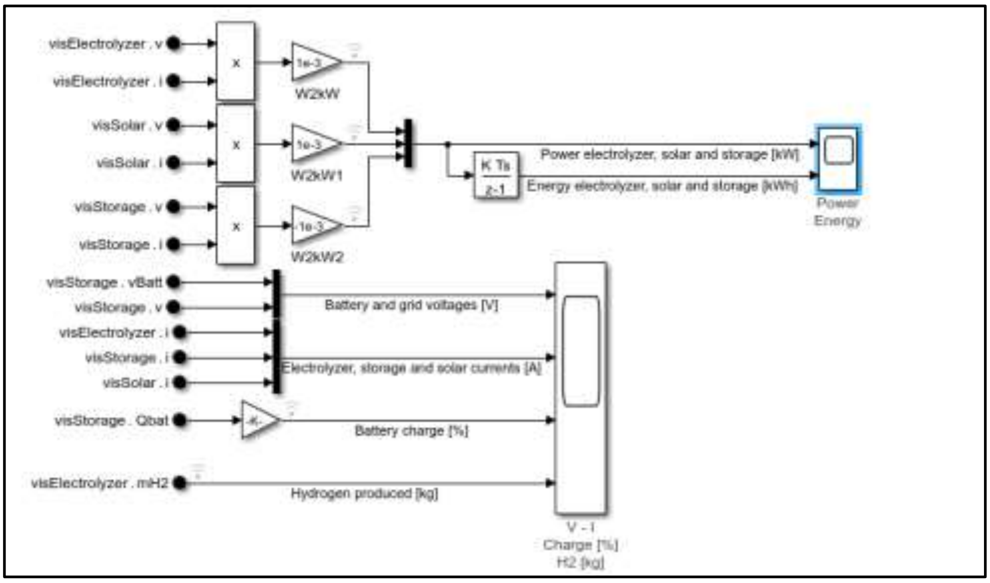


Figure 5.16: Chart 5-3: The Power of The Electrolyzer, Solar and Storage System, Battery Charge Level, and Hydrogen Produced.

5.4 ANALYSIS OF THE RESULTS

1.The results of the simulation provide several important insights into the attitude and performance of the hydrogen production system. Firstly, it appears that there is a direct relationship between the state of the battery and the production of hydrogen, with hydrogen production increasing as the battery state decreases. This may suggest that the hydrogen production system is designed to prioritize the production of hydrogen over battery storage when the battery is depleted.

2. Additionally, the voltages of the battery and grid are very close, indicating that the battery is being effectively charged by the grid. The maximum power of both the electrolyser and the solar system is 200KW, suggesting that the system is designed to operate at this level and may have been optimized for maximum power output.

3. The results also show that the PID controller is effective at achieving Maximum Power Point Tracking (MPPT), which allows for the production of a large amount of green hydrogen based on solar energy. The energies of both the electrolyser and the solar system increase linearly over time, indicating that the system is operating efficiently and generating a steady amount of energy.

4. However, it should be noted that the energy stored in the batteries decreases over time, which may suggest that the battery is not able to fully store all the energy generated by the solar system and electrolyser. This could be due to limitations in the battery's capacity or the charging capabilities of the system.

5.Overall, the simulation results demonstrate the effectiveness of the hydrogen production system and provide valuable insights into its performance. These insights can be used to optimize the design and operation of the system and to ensure that it operates at maximum efficiency while meeting the desired performance targets.

5.5 CONCLUSION

The scope of this study was to present a system to maximize the power of the solar system in order to produce hydrogen. The proposed model is composed of three blocks. One will be the energy source which is the solar system. This system is based on an algorithm to maximize the power. We worked with the PID regulator, and the latter gave excellent results, the second block is used to store the energy from the solar energy source, and the third is the most crucial. It is the block that allows us to produce hydrogen.

According to the findings, utilizing a PID as the controlling mechanism for the suggested model was an excellent decision. Because the components of the system interact with one another, implementing complex parameter studies is the only way to evaluate the direct influence of different parameter variations based on such a simulation. This is because the components of the system influence one another. These findings will serve as a foundation for further research in the future.

