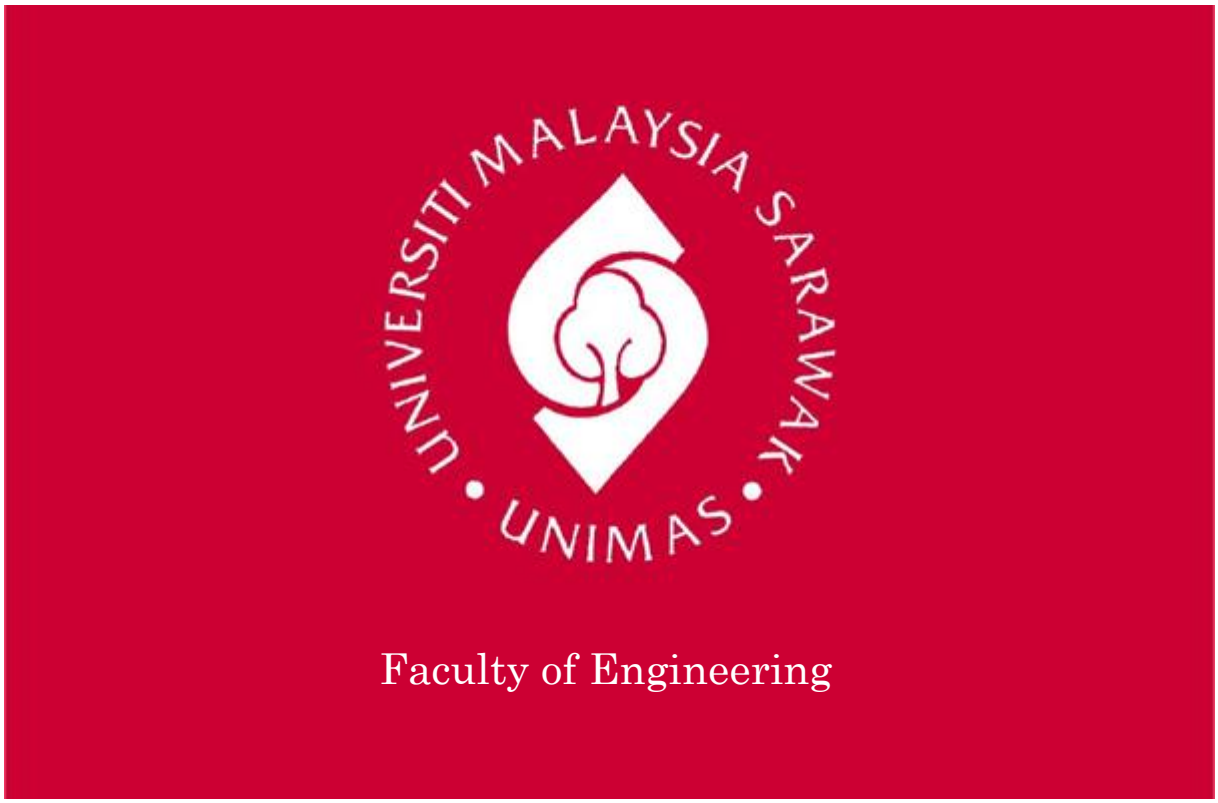

ANALYSIS OF HYBRID SOLAR AND WIND POWER GENERATION SYSTEMS

CHOO CHEE YEAK

Bachelor of Engineering

Electrical and Electronics Engineering with Honours

2023

UNIVERSITI MALAYSIA SARAWAK

Grade: _____

Please tick (√)

Final Year Project Report	√
Masters	
PhD	

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Analysis Of Hybrid Solar And Wind Power Generation Systems

CHOO CHEE YEAK

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering
Electrical and Electronics Engineering with Honours

