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Renewable Energy Role in Climate Stabilization and Water Consumption Minimization in Jordan

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Abstract: Climate change is one of the most essential phenomena studied by several researchers in the last few decades. The main reason this phenomenon occurs is greenhouse gases (GHG), chiefly CO2 emissions. About 30% of the created GHG emissions are achieved by electricity generation. This article investigates the role of renewable energy projects in Jordan, specifically wind and solar energy, in mitigating climate change and water consumption reduction using RETScreen software. It was found that the cumulative water consumption reduction from 2017 to 2021 due to the use of wind and solar projects is equal to 6.9491 × 109 gallons. Finally, the results show that the future dependence on renewable energy projects in Jordan to meet the growth in demand by the year 2030 reduces the expected increment in the climate temperature by 1.047 °C by that year.

Keywords: climate change; GHG emissions; CO_2 emissions; renewable energy projects; water consumption

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Citation: Al-Quraan, A.; Darwish, H.; Malkawi, A.M.A. Renewable Energy Role in Climate Stabilization and Water Consumption Minimization in Jordan. *Processes* **2023**, *11*, 2369. https://doi.org/10.3390/pr11082369

Academic Editors: Davide Papurello and Mohan Lal Kolhe

Received: 14 June 2023
Revised: 2 August 2023
Accepted: 4 August 2023
Published: 7 August 2023

1. Introduction

Over the past few decades, scientists have extensively relied on climate models to forecast global climate change. These models illustrated that when the levels of greenhouse gases (GHG), like carbon dioxide, rise in the atmosphere, the corresponding earth's surface temperature, as a result, rises. The justification of this observation is that when the GHG increases in the atmosphere, most fallen solar radiation will be trapped and suppressed. This causes more longwave radiation to be absorbed in the atmosphere. Accordingly, this leads to an increase in the average temperature of the surface where the GHG exists in abundance [1].

Climate change is widely accepted as a scientific fact that requires immediate action to prevent its negative effects, minimize economic damage, and prevent catastrophe and crisis. It is considered one of the most significant issues facing the world as it poses a threat to human survival and future prosperity [2]. Moreover, climate change, directly and indirectly, impacts mental health [3].

These days, the attention of research is oriented toward investigating the effects of climate change on the whole life aspects. However, there is still a lack of agreement on how to transition to low-carbon societies and economies, which is essential for the survival of humanity, avoiding business risk, and promoting economic growth.

Long-term exposure to risks associated with climate change can lead to several issues. Climate change is a widely recognized and discussed problem, both in academic circles and in society as a whole. Recently, the term "climate change" has been frequently used in everyday conversations and research papers. It has been an ongoing issue and has a significant direct or indirect impact on many aspects of human life. As a global problem, climate change has generated significant concern among countries worldwide. This study discusses the topics of climate change, corresponding temperature raising, renewable energy's role in minimizing CO_2 percentage, and water consumption reduction due to the replacement of fossil fuel with renewable energy projects.

1.1. Climate Change Occurrence Due to CO_2 Release

By and large, anthropogenic activities, headed by burning fossil fuels, are causing an increase in carbon dioxide (CO_2) concentration in the atmosphere. CO_2, like other greenhouse gases, absorbs long-wave radiation from the Earth. Consequently, when there is an increase in the concentration of these gases, it results in the trapping of heat waves and leads to an increase in the temperature of the earth [4]. To put it simply, this process is illustrated in Figure 1a.

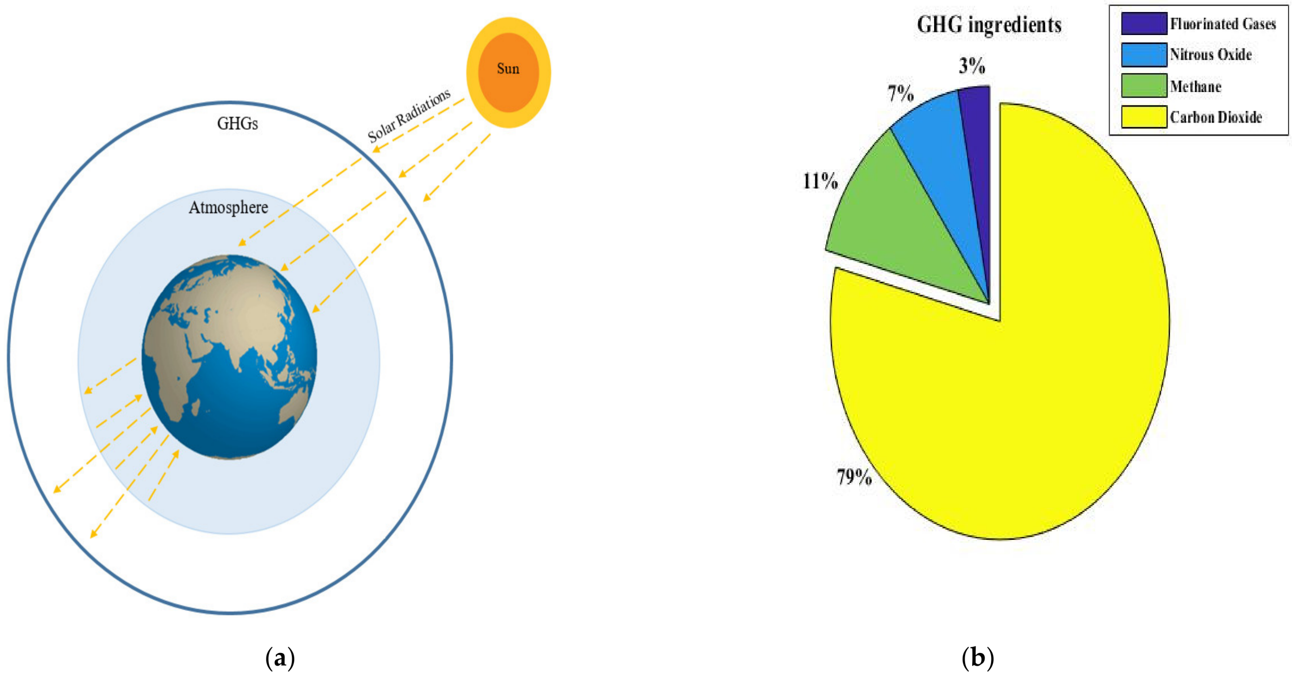


Figure 1. (**a**) Trapping the solar radiation due to the existence of GHG, (**b**) percentages of GHG ingredients.

In addition to the rise in average surface air temperature, scientists predict several other responses due to the increase in the GHG concentration, such as an increase in global mean rates of precipitation and evaporation, rising seas level, and changes in the biosphere. These predictions are based on computer models that simulate basic earth processes. Anyway, the main GHG that has increased during the industrial period are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons CFC-11 ($CC1_3F$), and CFC-12 ($CC1_2F_2$) [5]. Figure 1b clarifies the percentages of these gases among the GHG [6]. These two gases play a significant role in the increase of temperature on Earth [7].

The term "greenhouse" refers to trapping solar radiation in the atmosphere, resulting in higher average temperatures. Among the greenhouse gases, carbon dioxide (CO_2) is the most notable because of its long lifespan in the atmosphere and the large amounts released through human activities. Efforts to reduce these emissions through "climate change mitigation" actions can potentially make a significant impact [8].

1.2. Fossil Fuel Contribution to Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC) Working Group III (WG3), global GHG emissions sources are typically categorized into several sectors such as energy systems, industry, buildings, transport, and AFOLU (agriculture, forestry, and other land uses) [9]. In more detail, the contribution of each sector is clarified in Figure 2 [10].