The simulation via Simulink showed that considering a battery to store energy was also an excellent choice because, thanks to this solution, we can produce energy during the night.

5.6 SUGGESTIONS ET RECOMMANDATIONS

Hydrogen production based on renewable energy, especially solar energy, is exceptional because this solution will allow us to produce much hydrogen based on green energy, a non-polluting energy source. The proposed solution is to implement a PID controller to produce the most significant amount of hydrogen, but using solar energy in real life will be expensive because if we take wind energy, for example, it will be better. After all, producing 1 kWh using wind energy is cheaper than solar energy. We are waiting for technological progress so that we can get kWh. At a low price, why not be cheap compared to wind plants? We can propose a solution based on wind power, and to maximize the power produced by wind, we can work with advanced control algorithms such as nonlinear controllers.

5.7 OUTLOOK

Future studies must concentrate on improving the control system and analysing which component dimensioning is preferred under which circumstances in terms of resource and energy efficiency as well as life extension. The control algorithm will be improved to increase the system's efficiency and produce the maximum hydrogen. Future studies will simulate the lifetime attitude of the entire energy system, taking degradation effects into account. Future research should also include a profitability analysis for this type of energy system in this setting.

Additionally, it is intended to compare the simulation findings to those of a natural system.

REFERENCES

[1] J. Ahmed and Z. Salam, “A modified P&O maximum power point tracking method with reduced steady-state oscillation and improved tracking efficiency,” *IEEE Trans Sustain Energy*, vol. 7, no. 4, pp. 1506–1515, 2016.

[2] R. Saini, C. S. Osorio-Gonzalez, S. K. Brar, and R. Kwong, “A critical insight into the development, regulation and future prospects of biofuels in Canada,” *Bioengineered*, vol. 12, no. 2, pp. 9847–9859, 2021.

[3] N. K. Allam, “Untapped potential of 2D charge density wave chalcogenides as negative supercapacitor electrode materials,” *RSC Adv*, vol. 12, no. 11, pp. 6433–6439, 2022.

[4] R.-U. Dietrich *et al.*, “Application of techno economic and ecological process assessment for cost estimation of renewable fuels,” 2020.

[5] T. Kober, H.-W. Schiffer, M. Densing, and E. Panos, “Global energy perspectives to 2060–WEC’s World Energy Scenarios 2019,” *Energy Strategy Reviews*, vol. 31, p. 100523, 2020.

[6] B. M. Hashim, M. A. Sultan, A. Al Maliki, and N. Al-Ansari, “Estimation of greenhouse gases emitted from energy industry (oil refining and electricity generation) in Iraq using IPCC methodology,” *Atmosphere (Basel)*, vol. 11, no. 6, p. 662, 2020.

[7] A. A. Kazem, M. T. Chaichan, and H. A. Kazem, “Dust effect on photovoltaic utilization in Iraq,” *Renewable and Sustainable energy reviews*, vol. 37, pp. 734–749, 2014.

[8] S. Lipiäinen, E. Sermyagina, K. Kuparinen, and E. Vakkilainen, “Future of forest industry in carbon-neutral reality: Finnish and Swedish visions,” *Energy Reports*, vol. 8, pp. 2588–2600, 2022.

[9] M.-C. Ţuţuianu, “The Strategic Planning Capacity of the Romanian Ministry of Energy: Characteristics and Effects. Study Case-the Offshore Law.,” *Economy Transdisciplinarity Cognition*, vol. 25, no. 1, 2022.

[10] D. J. Jasim, T. J. Mohammed, and M. F. Abid, "Review on the natural gas in Iraq, currently and future prospects for improving the economic and environmental situation," in *AIP Conference Proceedings*, AIP Publishing, 2022.

[11] H. M. Almusawi and A. Farnoosh, "Economic Analysis of the Electricity Mix of Iraq using Portfolio Optimization Approach," *International Energy Journal*, vol. 21, no. 2, pp. 235–244, 2021.