Faculty of Engineering

Universiti Malaysia Sarawak

2023

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ABSTRACT

In recent past few decades, electricity generation in Malaysia mostly relies on non-renewable or carbon-based energy such as the combustion of fossil fuels and coals. Those sources create the emission of pollutants, especially carbon dioxide that leads to global warming and climate change. As a result, the Earth's mean temperature has increased at an unusual level in these couple of years due to the emission of greenhouse gases. Therefore, renewable energy sources received important concern and attention in the early 2000s century, for instance, the use of solar energy, wind energy, and hydropower are replacing gradually the typical energy source to generate electricity for the consumer. The aim of this project is to analyse the performance of the hybrid system and to optimize the hybrid system up to the maximum output performance of the electricity. Due to inconsistent weather conditions and some uncertainties, renewable energy is harvesting and generating electricity in a hybrid manner. Furthermore, the unstable power distribution is solved by optimizing the output power using relevant mathematical algorithms. For this final year project, instead of using one renewable energy, it is encouraged to switch the power generation into a hybrid manner. A combination of solar and wind energy systems is modelled in this thesis writing. The necessary power converters are included, and different working scenarios are simulated using MATLAB Simulink for the purpose of performance analysis.

ABSTRAK

Dalam beberapa dekad kebelakangan ini, penjanaan elektrik di Malaysia kebanyakannya bergantung pada tenaga yang tidak boleh diperbaharui atau berasaskan karbon seperti pembakaran bahan bakar fosil dan arang batu. Sumber-sumber tersebut mewujudkan pelepasan bahan pencemar, terutama karbon dioksida yang membawa kepada pemanasan global dan perubahan iklim. Akibatnya, suhu rata-rata Bumi telah meningkat pada tahap yang tidak biasa dalam beberapa tahun ini kerana pelepasan gas rumah hijau. Oleh itu, sumber tenaga boleh diperbaharui mendapat perhatian dan perhatian penting pada awal abad 2000-an, misalnya, penggunaan tenaga suria, tenaga angin, dan tenaga hidro menggantikan secara beransur-ansur sumber tenaga khas untuk menjana elektrik bagi pengguna. Tujuan projek ini adalah untuk menganalisis prestasi sistem hibrid dan mengoptimumkan sistem hibrid sehingga prestasi output maksimum elektrik. Oleh kerana keadaan cuaca yang tidak konsisten dan beberapa ketidakpastian, tenaga boleh diperbaharui adalah menuai dan menjana elektrik secara hibrid. Selanjutnya, pengagihan daya yang tidak stabil diselesaikan dengan mengoptimumkan daya output menggunakan algoritma matematik yang relevan. Untuk projek tahun akhir ini, bukannya menggunakan satu tenaga yang boleh diperbaharui, digalakkan untuk menukar penjanaan kuasa menjadi cara hibrid. Gabungan sistem tenaga suria dan angin dimodelkan dalam penulisan tesis ini. Penukar kuasa yang diperlukan disertakan, dan senario kerja yang berbeza disimulasikan menggunakan MATLAB Simulink untuk tujuan analisis prestasi.

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LIST OF ABBREVIATIONS

Notations

OECD	-	Organization of Economic Cooperation and Development
GDP	-	Gross Domestic Product
EIA	-	Energy Information Administration
MPPT	-	Maximum power point tracking
PID	-	Pulse width modulation
NASA	-	National Aeronautics and Space Administration
IPCC	-	Intergovernmental Panel on Climate Change
FLC	-	Fuzzy logic controller
PV	-	Photovoltaic
CSP	-	Concentrated solar power
TWh	-	Terawatt hour
Ibatt	-	Current of battery
AC	-	Alternating current
DC	-	Direct current
Vbatt	-	Voltage of battery
P&O	-	Perturb and Observe
PMSG	-	Permanent magnet synchronous generator
LC	-	Inductor-Capacitor
LMS	-	Least Mean Square
SPWM	-	Sinusoidal Pulse Width Modulation
FLC	-	Fuzzy Logic Controller

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 The development of electricity

The widespread use of electricity has made it one of the most significant technological advances of all time. While it was obviously not necessary for human survival for ages, it is now considered to be an important role in nowadays human life [1]. According to the OECD, there are approximately about 23,387 billion kWh of electricity net consumption by world in year 2018, and in year 2019, it is counted 23,774 billion kWh of electricity consumption that have been used in world communities. As we can observed that there are about 387 billion kWh of electricity amount increase, or about 2% of growing rate of energy demands from 2018 to 2019, in duration of two years. It is expected that by 2050, OECD countries will account for 33 percent of global electricity consumption [2].