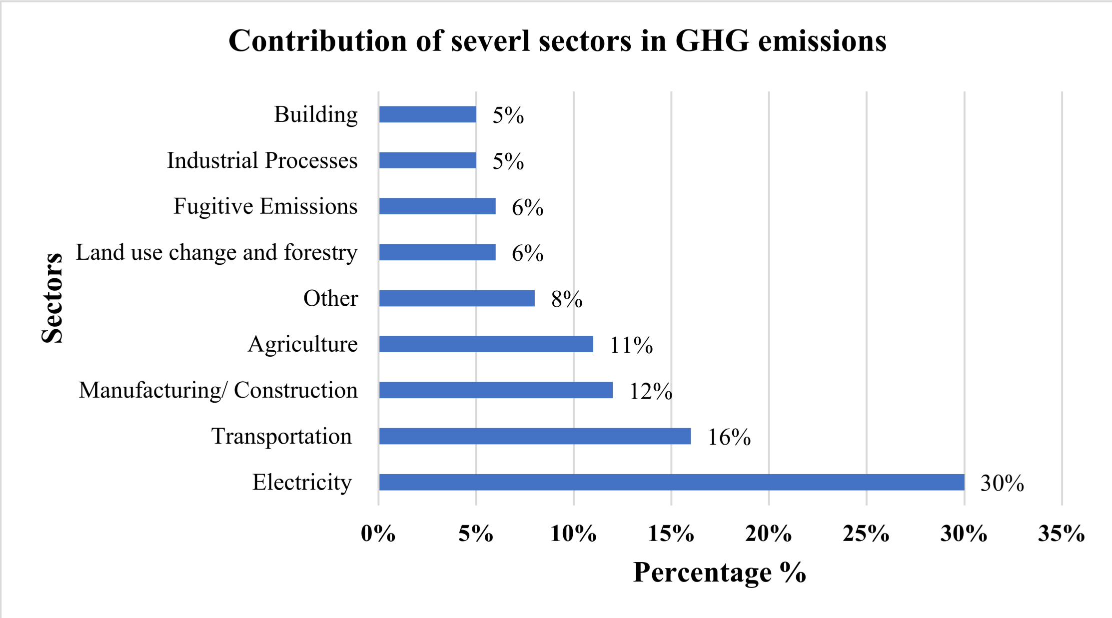


Figure 2. Emissions of GHGs based on each sector.

Electricity is commonly produced by burning fossil fuels that release waste gases, known as combustion products, into the atmosphere. The most significant combustion product is carbon dioxide (CO_2), a colorless and odorless gas. Since the beginning of the industrial revolution, the levels of CO_2 in the Earth's atmosphere have been increasing and are linked to the burning of fossil fuels by humans.

CO_2 absorbs infrared radiation and traps heat, leading to the warming of the atmosphere and disrupting the global climate. This physics is well understood and has been for centuries. The geological record also shows clear examples of past climate changes that are correlated with changes in the concentrations of carbon dioxide and other heat-trapping gases in the atmosphere [8]. Despite some claims to the contrary, the science is clear, the evidence is overwhelming, and the connections are apparent. In Jordan, fossil fuel is the dominant source, headed by natural gas [11], for electricity generation, which jeopardizes the ecological balance and human health due to its harmful impacts.

Global fossil CO_2 emissions have risen steadily since the beginning of the 21st century, primarily due to increased emissions from China, India, and other countries. The COVID-19 pandemic caused a slowdown in the global economy during the first half of 2020, which led to a temporary decrease in global CO_2 emissions, but in 2021, the emissions rebounded. The estimates for 2021 from EDGAR indicated that global human-caused fossil CO_2 emissions increased by 5.3% from 2020, reaching 37.86 Gt CO_2, which is only 0.36% less than the 37.99 Gt CO_2 emissions recorded in 2019 [12].

The burning and use of fossil fuels for energy and transportation have resulted in the release of large amounts of carbon dioxide and methane, significant contributors to greenhouse gases. The increasing emissions from fossil fuels have also led to a rise in average global temperatures of 1.1 °C since preindustrial times. The Intergovernmental Panel on Climate Change has stated that immediate action is necessary to limit global warming to 1.5 °C and prevent severe consequences [13]. Accordingly, based on Figure 2, it can be noticed that electricity contributes to GHG emissions has the largest percentage. Hence, it is necessary to encourage and promote electricity generation from other clean sources. CO_2 emissions due to fossil fuel burning are the major cause of climate change human-induced. Over long periods, these emissions have either risen or lowered over timescales in several countries, Figure 3 depicts several scenarios where in some countries, the emissions were tackled and reduced, while in other countries, the CO_2 emissions are increasing continuously, and in the rest of countries, the CO_2 emissions were reduced then risen again [14,15].

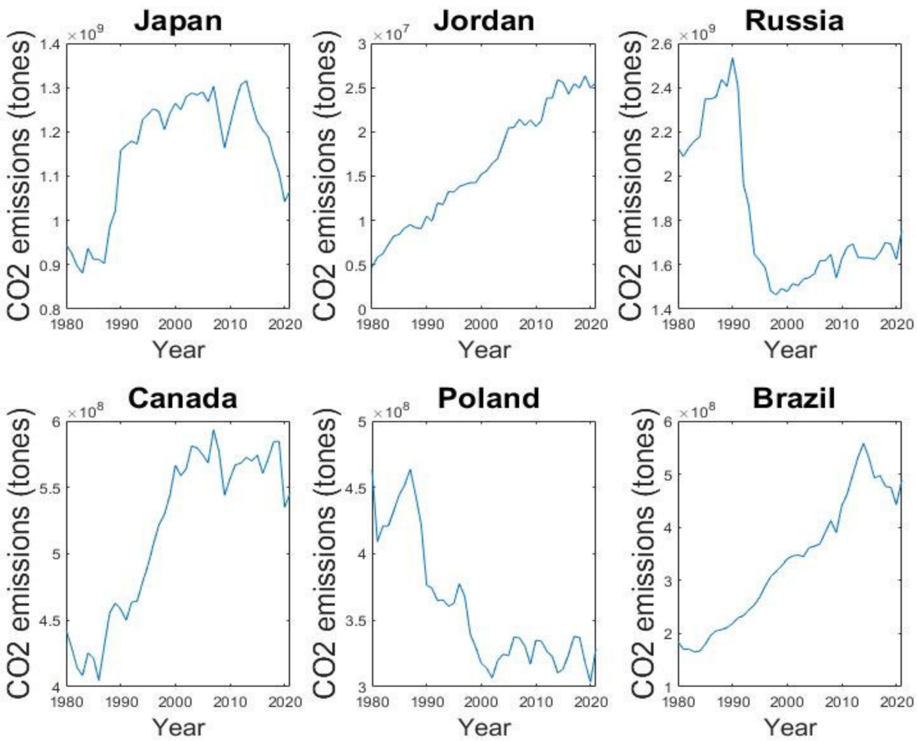


Figure 3. CO_2 emissions in some countries.

Fossil fuels, encompassing coal, oil, and natural gas, have been the predominant energy source for centuries. However, these energy sources entail significant drawbacks concerning the environment, economy, and public health. Consequently, there has been a recent shift towards renewable energy sources. The combustion of fossil fuels emits substantial quantities of carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change and global warming. The repercussions of these transformations are becoming increasingly apparent, including the escalation of sea levels, extreme weather events, and the decline of biodiversity.

Additionally, the extraction, transportation, and combustion of fossil fuels can cause substantial harm to the environment, such as oil spills and air pollution, which detrimentally affect ecosystems and human well-being. Recognizing these adverse impacts, the world is embracing renewable energy alternatives like solar, wind, hydro, and geothermal. These sources present numerous advantages, including cleaner energy production, reduced emissions of GHG, and improved air quality which justify the orientation into renewable energy sources [14,15].

Several recent studies investigated environmental topics from several points of view, which are clarified in Table 1.

Table 1. Summary of some related works.

Ref	Year	Country	Climate Change	Water Issues	Aim	Advantage	Disadvantage	Software/Tool	Used Standard/s	Duration of the Study
[16]	2023	Jordan	✓	✓	This study aimed to assess the possible effects resulting from climate change phenomenon, especially on the water surface ofAmman-Zarqa Basin, Jordan	The proposed model in this study provides the possibility for future estimation based on several scenarios presented in the paper.	• only one iteration was implemented for a validation process. • The future expectation was for a relatively long period since it was for around a century, which is an exaggerated period. • No specific amount of expected increase in CO_2 or temperature was introduced	• Soil Water Assessment Tool model (SWAT), • Coordinated regional climate downscaling experiment (CORDEX)	• The Representative concentration pathways (RCP) 4.5 and RCP 8.5 standards were shown in this study. • Based on Intergovernmental Panel on Climate Change (IPCC): RCP 4.5 means that the emissions of CO_2 will continue to rise and then decline again in the future. RCP 8.5 is classified as a more severe case compared with RCP 4.5 [17]	2018–2100
[18]	2022	Germany, the UK, France, Italy, the USA, China and India	✓	✗	To investigate the behavior of the world, based on empirical analysis, if the goals of the EU that were set for emissions, energy consumption, and some other aspects were achieved	The presented scenario was based on the most polluting countries in the EU, which means that the proposed methodology is based on the worst case	• It depends on Kaya Identity, which suffers from several drawbacks, such as not giving precise outcomes as long as some limitations, as stated in [19,20]	NA	NA	1990–2018
[21]	2022	Canada	✓	✗	Aimed to investigate the role of rural municipalities in planning for climate change risks	The first study that provides a comprehensive assessment of the rural climate change plans in Ontario and Canada more broadly	• Although this study involved about 108 Ontario municipalities, the concentration of it was based on the population organized in descending order. • No details regarding the produced emitted gases, such as: where from the CO_2, were provided.	NA	NA	NA
[22]	2022	China	✗	✓	This study aimed to clarify that China has an interesting plan for water conservation in addition to enhancing the efficiency of water	Based on the implications and lessons of this study, developing countries may have insights to be able to manage water usage, especially in the agriculture sector	• Concentrates on the agriculture sector only in conjunction with the pricing aspect and ignores the rest sectors	NA	NA	NA