[12] A. S. Aziz, M. F. N. Tajuddin, M. R. Adzman, A. Azmi, and M. A. M. Ramli, "Optimization and sensitivity analysis of standalone hybrid energy systems for rural electrification: A case study of Iraq," *Renew Energy*, vol. 138, pp. 775–792, 2019.

[13] A. M. Khan, S. K. Ray, N. K. Mohalik, D. Mishra, S. Mandal, and J. K. Pandey, "Experimental and CFD Simulation Techniques for Coal Dust Explosibility: A Review," *Min Metall Explor*, vol. 39, no. 4, pp. 1445–1463, 2022.

[14] J. H. L. Voncken and J. H. L. Voncken, "The origin and classification of coal," *Geology of Coal Deposits of South Limburg, The Netherlands: Including Adjacent German and Belgian Areas*, pp. 25–40, 2020.

[15] J. Lu, H. Chen, and X. Cai, "From global to national scenarios: Exploring carbon emissions to 2050," *Energy Strategy Reviews*, vol. 41, p. 100860, 2022.

[16] J. C. Lentijo, "International Atomic Energy Agency Deputy Director General Nuclear Safety and Nuclear Security's closing remarks [International conference on management of spent fuel from nuclear power reactors: Learning from the past, enabling the future, Vienna (Austria), 24-28 June 2019]," in *Management of Spent Fuel from Nuclear Power Reactors: Learning from the Past, Enabling the Future. Proceedings of an International Conference*, 2020.

[17] B. K. Nayak, S. K. Sansaniwal, J. Mathur, T. Chandra, and V. Garg, "Identifying building archetypes based on energy performance as the major criteria: a case of Jaipur, India," *Advances in Building Energy Research*, pp. 1–26, 2023.

[18] B. K. Nayak, S. K. Sansaniwal, J. Mathur, T. Chandra, and V. Garg, “Identifying building archetypes based on energy performance as the major criteria: a case of Jaipur, India,” *Advances in Building Energy Research*, pp. 1–26, 2023.

[19] A. Bahadori, *Natural gas processing: technology and engineering design*. Gulf Professional Publishing, 2014.

[20] S. Ahsan, T. Ahmmed, and F. Alam, “The COVID-19, power generation and economy–Case study of a developing country,” *The Electricity Journal*, vol. 35, no. 6, p. 107145, 2022.

[21] F. Dunn, W. M. Hartmann, D. M. Campbell, and N. H. Fletcher, *Springer handbook of acoustics*. Springer, 2015.

[22] H. M. Jassim, “Lead pollution in Iraqi Kurdistan Region,” *International Journal of Engineering Trends and Technology (IJETT)*, vol. 4, no. 6, 2013.

[23] S. Lipiäinen, E. Sermyagina, K. Kuparinen, and E. Vakkilainen, “Future of forest industry in carbon-neutral reality: Finnish and Swedish visions,” *Energy Reports*, vol. 8, pp. 2588–2600, 2022.

[24] J. Grundius, “Estimation of DB Schenkers solar potential.” 2016.

[25] R. O’hayre, S.-W. Cha, W. Colella, and F. B. Prinz, *Fuel cell fundamentals*. John Wiley & Sons, 2016.

[26] C. Vilela, A. J. D. Silvestre, F. M. L. Figueiredo, and C. S. R. Freire, “Nanocellulose-based materials as components of polymer electrolyte fuel cells,” *J Mater Chem A Mater*, vol. 7, no. 35, pp. 20045–20074, 2019.

[27] P. Charoen-amornkitt, T. Santiprasertkul, P. Munprakobkij, and N. Limjeerajarus, “Numerical Study of a Polymer Electrolyte Fuel Cell with a Hybrid Serpentine-Interdigitated Flow Field Design,” in *6th TSME International Conference on Mechanical Engineering, Hua-Hin*, 2015.

[28] M. Saitoh *et al.*, “2-{3-[4-(Alkylsulfinyl) phenyl]-1-benzofuran-5-yl}-5-methyl-1, 3, 4-oxadiazole derivatives as novel inhibitors of glycogen synthase kinase-3β with good brain permeability,” *J Med Chem*, vol. 52, no. 20, pp. 6270–6286, 2009.