Since energy is used in so many stages of the manufacturing and consumption processes, it is undeniably an important contributor to economic expansion. To put it simply, energy is a crucial factor in fostering economic growth. Energy consumption is a physical catalyst for economic activity. The lifeblood of any successful contemporary economy, driving both industrial expansion and productivity gains. Some researchers have found a correlation between increased energy use and higher GDP. Economic expansion was stymied by the energy crises and sky-high energy costs of the 1970s. Numerous researchers have used cutting-edge time series econometric techniques to examine the correlation between energy use and economic growth since the late 1970s. Numerous studies have found that increasing energy usage is strongly correlated with expanding economies. Numerous studies have investigated the relative importance of economic growth and energy use, but the empirical evidence is inconsistent and often contradictory [3].

1.1.2 Energy composition in world

In today world, the energy source can be categorized into many types of sectors, for instance, non-renewable energy sources like fossil fuels, coals, and natural gases, on another hand, the energy that renewable for instance hydropower, wind energy, solar energy, biomass, nuclear energy, and energy from the tidal. With the statistics given by Our World in Data in year 2019, it is investigated that about 63.3% of energy source comes from high-carbon energy, which is non-renewable energy, and about 36.7% comes from low-carbon energy source, which is renewable energy.

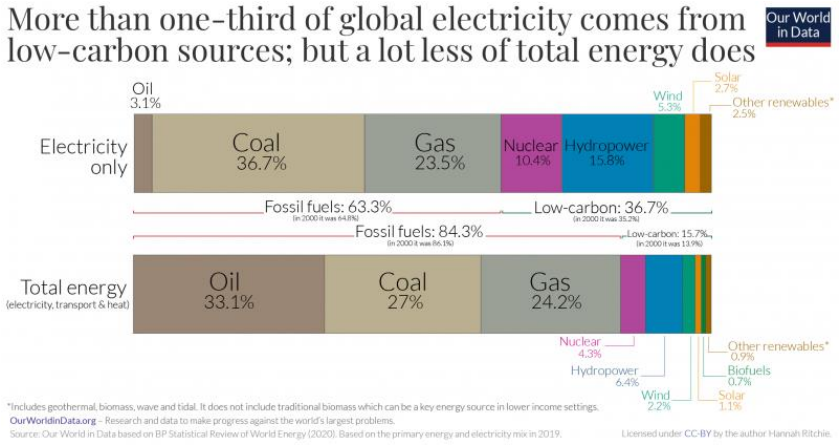

Figure 1.1: Composition of Global Energy used [7]

By referring the Figure 1.1, we can notice that the main source of energy is still relied on fossil fuels, generation of electricity by combustion of fuels, coals, and natural gases. Besides that, we can see that renewable energy contributes about one-third quarter of world energy usage percentage, for example nuclear and hydropower plant supply about 26.2% of electricity to the worldwide communities [7]. By right, renewable energy is encouraged to be increased in electricity generation as it is very crucial to be used, and free from pollution issues. Unlike the non-renewable energy, those kinds of low-carbon resources will not emit any poisonous or unhealthy substances like carbon monoxide, or any carbon substances that will eventually lead to pollution towards the environment.

1.1.3 Malaysia Energy Consumption

The demand for power in Malaysia, which is primarily satisfied by natural gas and coal, continues to increase at a rapid rate. This expansion, along with an insufficient supply of natural gas in high-demand areas, is driving the government to diversify its power generation fuel mix and boost electrical capacity to avoid future power shortages. According to the US EIA,

petroleum and other liquids will account for 37% of Malaysia's total energy consumption in 2019, while natural gas will account for 36%. Coal provides around 21% of the nation's energy needs. The remaining 6% of total power utilized comes from renewable sources. [8]. It is obvious to notice that the usage of non-renewable energy sources is still occupied so much large percentage in the country. For the information, those fossil fuels, coals, and natural gases will be used up by one day in the future. According to a study that was conducted using data from 2015, the following is the current statement of when our supplies would be depleted: oil will be last for 51 years, coals will be last for 114 years, and natural gases will be last for 53 years [9]. Therefore, it is encouraged to have the new renewable technologies to be developed and used widely in the energy generation sector in Malaysia.

To improve the global distribution of sustainable energy, researchers have been putting a lot of time and effort into developing hybrid renewable energy systems. The use of two or more different types of hybrid renewable energy eventually results in benefits for making up for a shortage of electrical energy and providing support for variable renewable energy sources [10]. Therefore, the modelling and analysis of hybrid power generation system must be undergoing and developed, and optimization of suitable system parameter together with the appropriate components design must be planned and analyzed.