Table 1. *Cont.*

Ref	Year	Country	Climate Change	Water Issues	Aim	Advantage	Disadvantage	Software/Tool	Used Standard/s	Duration of the Study
[23]	2023	India	✓	✓	The aim of this study can be summarized by investigating and evaluating the future risks due to climate change	This study is helpful for drought managers, administrations and policymakers since it aids in developing the decision support for efficient drought management	• This study used Bivariate choropleth analysis, which has several disadvantages, as clarified in [24]	NA	• Drought index (MSDI) • SSP2 • RCP	Historical data from 1980 to 2005 to make projections till 2099
[25]	2023	Australia	✓	✗	This study aims to specify the extent that the environmental health officers (EHOs) are involved in climate change plans and health protection plans	This study shed light on some new aspects that are affected by climate change, such as the zoonoses	• This study depends on survey outcomes which have several disadvantages, as depicted in [26]	Qualtrics	NA	NA
[27]	2023	Egypt	✗	✓	The paper aimed to provide the helpful lessons that were learned from a pilot project to enhance the management of stormwater in a reasonable, cost-effective approach	It mentioned two real accidents that occurred due to the heavy rain in Cairo in 2018 and 2020, and based on them, their analysis was conducted	• The contribution of this study concentrates on summarizing the learned lessons from real accidents, but it did not tackle the issue of water scarcity as expected from the title. • Moreover, this study relied on the outcomes which were collected from a survey, and this has several drawbacks, as clarified in [26]	NA	NA	NA
[28]	2023	France	✗	✓	This study aimed to locate the water quality monitoring networks (WQMNs) effectively to enhance the economic value of information (EVOI) which are gathered by the WQMNs	It helped in defining a policy to reduce theagricultural nitrogen, therefore, reaching the desired nitrate at the WQMS	• The study is based on the estimation economic models that were conducted depending on several assumptions regarding ecological damage. • No real data were used, which underestimates the outcomes	NA	NA	NA

Table 1. *Cont.*

Ref	Year	Country	Climate Change	Water Issues	Aim	Advantage	Disadvantage	Software/Tool	Used Standard/s	Duration of the Study
[29]	2022	Japan	✓	✗	This study aimed to test the effects of the manufacturing process for some raw materials, such as copper, on CO_2 emissions and climate change	The proposed methodology showed that the manufacturing process can be still introduced and minimize the CO_2 emissions	• The CO_2 emissions from the manufacturing process may be reduced. On the other hand, the cost of secondary raw materials manufacturing will be increased. Thus, this study tackled the CO_2 emissions issue as a trade-off for the cost issue.	NA	NA	NA
[30]	2023	Egypt	✓	✗	This paper aimed to examine the climate change impact in Egypt and how the Egyptian Government adopted this topic	Several resources were used to conduct this research, which made it dependability one	• Did not investigate the reasons for climate change, such as the increase in some gases, CO_2, instance.	NA	NA	Based on the data collected in the period 1961–2000
[31]	2022	Jordan	✗	✓	This study aimed to assess the energy and Carbon Footprints of the Amman Urban Water Cycle (UWC).	It clarified the contribution of the wastewater based on several scenarios.	• No deep details regarding GHG emissions were introduced	Energy Performance and Carbon Emission Assessment and Monitoring Tool (ECAM 2.2)	NA	NA
[32]	2020	Jordan	✗	✓	This study investigates the current state of Jordan's energy sector, highlighting its primary challenges and future aspirations.	It adds valuable insights to the ongoing discourse on how Jordan can attain environmental, economic, social, and political sustainability in its energy sector.	In the energy policy and strategies section, this paper concentrated on the history of Energy instead of focusing on the nowadays energy policies. Moreover, the absence of effective collaboration and mutual reliance among stakeholders in the energy sector and its associated sectors is evidence of inadequate governance and the untapped potential for harnessing the natural synergies between these industries.	NA	NA	NA

Table 1. *Cont.*

Ref	Year	Country	Climate Change	Water Issues	Aim	Advantage	Disadvantage	Software/Tool	Used Standard/s	Duration of the Study
[33]	2007	Jordan	✗	✓	This study demonstrates the government's adoption of a comprehensive approach to addressing water scarcity, encompassing both water resources planning and management and a strong emphasis on water demand management.	This paper explains the water supply types in Jordan deeply.	Most of the involved tables do not carry references.	NA	Public health standard.	The study forecasted the water resources development until 2020, starting from 2005 (2005, 2010, 2015, and 2020).
[34]	2022	Jordan	✓	✓	This study explores the current state of water security in Jordan and outlines the necessary policies and programs to achieve a more robust and resilient water security situation.	This paper links the water issues with climate change, the most essential topic in Jordan.	This paper investigated several points regarding water issues deeply, except water pollution in a deep manner.	NA	NA	NA
[35]	2017	Jordan	✗	✓	This paper analyzes the key strategies employed by the Jordanian government to regulate well expansion and water abstraction, as well as the corresponding reactions of farmers in the Azraq basin. Furthermore, it documents the recent proactive measures the Ministry of Water and Irrigation took to strengthen law enforcement and exert greater pressure on groundwater users, employing a range of innovative direct and indirect approaches.	This paper also discussed the agriculture sector and how it links with the water situation.	Concentrate on the law and policies without providing any recommendations regarding these laws and how they can be improved.	NA	NA	Based on the data of the world bank in the 1990s
[36]	2019	Jordan	✗	✓	This article addresses the existing research gap by examining the influence of the water scarcity discourse on three instances of transboundary water governance in Jordan: the Yarmouk River, the Jordan River, and the Disi Aquifer.	This study shed light on the reasons that lead to water scarcity	It focuses on the agreement between Jordan and the surrounding countries regarding water cooperation, although the title implies that it will discuss	NVIVO software	NA	NA

In this study, the main contributions based on the gaps of the previous ones, which align in the same field of research, are summarized in the following points:

- This study investigates the amount of the mitigated amount of CO_2 due to producing electricity from wind and solar PV projects in Jordan, accordingly estimating the mitigated rising in temperature.
- The water consumption reduction due to cooling—the free phase in wind and solar PV projects is also discussed.
- Providing a section that clarifies the future situation based on covering the demand for renewable energy projects.

This paper is divided into six major sections starting from the introduction, which provides some knowledge regarding the observed phenomenon, climate change, in addition to providing a table that clarifies a literature survey that consists of the recent studies that investigated (1) climate change phenomenon, (2) water scarcity issues, or (3) both. In the immediate next section, the role of renewable energy sources is visualized, followed by a section that discusses the water consumption reduction in case of replacing the traditional energy sources with clean energy sources. Afterwards, the implemented methodology in this paper is clarified. Next, the obtained results regarding both the temperature rising avoidance estimation and water consumption reduction were involved in the penultimate section. And finally, the last section shows the role of renewable energy sources in the future from both temperature rising avoidance and water consumption reduction, assuming that the demand growth will be covered by wind and PV farms.