[29] B. K. Hodge, *Alternative energy systems and applications*. John Wiley & Sons, 2017.

[30] H. Vaghari, H. Jafarizadeh-Malmiri, A. Berenjian, and N. Anarjan, “Recent advances in application of chitosan in fuel cells,” *Sustainable Chemical Processes*, vol. 1, no. 1, pp. 1–12, 2013.

[31] U. M. Zavorotnaya, I. I. Ponomarev, Y. A. Volkova, and V. V Sinitsyn, “Development of High-Performance Hydrogen-Air Fuel Cell with Flourine-Free Sulfonated Co-Polynaphthoyleneimide Membrane,” *Membranes (Basel)*, vol. 13, no. 5, p. 485, 2023.

[32] P. Arunkumar, M. Meena, and K. S. Babu, “A review on cerium oxide-based electrolytes for ITSOFC,” *Nanomaterials and Energy*, vol. 1, no. 5, pp. 288–305, 2012.

[33] Y. Qiblawey, M. E. H. Chowdhury, F. Musharavati, E. Zalnezhad, A. Khandakar, and M. T. Islam, “Instrumented hip implant: A review,” *IEEE Sens J*, vol. 21, no. 6, pp. 7179–7194, 2020.

[34] Y. Zahraoui, M. R. B. Khan, I. AlHamrouni, S. Mekhilef, and M. Ahmed, “Current status, scenario, and prospective of renewable energy in Algeria: A review,” *Energies (Basel)*, vol. 14, no. 9, p. 2354, 2021.

[35] B. Zycher, *Renewable electricity generation: Economic analysis and outlook*. Rowman & Littlefield, 2011.

[36] K. Valls-Val and M. D. Bovea, “Carbon footprint assessment tool for universities: CO2UNV,” *Sustain Prod Consum*, vol. 29, pp. 791–804, 2022.

[37] A. Khaligh and O. C. Onar, *Energy harvesting: solar, wind, and ocean energy conversion systems*. CRC press, 2017.

[38] D. Mulvaney, “Identifying the roots of Green Civil War over utility-scale solar energy projects on public lands across the American Southwest,” *J Land Use Sci*, vol. 12, no. 6, pp. 493–515, 2017.

[39] S. Cheng, Z. Li, H.-P. Mang, E.-M. Huba, R. Gao, and X. Wang, “Development and application of prefabricated biogas digesters in developing countries,” *Renewable and sustainable energy reviews*, vol. 34, pp. 387–400, 2014.

[40] K. De Pryck, “Controversial practices: tracing the proceduralization of the IPCC in time and space,” *Glob Policy*, vol. 12, pp. 80–89, 2021.

[41] B. K. Hodge, *Alternative energy systems and applications*. John Wiley & Sons, 2017.

[42] Y. Yang *et al.*, “Progress in coal chemical technologies of China,” *Reviews in Chemical Engineering*, vol. 36, no. 1, pp. 21–66, 2019.

[43] K. Kundu, A. Chatterjee, T. Bhattacharyya, M. Roy, and A. Kaur, “Thermochemical conversion of biomass to bioenergy: a review,” *Prospects of alternative transportation fuels*, pp. 235–268, 2018.

[44] S. M. H. D. Perera, C. Wickramasinghe, B. K. T. Samarasiri, and M. Narayana, “Modeling of thermochemical conversion of waste biomass–a comprehensive review,” *Biofuel Research Journal*, vol. 8, no. 4, pp. 1481–1528, 2021.

[45] A. Faaij, “Modern biomass conversion technologies,” *Mitig Adapt Strateg Glob Chang*, vol. 11, pp. 343–375, 2006.

[46] G. Marrero-Girona and J. H. Vogel, “Can" Monkey Business" Resolve the Most Contentious Issue in the Convention on Biological Diversity?,” *Int J Psychol Stud*, vol. 4, no. 1, p. 55, 2012.

[47] D. Enescu, “Thermoelectric energy harvesting: basic principles and applications,” *Green energy advances*, vol. 1, p. 38, 2019.