1.2 Problem Statement

Previously, we have discussed that the largest amount of energy generation supplies mainly come from non-renewable or high-carbon natural resources, which are coals, fossil fuels, and natural gases. It is generally accepted knowledge that the combustion of fossil fuels has a negative impact on the surrounding environment and is also accountable for the occurrence of climate change and global warming. Furthermore, since it takes billions of years for non-renewable energy sources to originate, they are gradually but surely disappearing from the world [11].

Global emphasis has been focused on hybrid energy systems as a viable option for off-grid places that cannot obtain power from the grid [12]. To ensure that even the most isolated places have access to a reliable source of electricity, a variety of renewable energy technologies, such as standalone solar systems and mini grids, have been installed. On the other hand, many of them do not offer true versatility to the end user or are not viable when they are released. This is typically because there are not enough sales to balance the price of product

replacement as well as running and repair expenses. Most importantly, climate change brought on by the growing of human activities that produce the emissions of greenhouse gases is obviously contributing a widespread impact on the planet's ecology. Therefore, it is more crucial and put in the priority to use renewable technologies in the country.

Despite that, the current renewable energy implementation and installation seems not enough to fulfil society's electricity demands which have the industrial estates, housing area, public service area and so on. For instance, a solar energy is used in somewhere that have quite a number of resident units, it supposedly to produce the amount of electricity based on the design and implementation of solar generation system, however due to the frequent rainy day or cloudy day, the solar panels do not acquire enough sunlight and convert the energy into the required energy amount, due to the shaded of solar panels surfaces and low exposure area to the sunlight. Eventually, the system efficiency will decrease, and it will become not commercial to be applied in the country. Therefore, a hybrid power system must be considered to get the necessary power demands.

Consequently, it is very clear to see that renewable energy should be used widely in today world. We can use these green technologies to reduce the environmental issues and enhance the quality of living atmosphere. To achieve that, one of the recent developments in the sector of renewable energy technology has been the integration of various sources of energy as well as systems for energy storage [14]. The combination of wind power and solar photovoltaics is widely regarded as the most effective hybrid combination of all renewable energy systems. It is also appropriate for most applications when considering the effects of seasonal fluctuations [15].

1.3 Objectives

The objectives of this thesis will be:

1. To construct and simulate a model of hybrid renewable power system which combines solar power and wind power into a generation system.
2. To analyze and evaluate the hybrid system's performance under different input conditions.
3. To perform the optimization algorithm to regulate the power generation system.

1.4 Project Significance

From this final year project, it is expected to construct and simulate a complete, accurate, and non-error hybrid solar and wind power generation system. The combination of several electrical components is necessary to be implemented and designed. Other than that, this project can get the most optimum parameters and data in order to launch and operate this particular system by performing several mathematical operations and coding. From there, better ways of design and optimization of hybrid power system can be done in the future development of renewable power technologies.

1.5 Scope

To achieve the objectives, the project studies will be included that:

1. Modelling and simulation of hybrid solar and wind power generation system using MATLAB 2022a, SIMULINK.
2. Function blocks design, which is MPPT design for solar panels, PWM controller for inverter, and charge controller for battery charging system.
3. Finding the most optimum parameters of the system by designing the features and performing the mathematical operation.
4. Analysis of system performance at different input parameters by considering several cases of scenarios.
5. Implementation and comparison of optimization methods regarding performance.

1.6 Thesis Outline

This paper presents the information about the analysis of hybrid solar and wind power generation system based on the performance, stability, and the optimum operation analysis.

Chapter 1 presents an introduction about this paper including the general information about the renewable energy technologies and development of current energy revolution.

Chapter 2 presents the extensive literature review for the relevant topic. Other works and finding from researchers will be included as a reference and research gap. The first subtopic is identifying the research problem which is the issue regarding the emission of carbon that led

to the global warming. The next topic is introducing and discussing the source of renewable energy sources, in this case especially the solar energy and wind energy. In the third subtopic, the different modelling, simulation, analysis, and optimization of hybrid power system have been discussed. The last chapter will illustrate the research gap between those reference papers.