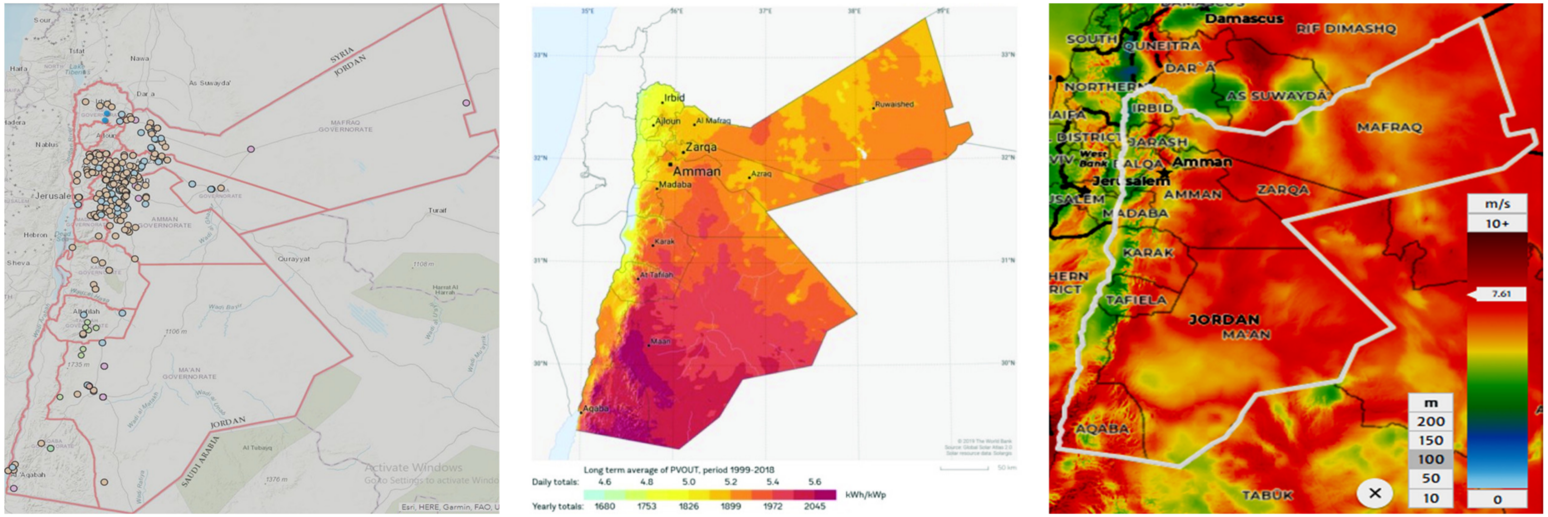
2. Role of Renewable Energy in CO_2 Reduction

This section emphasizes the role of Renewable Energy Technologies (RETs) in reducing GHG emissions, which is a critical subject in addressing climate change. Research has shown that increasing the use of RETs, such as hydropower, solar, wind, biogas, etc. [37], will decrease GHG emissions. Many countries worldwide are placing a significant emphasis on renewable energy sources due to the detrimental effects of GHG emissions from non-renewable energy sources on the environment. Energy generation based on RETs is the backbone of CO_2 emissions reduction, health and environmental complications associated with fossil fuel pollutants [38].

The relationship between renewable energy and climate change is closely linked. Studies have shown that renewable energy can have a positive impact on reducing the effects of climate change. Renewable energy sources decrease carbon emissions in the atmosphere and improve living standards. As such, it is often used as a policy tool to address climate change and plays a vital role in strategies for adapting to it [39].

Around the world, there is a trend toward using renewable energy sources to address environmental problems caused by climate change. RETs have become a common way to adapt to a changing climate and reduce the emissions of greenhouse gases in countries that are both developed and developing [40]. RETs not only help to reduce GHG emissions but also decrease the dependence on natural resources like forests, reduce air pollution, and have a less negative impact on the environment [41].

Jordan is a country with abundant renewable energy sources and an incubator for a wide range of renewable energy projects extending from just a few kW to thousands of kW. Figure 4a shows the distribution of wind and solar PV projects in Jordan [42], which is an evidence that this country gears its policies to expand its inexhaustible energy sources for energy harvesting and generating, accordingly reducing its dependency on fossil fuel. However, Figure 4b,c show the photovoltaic power potential in conjunction with the average wind speed at the height of 100 m in Jordan respectively [43,44].



(a) (b) (c)

Figure 4. (**a**) Distribution of renewable energy project in Jordan, (**b**) photovoltaic power potential in Jordan, and (**c**) mean wind speed in Jordan at a height of 100 m.

By a cursory glance at the previous figures, it is manifest that Jordan owns a lush amount of radiation and wind speed throughout the year, making it a fertile country to implement solar and wind energy projects. Jordan recognizes the prompt need to combat the climate change phenomenon. Therefore, it sets ambitious goals and targets to minimize CO_2 emissions through renewable energy projects development. Hereby, by investing in renewable energy, Jordan is not merely minimizing the cost of electricity generation but also reducing the CO_2 emissions generally caused by burning fossil fuel, as clarified in the previous section.

In recent years, renewable energy uptake in Jordan has been gaining momentum as the nation aims to diversify its energy sources, decrease dependence on imported fossil fuels, and mitigate the environmental impact of conventional energy generation. For instance, Jordan possesses abundant solar resources and has significantly emphasised solar energy as part of its renewable energy initiatives. The country has invested in large-scale solar projects, including the Shams Ma'an Solar Power Plant, one of the largest solar facilities in the Middle East [45]. The government has also introduced policies encouraging installing rooftop solar systems, such as net metering and feed-in tariffs.

Moreover, Jordan is actively exploring the potential of wind energy. The country has established wind farms in areas with favorable wind conditions, such as the Tafila Wind Farm, boasting a capacity of 117 MW. Jordan intends to develop its wind energy sector further and has identified several locations for future wind farm projects. And finally, Jordan has implemented supportive policies and regulations to stimulate investments in renewable energy. Similarly, as stated in [46,47] Jordan was declared one of the top three emerging markets in renewable energy investment in 2018.

It is worth mentioning that even renewable energy technologies emit some CO_2 that is ignorable when compared with fossil fuel. Figure 5 compares the amount of CO_2 emissions from using several types of energy sources, renewable and non-renewable [48]. In other words, renewable energy sources are not totally CO_2 free. Based on Figure 5, it is unequivocal that coal is the worst energy source from CO_2 emissions aspect as it emits an immense amount of tCO_2 per GWh, followed by oil, which stands between coal and natural gas, with a difference of only 153 tCO_2 per GWh lower than that of the coal.

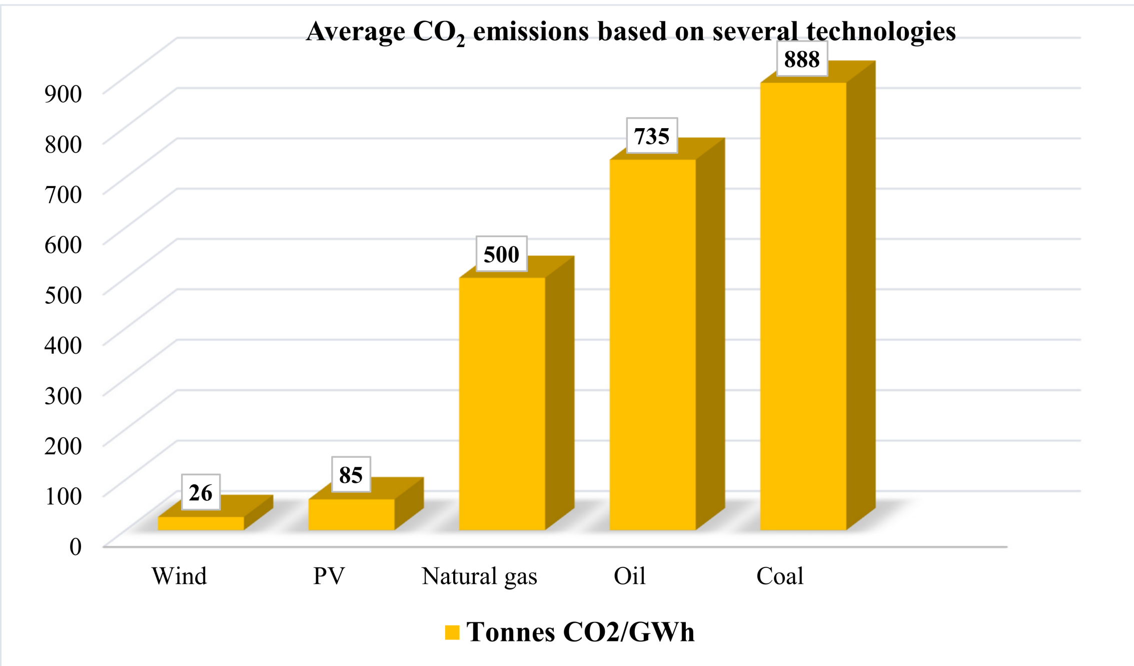


Figure 5. CO_2 emissions are caused by several technologies.