[48] J. Twidell, *Renewable energy resources*. Routledge, 2021.

[49] W. E. Glassley, *Geothermal energy: renewable energy and the environment*. CRC press, 2014.

[50] L.-I. Tegou, H. Polatidis, and D. A. Haralambopoulos, “Distributed generation with renewable energy systems: the spatial dimension for an autonomous Grid,” in *47th conference of the European Regional Science Association, ERSA. Paris, France*, 2007, pp. 1731–1744.

[51] L. C. F. A. PUTHOFF, “College”.

[52] W. Liu, C. Liu, P. Gogoi, and Y. Deng, “Overview of biomass conversion to electricity and hydrogen and recent developments in low-temperature electrochemical approaches,” *Engineering*, vol. 6, no. 12, pp. 1351–1363, 2020.

[53] O. Elbaksawi, “Design of photovoltaic system using buck-boost converter based on MPPT with PID controller,” *Universal Journal of Electrical and Electronic Engineering*, vol. 6, no. 5, pp. 314–322, 2019.

[54] irena, “Hydrogen,” *[Online]. Available: https://www.irena.org/costs*, 2022.

[55] H. Gohar Ali, “Maximum Power Point Tracking of Photovoltaic system using Non-Linear Controllers,” 2020.

[56] C. Sharma and A. Jain, “Modeling of Buck Converter Models in MPPT using PID and FLC,” *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 13, no. 4, pp. 1270–1280, 2015.

[57] V. Bagyaveereswaran, G. Petchinathan, and R. Anitha, “PARTICLE SWARM OPTIM CONTROLLER”.

[58] M. J. Hasan and M. Y. Hellan, “Control and Modeling of PSO-PID based MPPT,” *Int J Comput Appl*, vol. 975, p. 8887.

[59] R. A. Shirazi, I. Ahmad, M. Arsalan, and M. Liaquat, “Integral Backstepping based MPPT controller for photo-voltaic system using SEPIC converter,” in *2019 7th International Conference on Control, Mechatronics and Automation (ICCMA)*, IEEE, 2019, pp. 62–67.

[60] T. Lajnef, S. Abid, and A. Ammous, "Modeling, Control, and Simulation of a Solar Hydrogen/Fuel Cell Hybrid Energy System for Grid-Connected Applications.," *Advances in Power Electronics*, 2013.

[61] V. Ram, Infantraj, and S. R. Salkuti, "Modelling and simulation of a hydrogen-based hybrid energy storage system with a switching algorithm," *World Electric Vehicle Journal*, vol. 13, no. 10, p. 188, 2022.

[62] A. Chatterjee, A. Brent, R. Rayudu, and P. Verma, "Microgrids for rural schools: An energy-education accord to curb societal challenges for sustainable rural developments," *International journal of renewable energy development*, vol. 8, no. 3, p. 231, 2019.

[63] R. J. Ackermann and M. Tetenbaum, "High-temperature thermodynamic properties of the thorium-oxygen system.[2400 to 2655/sup 0/K]," Argonne National Lab., IL (USA), 1979.

[64] W. Hunt, P. J. Hay, and W. A. Goddard Iii, "Self-consistent procedures for generalized valence bond wavefunctions. Applications H3, BH, H2O, C2H6, and O2," *J Chem Phys*, vol. 57, no. 2, pp. 738–748, 1972.

[65] M. Santamouris, C. Cartalis, A. Synnefa, and D. Kolokotsa, "On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review," *Energy Build*, vol. 98, pp. 119–124, 2015.

[66] E. J. Piechota and G. J. Meyer, "Introduction to electron transfer: Theoretical foundations and pedagogical examples," *J Chem Educ*, vol. 96, no. 11, pp. 2450–2466, 2019.

[67] A. Diekmann, "The power of reciprocity: Fairness, reciprocity, and stakes in variants of the dictator game," *Journal of conflict resolution*, vol. 48, no. 4, pp. 487–505, 2004.

[68] R. Schlögl, "Chemical energy storage: Part of a systemic solution," in *EPJ Web of Conferences*, EDP Sciences, 2017, p. 00015.