Chapter 3 presents about the methodology of creating simulation. This chapter will include the modelling of hybrid renewable power system using MATLAB Simulink, parameter settings, mathematical formulas, simulation of single system and hybrid system, procedures, and optimization methods. The system is analyzed with different scenarios and the output parameters like the power, voltage, and current are recorded using different illustrations of data. The figures of the system, settings, and procedures are all included in this section. The optimization methods including Perturb and Observe algorithms and Fuzzy Logic Control algorithms are utilized to apply in MPPT control algorithms for the improvement of output power.

Chapter 4 presents the results and discussion of output waveforms of hybrid power system. The simulation and experiments are repeated by different types of operation scenarios such as solar system operates alone, wind system operates alone, hybrid system operates, and comparison with two distinct mathematical algorithms. The waveforms such as output power, current, voltage, rotor speed, and many more are obtained, analyzed, and discussed in this section. Their efficiency, reliability, and stability are analyzed and discussed in accordance with the system explanation and discussion. Several final decisions on the best options of system configuration, optimization method, and so on are made to fulfill the current requirements of power generation.

Chapter 5 presents the conclusion and recommendations of this thesis. The three objectives were successfully achieved and the best option of the hybrid renewable energy system which combines solar and wind power is configured and optimized. Several future recommendations are discussed to enhance the overall research for this field in the coming future time.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Research related to renewable resources has been pushed forward as a direct result of the ever-increasing awareness of environmental problems and the ongoing depletion of fossil fuels. There are a variety of non-conventional sources of energy that can never be depleted, for example solar, wind, hydro, and these will be the primary focus of the energy industry in the next decades. Therefore, this thesis will draw attention to the modelling of hybrid power generation system, which combines solar energy together with wind energy. For this chapter, several relevant topics will be further clarified and discussed. For instance, the source of energy, the hybrid power configuration, solar system, wind system, method of analysis, and method of power optimization. Photovoltaic energy and wind energy will include solar panels, energy storage, converter, inverter and so on. Furthermore, the method of optimization is also discussed such as the maximum power algorithm, control algorithm, and many more. At the end, an overall summarization will be presented to conclude the current knowledge of studies.

2.2 Global Warming and Climate Change

For the further declaration of global warming and climate change, there are different ways of explanation from various authors or expertise. For the first author, Gale stated that the phrase, which is climate change speaks of the lengthy period variations changes in weather conditions of the Earth, which have an impact on variables such as humidity, temperature, wind direction and speed, cloud cover, and precipitation totals. "Global warming" is the term used to describe the rise in the average Geomorphological temperatures that has been shown to be caused by human activity, most notably the combustion of fossil fuels [17]. Other than that, according to NASA, they point out the Earth's surface over the long term as what has been seen since the pre-industrial era. (in between the year 1850 and, in year 1900) is always linked to Global Warming. This warming was the bad result due to human activities, most notably the

burning of fossil fuels, which results in an increase in the amount of trapped heating gases within the atmosphere. Besides that, they specified that the term "climate change" refers to an alteration in the usual meteorological conditions which already evolved to declare regional, global climate topologies, and local of the Earth over a prolonged period [18].

Based on the previous definition, it is generally accepted in the scientific community that the emissions of greenhouse gases that are created by energy sources that rely on fossil fuels are a contributing factor in climate change and therefore global warming. For this phenomenon, carbon dioxide and the rest of possible pollutants team up within the atmosphere, whereby they take in solar energy that has been reflected off the earth's surface as well as direct sunlight, resulting in global warming. Normally, this radiation would be discharged into space, but because of the pollutants, which may linger in the atmosphere for years or even decades, the heat is trapped, and the planet's temperature continues to rise. A set of pollutants, including carbon dioxide, methane, nitrous oxide, water vapor, and artificial fluorinated gases, are referred to as "greenhouse gases" because they trap heat. The effect that these gases have is known as the greenhouse effect. [19].

The graph in Figure 2.1 below presents a breakdown of world emissions (shown as the black line) in terms of their contribution from fossil fuels (shown in grey line) and land use (shown in yellow line). In recent years, fossil CO2 emissions have represented the bulk of overall world emissions. In 2022, fossil CO2 emissions are expected to account for around 91% of emissions (compared to 9% for land-use emissions). When come into the era and a half into the 20th century, emissions from land use were about equivalent to emissions from fossil fuels. This reflects a significant shift from that time [20].