Similarly, regarding natural gas, the prevailing energy source in Jordan, it is plain that it is the inferior type of traditional energy source from a CO_2 emitting point of view compared to the aforementioned traditional energy sources. Even though the consistent usage of these fossil fuel resources devastates and spoils the environment.

On the other hand, the stance of renewable energy sources shows its competent and eco-friendly trends where a plummet of CO_2 emissions per GWh is recorded by generating electricity from renewable energy sources compared with the traditional ones, where solar PV projects and wind projects emit only 0.17 and 0.052 of tCO_2 that is emitted from natural gas respectively.

In the current decade, Jordan promoted renewable energy technology as it relies strongly on energy importing from neighboring countries.

Thus, it is, hitherto, vulnerable and exposed to the fluctuation in global energy prices. The booming of solar and wind energy projects in Jordan can be visualized by understanding the amount of electrical energy purchased by these two renewable sources in Jordan (GWh), as prominent in Figure 6 [49]. Consequently, Jordan made significant efforts to tackle the aforementioned issue, summarized by establishing several RE projects where the contribution of the wind and solar PV projects, combined, in terms of the electrical energy purchased from these two sources, are clarified in Figure 6. In contrast, Figure 7 represents the separate contribution of each type from 2017 to 2021. However, several renewable energy projects were constructed in Jordan, as clarified in Figure 8, in conjunction with their corresponding AC capacities [11,50,51], which is the springboard of this research, and it is worthy to mention that these listed projects are the most known ones in Jordan.

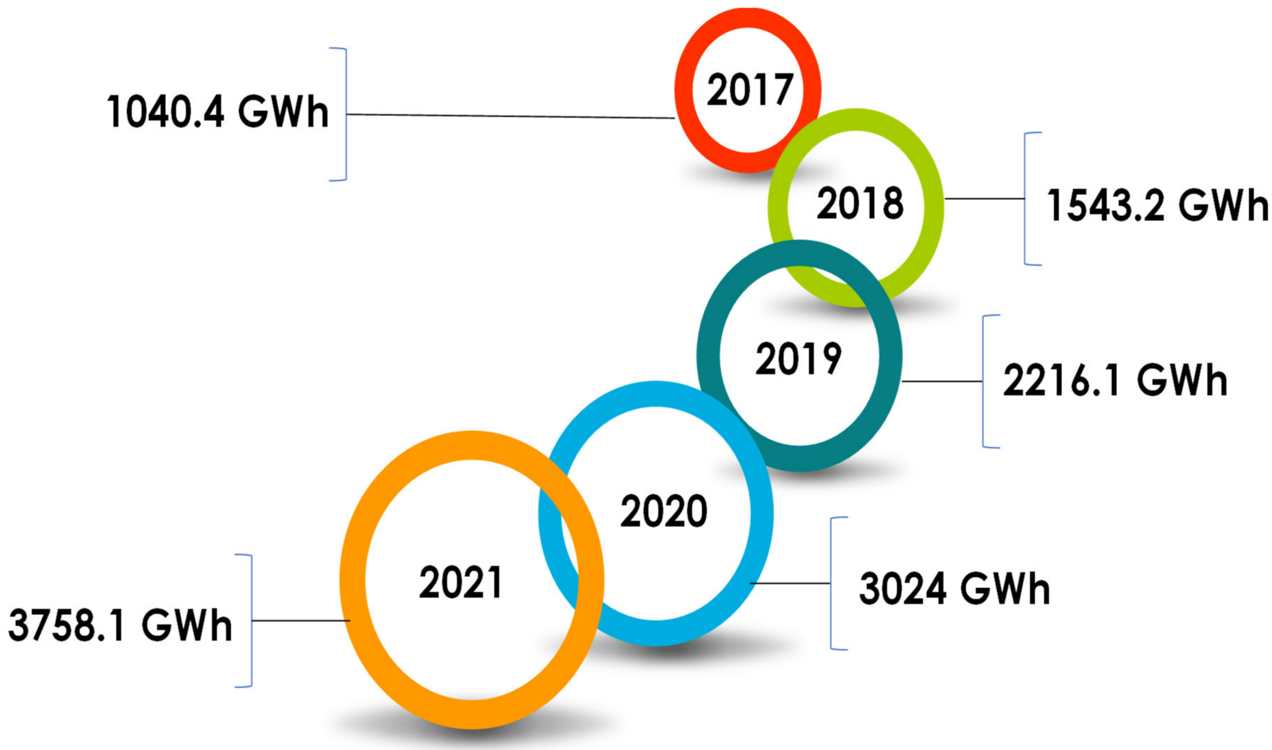


Figure 6. Combined electrical energy purchased from solar and wind energy in Jordan (GWh).

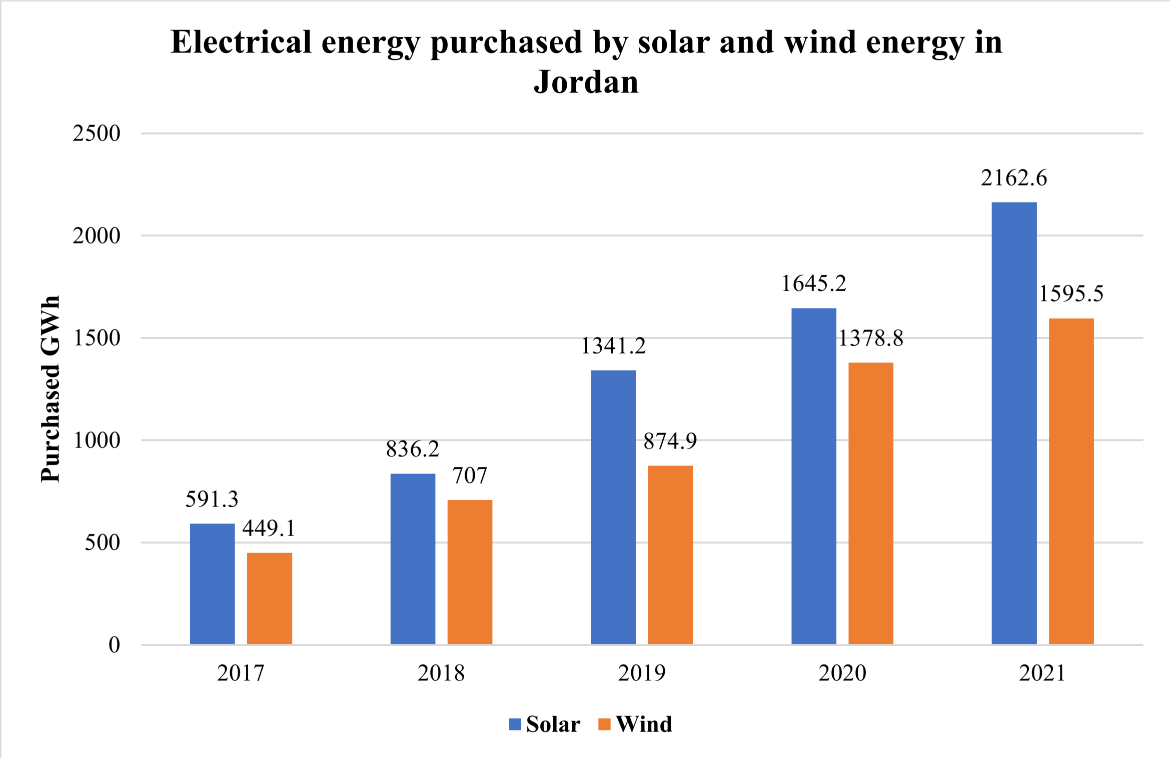


Figure 7. Detailed electrical energy purchased by solar and wind energy in Jordan (GWh).

Jordan possesses a diverse array of renewable energy sources that are utilized for electricity generation and hold the potential to diminish GHG emissions substantially. Adopting these renewable energy sources in Jordan significantly reduces GHG emissions [52]. By replacing traditional fossil fuel-based electricity generation, renewable energy sources aid in mitigating climate change by minimizing the release of carbon dioxide (CO_2) and other GHG into the atmosphere. A study conducted by [32] shows that regarding the advancement of renewable energy resources, the strategic approach highlighted the necessity of implementing a renewable energy law, attracting private sector investments, and establishing a dedicated fund to bolster renewable energy initiatives. The beginning of the "Renewable Energy and Energy Efficiency Law" (RE & EE) in 2012 (Law No. 13 of 2012) marked a significant and indispensable initial stride towards the expansion of renewable energy projects within the kingdom. However, the RE & EE Law lacked clarity regarding the expenses of integrating renewable energy projects into the national grid. It failed to provide a definitive pricing framework for feed-in tariffs.