[69] A. Bokulich and N. Oreskes, "Models in geosciences," *Springer handbook of model-based science*, pp. 891–911, 2017.

[70] L. Di Biase *et al.*, "Left atrial appendage isolation in patients with longstanding persistent AF undergoing catheter ablation: BELIEF trial," *J Am Coll Cardiol*, vol. 68, no. 18, pp. 1929–1940, 2016.

[71] D. Gebreselasie, "ELECTRICITY, MAGNETISM, OPTICS AND MODERN PHYSICS." bookboon. com, 2015.

[72] Y. Demirel and Y. Demirel, "Energy Coupling," *Energy: Production, Conversion, Storage, Conservation, and Coupling*, pp. 419–440, 2016.

[73] Y. Huang, S. Rebennack, and Q. P. Zheng, "Techno-economic analysis and optimization models for carbon capture and storage: a survey," *Energy Systems*, vol. 4, no. 4, pp. 315–353, 2013.

[74] W. M. Saslow, *Electricity, magnetism, and light*. Elsevier, 2002.

[75] F. S. Bersani *et al.*, "Deep transcranial magnetic stimulation as a treatment for psychiatric disorders: a comprehensive review," *European Psychiatry*, vol. 28, no. 1, pp. 30–39, 2013.

[76] S. Deshpande, S. C Sajjan, and H. Pujar, "System to Transform Sound Energy into Electricity," in *2nd International Conference on Non-Conventional Energy: Nanotechnology & Nanomaterials for Energy & Environment (ICNNEE)*, 2019.

[77] D. Vélez, "Science for all students: differentiating instruction with FOSS," *FOSS Newsletter*, vol. 18, 2015.

[78] M. Sterner and I. Stadler, *Handbook of energy storage: Demand, technologies, integration*. Springer, 2019.

[79] H. A. Behabtu *et al.*, "A review of energy storage technologies' application potentials in renewable energy sources grid integration," *Sustainability*, vol. 12, no. 24, p. 10511, 2020.

[80] B. Mohammadi-Ivatloo and F. Jabari, *Operation, planning, and analysis of energy storage systems in smart energy hubs*. Springer, 2018.

[81] E. Hossain, H. M. R. Faruque, M. S. H. Sunny, N. Mohammad, and N. Nawar, “A comprehensive review on energy storage systems: Types, comparison, current scenario, applications, barriers, and potential solutions, policies, and future prospects,” *Energies (Basel)*, vol. 13, no. 14, p. 3651, 2020.

[82] H. Mehling, “What is energy, and why is it conserved? A review, analysis, and suggested explanation and definition”.

[83] A. A. Awamleh and M. M. Al-Khayat, “The Reasons of Using Dangerous Drugs in the Jordanian Society:" The Users’ Points of View,” *Jordan Journal of Social Sciences*, vol. 4, no. 2, 2011.

[84] N. Armaroli and V. Balzani, *Powering planet Earth: energy solutions for the future*. John Wiley & Sons, 2012.

[85] E. Arif, J. Hossen, G. R. Murthy, and M. A. Rahaman, “A novel PID controller based solar panel tracking system,” *transfer*, vol. 8, p. 2, 2018.

[86] A. Ma’arif and N. R. Setiawan, “Control of DC motor using integral state feedback and comparison with PID: simulation and arduino implementation,” *Journal of Robotics and Control (JRC)*, vol. 2, no. 5, pp. 456–461, 2021.

[87] R. P. Widarningtyas, “Potential of hydrogen production through alkaline water electrolysis using solar radiation around Semarang,” in *E3S Web of Conferences*, EDP Sciences, 2019, p. 10006.

[88] E. Deniz, “ANN-based MPPT algorithm for solar PMSM drive system fed by direct-connected PV array,” *Neural Comput Appl*, vol. 28, pp. 3061–3072, 2017.

[89] A. Nigam, A. K. Gupta, and S. Sharma, “Analysis between Conventional and Modified P&O Method for Solar PV Cell using MATLAB/SIMULINK,” *MIT International Journal of Electrical and Instrumentation Engineering*, vol. 6, pp. 51–54.