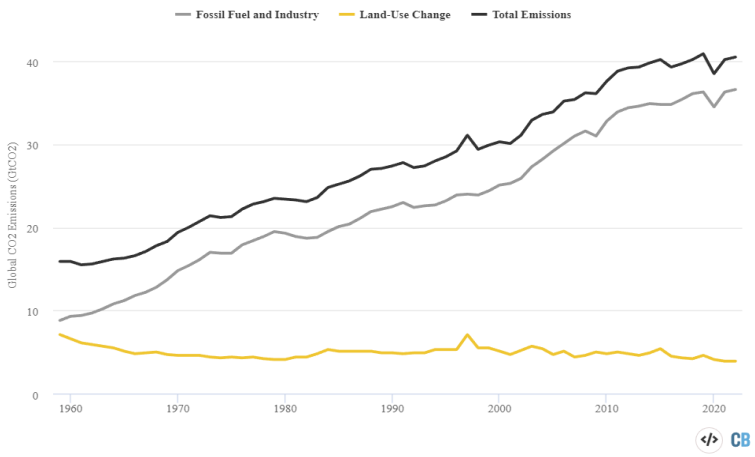

Figure 2.1: Statistic of Global Carbon Emission from year 1960 to 2020 [20]

A modelling examination of the dynamical behavior of global warming was developed and presented by Budzianowski. Hysteresis diagrams of the climate were also included. According to him, the thermal imbalance that now exists on Earth is more likely to amount to 0.6 K, but it has the potential to develop to 5 K by the year 2100 [21].

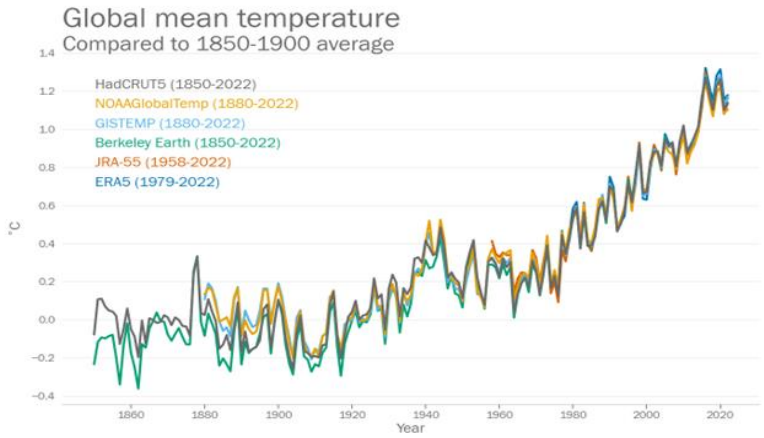

Figure 2.2: Statistics of Global Mean Temperature from year 1860 to 2020 [22]

Based on the statistics given by World Meteorological Organization, Because of growing greenhouse gas concentrations and accumulated heat, the last eight years are on course to be the eight hottest on record. Glaciers in the European Alps suffered an extremely high toll in the year 2022, with first indications of record-breaking melt. It has been raining rather than snowing in Greenland for the first time in September, which coincides with the 26th year in a row that the Greenland ice sheet has shrunk in size. It is now anticipated that the global mean temperature in 2022 will be around 1.15, in more specific data is about 1.02 to 1.28 degrees Celsius higher than the older pre-industrial normal, range from year 1850 to 1900. The occurrence of an unusual triple-dip during La Nia will likely result in 2022 being "just" the fifth or sixth hottest year on record. Despite this, the long-term trend will not be altered, and before another year breaks the record for greatest temperature, it is only a matter of time. Undoubtedly, the warming trend will persist. It is anticipated that the 10-year average temperature for the period of 2013 to 2022 will be around 1.14 degrees Celsius (rises from 1.02 to 1.27) higher than the baseline before industry of 1850-1900. In comparison, the IPCC Sixth Assessment report projected a temperature increase of 1.09 degrees Celsius from the years 2011 to 2020 [22].

As a result of increasing sea levels, the probable future repercussions of global warming continue to be a topic of intense controversy and considerable uncertainty. However, most specialists anticipate catastrophic and severe challenges for future generations. Hurricanes