One of the pivotal findings from [32] emerged from the interviews, wherein participants revealed many conflicts pertaining to Jordan's energy sector, which pose significant challenges to the long-term sustainability of energy security across various dimensions. These conflicts were not discernible by examining policies, governmental reports, or desk research. Notably, all interviewees expressed a collective preference for transitioning towards a future energy composition primarily driven by renewable sources, particularly solar and wind energy, complemented by a requisite proportion of conventional energy sources, namely imported natural gas and domestic oil shale.

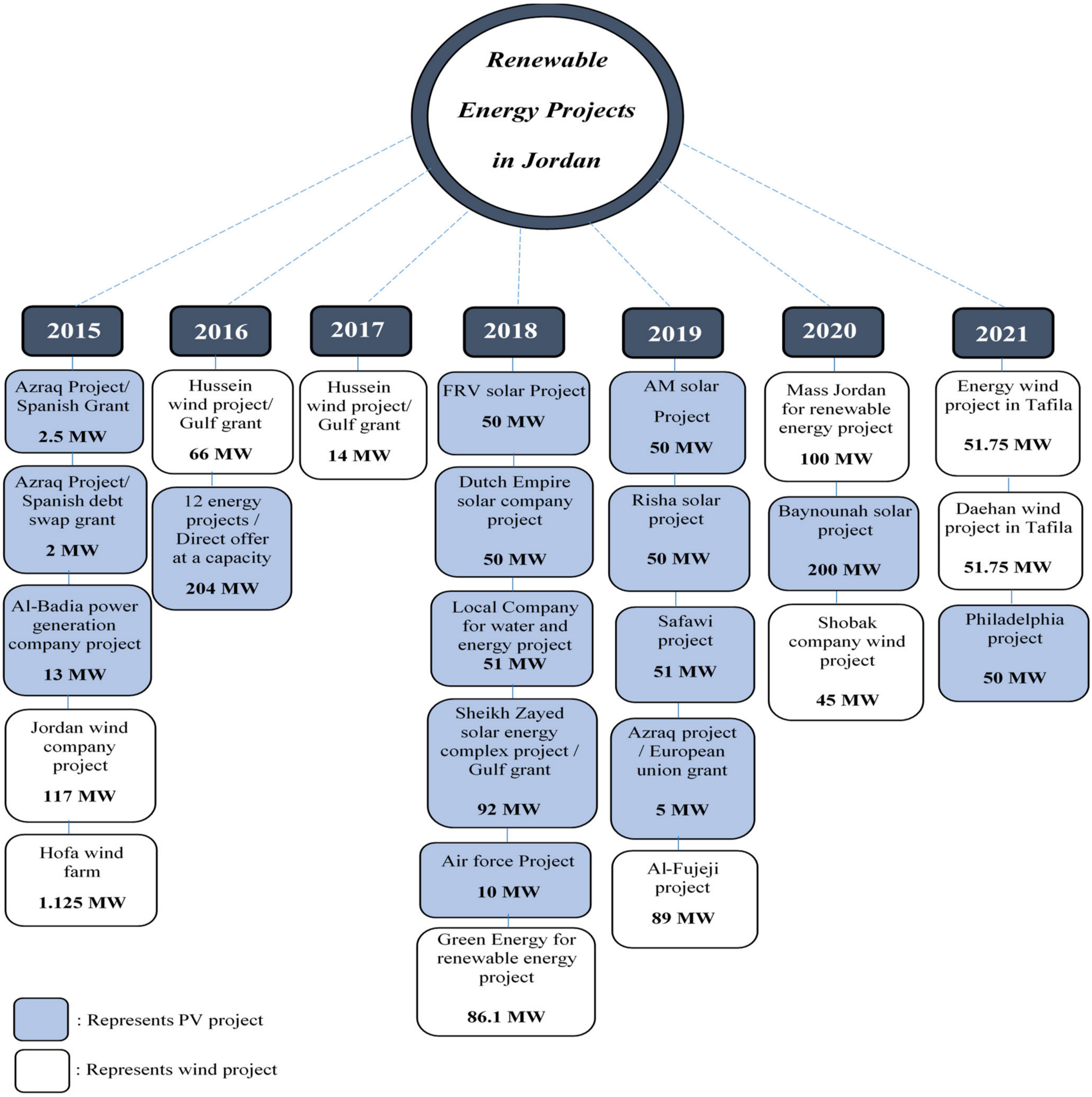


Figure 8. Renewable energy (wind and solar) ventures in Jordan found between 2015 and 2021.

3. Water Consumption Reduction Due to Fossil Fuel Replacement

Water plays a kernel role in electricity generation, and it has been claimed that producing electricity is deemed a bleeding driver of water scarcity and stress in Jordan. The main cause of this situation is due to exacerbated rate of population growth in addition to the climate change phenomenon [53]. Jordan is classified as one of the poorest countries in water resources worldwide. As a result, it meets significant crises and challenges in matching the water demand and the available resources.

The scarcity of water resources is the ultimate challenge that is met nowadays in Jordan since, based on per capita, the assigned quantity of water indicates that Jordan owns the lowest level of water resources globally. Although a few surface water resources are present in Jordan, collectable rain is the major source of water [54]. Unfortunately, the evaporation rate in Jordan, which is clarified in Figure 9, is relatively high, and this decimates water resources [55].

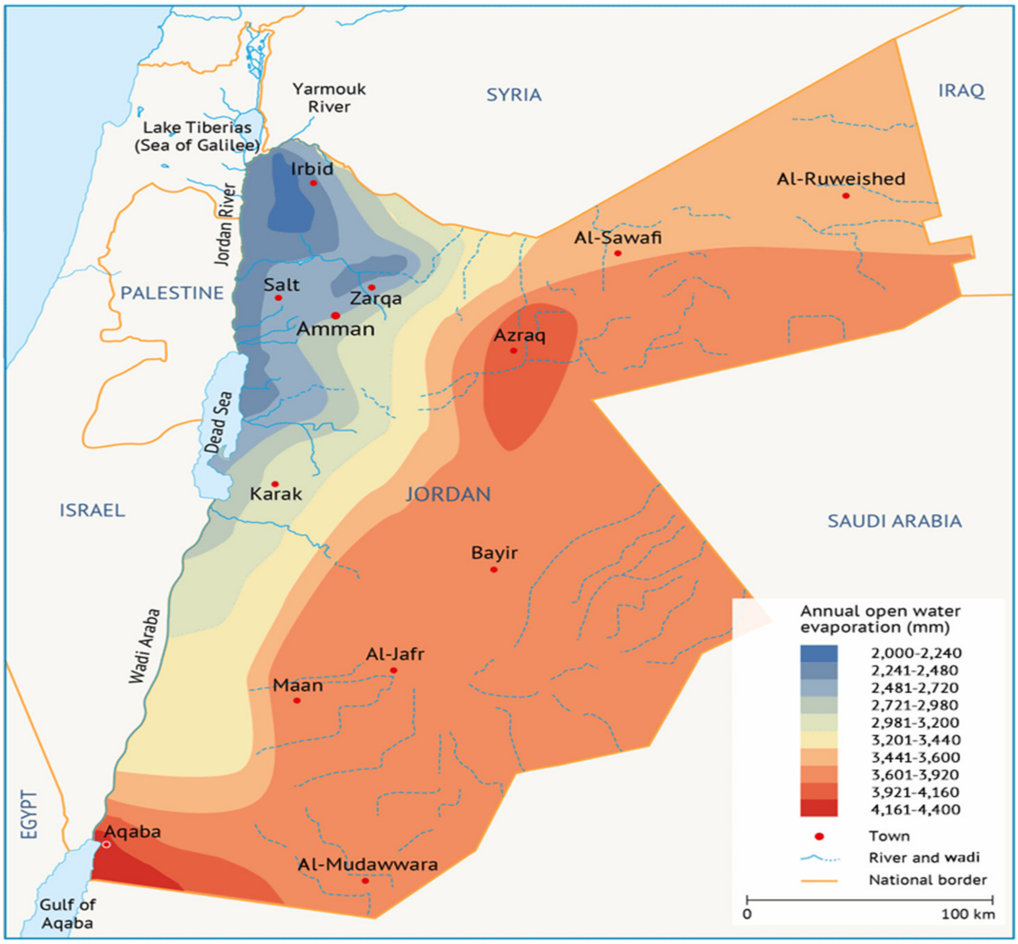


Figure 9. The annual rate of water evaporation in Jordan.