[90] H. Islam *et al.*, “Performance evaluation of maximum power point tracking approaches and photovoltaic systems,” *Energies (Basel)*, vol. 11, no. 2, p. 365, 2018.

[91] R. Hussan, M. Kumari, A. Sarwar, A. Iqbal, M. Tariq, and J. Guziński, "An optimal power point tracking algorithm in a solar PV generation system," *Acta Energetica*, no. 04, pp. 21–32, 2019.

[92] R. K. Sahu and B. Shaw, "Design of solar system by implementing ALO optimized PID based MPPT controller," *Trends in Renewable Energy*, vol. 4, no. 3, pp. 44–55, 2018.

[93] A. S. Hiwale, M. V Patil, and H. Vinchurkar, "An efficient MPPT solar charge controller," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, no. 7, pp. 10505–10511, 2014.

[94] N. Pundir, "Simulation/Modelling of MPPT Charge Controller for Solar Inverter using Matlab".

[95] S. Mohanty, B. Subudhi, and P. K. Ray, "A new MPPT design using grey wolf optimization technique for photovoltaic system under partial shading conditions," *IEEE Trans Sustain Energy*, vol. 7, no. 1, pp. 181–188, 2015.

[96] T. Porselvi, S. R. Y. A. Barathwaj, S. Ganesh, S. V. T. Sangeetha, and J. S. Priya, "Deep Learning Based Predictive Analysis of BLDC Motor Control," in *2022 IEEE 3rd Global Conference for Advancement in Technology (GCAT)*, IEEE, 2022, pp. 1–6.

[97] S. Saon and W. S. Chee, "Development of optimum controller based on MPPT for photovoltaic system during shading condition," *Procedia Eng*, vol. 53, pp. 337–346, 2013.

[98] Z. Jiang, "Feasibility Invetigation of Several Hydrogen Generation & Storage Methods," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 2022, p. 012017.

[99] A. Berastain *et al.*, "Design considerations of solar-driven hydrogen production plants for residential applications," in *ASME Power Conference*, American Society of Mechanical Engineers, 2021, p. V001T09A012.

[100] B. Meena, M. T. Scholar, D. Namdev, and K. GIET, “Improve performance of Solar based Hydrogen Tank Pressure System by Fuzzy Logic Controller”.

[101] S. O. Akansu, Z. Dulger, N. Kahraman, and T. N. Veziroğlu, “Internal combustion engines fueled by natural gas—hydrogen mixtures,” *Int J Hydrogen Energy*, vol. 29, no. 14, pp. 1527–1539, 2004.

[102] M. R. Shaner, H. A. Atwater, N. S. Lewis, and E. W. McFarland, “A comparative technoeconomic analysis of renewable hydrogen production using solar energy,” *Energy Environ Sci*, vol. 9, no. 7, pp. 2354–2371, 2016.

[103] M. M. Elamari, *Optimisation of photovoltaic-powered electrolysis for hydrogen production for a remote area in libya*. The University of Manchester (United Kingdom), 2011.

[104] W. Xiao, W. G. Dunford, P. R. Palmer, and A. Capel, “Application of centered differentiation and steepest descent to maximum power point tracking,” *IEEE Transactions on Industrial Electronics*, vol. 54, no. 5, pp. 2539–2549, 2007.

[105] M. Killi and S. Samanta, “Modified perturb and observe MPPT algorithm for drift avoidance in photovoltaic systems,” *IEEE transactions on Industrial Electronics*, vol. 62, no. 9, pp. 5549–5559, 2015.

[106] D. P. Hohm and M. E. Ropp, “Comparative study of maximum power point tracking algorithms,” *Progress in photovoltaics: Research and Applications*, vol. 11, no. 1, pp. 47–62, 2003.

[107] T. Taa’mneh, O. Ayadi, and J. Al Asfar, “Design of stand-alone proton exchange membrane fuel cell hybrid system under Amman climate,” *Journal of Ecological Engineering*, vol. 20, no. 9, pp. 1–10, 2019.