The lion's share of water consumption in Jordan goes to the agriculture sector. However, this sector contributes up to merely 3% of the gross domestic product (GDP), where almost 51% of the water resources go for irrigating purposes [56].

To tackle the water scarcity challenges, the government implemented several measures to manage and conserve water resources. For instance, it promoted improving the irrigation process, conducting research regarding wastewater and desalination treatment plants, and encouraging water-saving technologies. However, despite these put exertion, the unbalance situation of water in Jordan remains in dire need of ongoing efforts from both individuals and governments.

Water policies and strategies in Jordan play a vital role, given the country's limited water resources and growing challenges related to water scarcity. For instance, Jordan faces significant water scarcity challenges due to its limited freshwater resources and rapidly growing population. The country contends with issues such as water scarcity, droughts, and the depletion of groundwater aquifers. Regarding the national water strategy, Jordan has developed a comprehensive National Water Strategy as a roadmap for sustainable water management. The strategy prioritizes increasing water supply, enhancing water efficiency and conservation, and strengthening water governance and institutional frameworks. In response to the scarcity of freshwater resources, Jordan has increasingly explored desalination as an alternative water source. The country has implemented desalination projects, including the Red Sea-Dead Sea Water Conveyance

Project, which aims to desalinate seawater from the Red Sea and provide fresh water to the Dead Sea region [32].

And regarding water demand management, Jordan greatly emphasises water demand management strategies to reduce water consumption. These strategies include promoting water-saving technologies, raising awareness about water conservation practices, and implementing water pricing reforms to encourage efficient water use.

Efficient water usage and addressing water scarcity are significant concerns in the Jordan Valley, particularly agriculture. This region holds significant agricultural importance in Jordan, prompting the government and various organizations to undertake strategies and initiatives to resolve water management challenges in this sector [35]. The formulation of policies, regulations, and projects on water usage in agriculture, including pumping practices, falls under the jurisdiction of the Ministry of Water and Irrigation in Jordan and other relevant government entities. Their objectives encompass the promotion of sustainable water management, the advancement of irrigation techniques, and the enhancement of water-use efficiency within the agricultural domain. For instance, a project carried out by the National Energy Research Centre (NERC), Jordanian Ministry of Environment, Renewable Energy and Energy Efficiency program involved the inefficient electrical and diesel irrigation pumps substituted with Photovoltaic PV solar energy in the Jordan Valley, southern valleys, and highlands (including Azraq, Mafraq, and Madaba). A total of 214 water pumps in the Jordan Valley and southern valleys, as well as 106 pumps in the highlands, are affected by this replacement. The water pumps in the Jordan Valley and Southern Aghuar are responsible for drawing water from irrigation ponds on the farms. These irrigation pumps are supplied with water from the King Abdallah Canal via a pumping station and a gravity inlet owned and operated by the Jordanian Valley Authority (JVA) [57].

Using cooling water in thermal power plants has led to difficulties in managing water resources and determining how to distribute water fairly in various areas recently [58]. Approximately half of the water used in the United States and Western Europe is for energy production, mainly for cooling. In China, the majority of water withdrawals, at 84%, are for thermoelectric power generation, mostly used in coal-fired power plants. Worldwide, around 10% of water withdrawals are used for energy production. Along with cooling, some water is also used in fuel extraction, processing, and transportation for electricity generation [59]. While there is no need for water in renewable energy projects compared with the required amounts in thermal power plants. A massive amount of water is needed in power plants that use natural gas, oil, coal, and other sources. Figure 10 clarifies the average amount of water required by each energy source [60]. A study conducted by [33] stated that Water resources in Jordan can be classified into two main categories: conventional and unconventional. Conventional water sources encompass groundwater, rivers, and streams (including base flow and flood flow), while unconventional resources include treated wastewater, brackish water, and desalinated water. The primary source of water in Jordan is highly variable seasonal rainfall. However, substantial rainfall (exceeding 200 mm/year) is predominantly restricted to the highlands in the country's northwestern region. Approximately 5% of the rainfall infiltrates the ground, replenishing the groundwater aquifers, while a slightly smaller portion transforms into direct flood flow. More than 90% of the annual rainfall is lost through evapotranspiration. Besides local water resources, the contribution from regional watercourses and transboundary groundwater flow significantly adds to the country's renewable water resources.

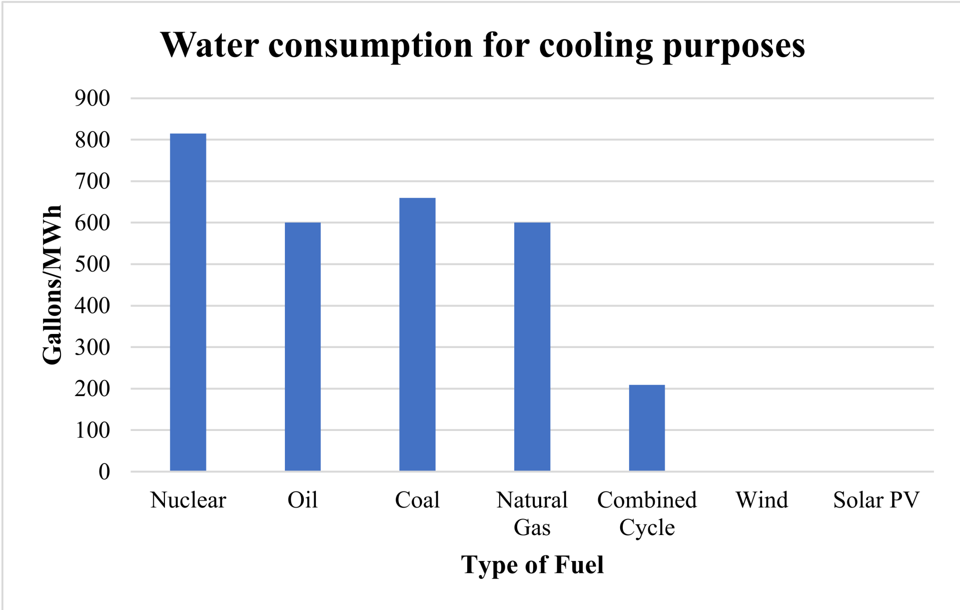


Figure 10. The amount of required water for cooling purposes in power plants.

4. Methodology

The approach of studying the relationship between climate and space-time is an interesting method. It is relatively comprehensive compared to methods that only focus on temperature or precipitation, as it allows for a more complete understanding of spatiotemporal climate patterns. This approach provides a more concrete and relatable understanding of projected future climate instead of just abstract projections. Using this method, it is possible to observe the projected future climate at many locations worldwide, in a different location that currently experiences similar conditions. This research has been carried out by applying eight main steps, represented in Figure 11.

These steps can be summarized by estimating the amounts of CO_2 reduced due to generating electricity from wind and PV technologies since, as mentioned before, the CO_2 emissions from RE projects are much lower than that of fossil fuel sources. The estimation of CO_2 reduction has been carried out with the aid of RETScreen software, as clarified in the following subsection. Afterwards, estimate the temperature is avoided by dint of the mentioned RE projects. The penultimate step is to discuss how these projects contribute to reducing water consumption as they do not require a cooling phase. Finally, the demand in 2030 will certainly increase due to the population increase, and the growth in demand will be assumed to be covered by the RE projects, keeping in mind that the existing traditional power plants will still work in parallel with the RE projects.

In this paper, a particular software has been used to estimate the reduction in CO_2 emissions due to implementing renewable energy projects, RETScreen. The RETScreen software is a promising tool to facilitate the feasibility and pre-feasibility analysis for renewable energy technologies. It is considered the quickest tool to estimate the viability of a potential renewable energy project. Moreover, several aspects are involved within this software, such as evaluating the energy production, life-cycle costs and gas emissions reduction for central-grid, and off-grid projects, ranging in size from large-scale to small-scale systems and for various types of renewable energy technologies. This software is used by several positions, such as funders and lenders, regulators and policymakers, consultants and product suppliers, planners, developers, and owners.

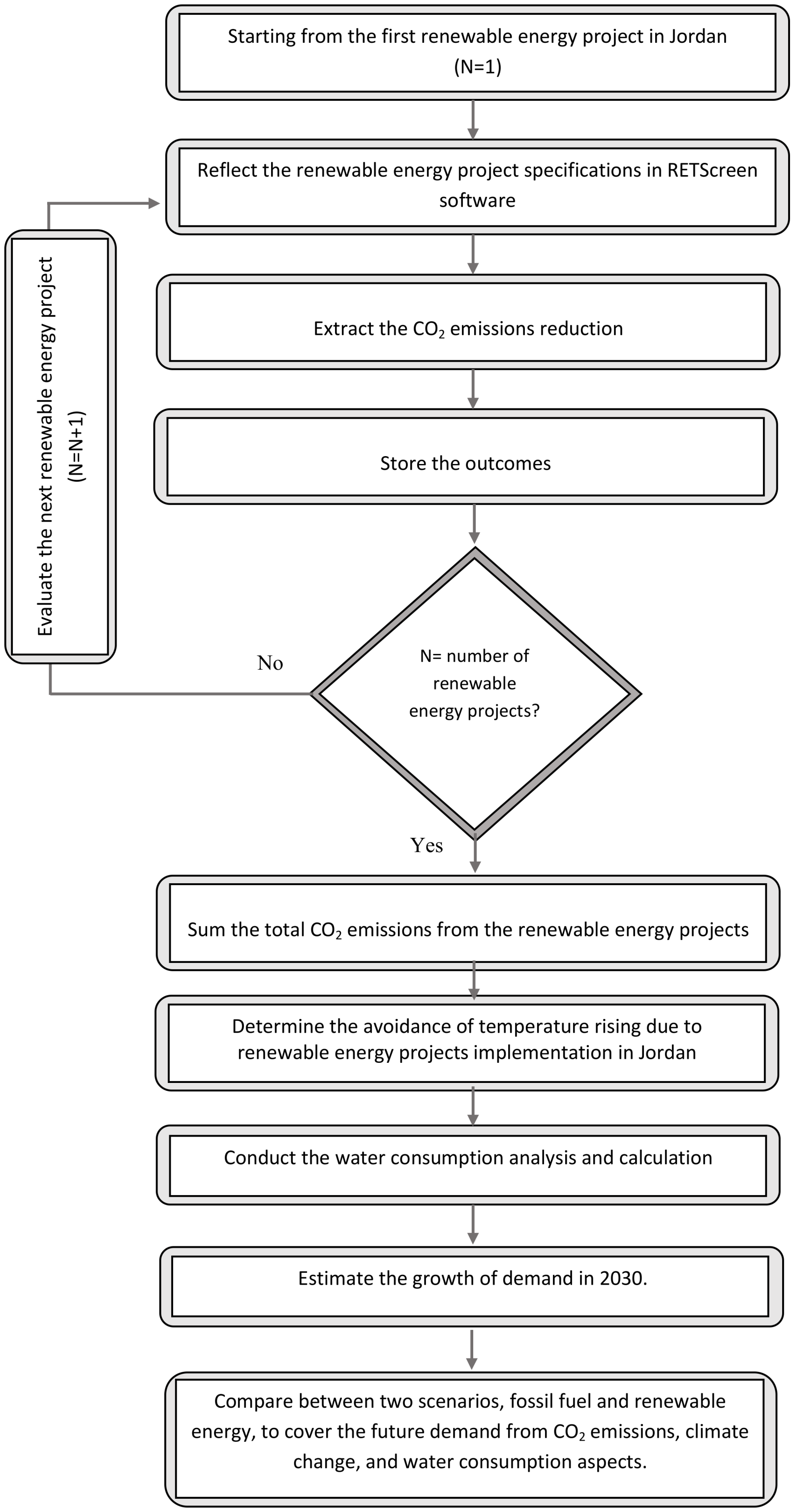


Figure 11. Steps of conducting the research.

RETScreen involves several worksheets (location, Facility, Energy, Cost, Emissions, Finance, Risk, . . . etc.). The attention of this paper is geared toward focusing on CO_2 reduction.

The GHG analysis portion is provided to help the user to estimate the GHG, certainly CO_2 gas, mitigation potential by the candidate project. This optional portion determines the annual reduction in the tCO_2 from using the proposed renewable energy technology instead of the base case technology (fossil fuel).

The tCO_2 emissions reduction potential is found simply by combining the difference of the GHG emission factors with other information determined by RETScreen by its built-in mathematical formulas, such as the annual energy delivered by the proposed project.

The annual tCO_2 emissions reduction is estimated based on the following formula [61]:

$$\Delta_{GHG} = \left(e_{base} - e_{prop}\right) E_{prop} \left(1 - \lambda_{prop}\right) \left(1 - e_{cr}\right) \quad (1)$$

where e_{base} is defined as the base case GHG emission factor, while e_{prop} is the term of the proposed case GHG emission factor, E_{prop} is the proposed case annual electricity produced, λ_{prop} is the fraction of electricity lost in transmission and distribution (T&D) for the proposed project, and finally, e_{cr} is the GHG emission reduction credit transaction fee. The user will not deal will this formula as it is a built-in one. On the other hand, the location of the investigated project, irradiation, wind speed, and the capacity of the proposed system will be considered and transferred into the tCO_2 reduction emissions.

5. Results and Discussion

5.1. Temperature Rising Avoidance Estimation

As mentioned, the RETScreen environment has been used to analyze CO_2 emissions. The tCO_2 reduction is achieved by comparing the energy that can be produced from the renewable energy projects with the base case, where the base case is the generation of electricity by a certain type of traditional energy source (fossil fuel) that the user selects.

For more clarification, the tCO_2 that would be reduced due to energy generation from renewable energy projects will be assumed to be generated using a particular fossil fuel type.

Based on the RETScreen environment, 100 tCO_2 can be translated into several equivalent quantities, which are clarified in Table 2. Accordingly, the outcomes of tCO_2 reduction for the aforementioned wind and solar farms obtained from RETScreen are clarified and reflected in Table 3.

Table 2. Equivalents to 100 tCO_2.

Alternatives	Quantity
Cars and Light trucks not used	18.3
Liters of gasoline not consumed	42,967
Barrels of crude oil not consumed	233
People reducing energy use by 20%	100
Acres of forest absorbing carbon	22.7
Hectares of forest absorbing carbon	9.2
Tons of waste recycled	34.5

However, it is necessary to shed light on a certain point regarding the emissions, where several factors play a major role in achieving minimal CO_2. For instance, more than two projects may have the same capacities but with an uneven amount of reduced CO_2. The justification for this likely observation is the locations of the projects. Assuming two solar PV projects with the same capacities were constructed in two distinct locations, the corresponding emissions for each will not be matched since the solar irradiation in each location has its profile.

Therefore, the corresponding energy to be produced from the two projects will differ, and as a result, the expected emissions will be varied from one project to another. In addition, another factor that affects the productivity of any project is the cleanness of the panels since dust accumulation hinders the conversion process from solar energy into electricity. So, to sum up, projects with the same capacities may not contribute identically from a CO_2 emissions point of view.

Table 3. Reflected tCO_2 emissions equivalents for the investigated wind and PV farms in Jordan.

		Reduced tCO_2	Unused Cars and Light Trucks	Saved Gasoline (L)	Saved Barrels of Crude Oil	People Reducing Energy by 20%	Acres of Forest Absorbing Carbon	Hectares of Forest Absorbing Carbon	Tons of Waste Recycled
Wind ventures	Tafila 117 MW	111,400	20,403	47,865,479	259,070	111,400	25,318	10246	38,414
	Maan66MW +Maan14 MW	139,060	25,469	59,750,211	323,395	139,060	31,605	12,790	47,952
	Fujeji	126,809	23,225	54,486,298	294,905	126,809	28,820	11,663	43,727
	Abour	57,621	10,553	24,758,140	134,002	57,621	13,096	5300	19,869
	Daehan	57,621	10,553	24,758,140	134,002	57,621	13,096	5300	19,869
	Tafila 100 MW	102,185	18,715	43,906,050	237,640	102,185	23,224	9398	35,236
	Shobak	48,801	8938	20,968,431	113,491	48,801	11,091	4488	16,828
	Rajif	109,561	20,066	47,075,312	254,793	109,561	24,900	10,077	37,780
	Hofa	244	44.7	104,840	567	244	55.5	22.4	84.1
Solar PV ventures	Azraq 2.5 MW	1844	338	792,315	4288	1844	419	170	636
	Azraq 2 MW	1475	270	633,766	3430	1475	335	136	509
	Albadia	10,322	1890	4,435,076	24,005	10,322	2346	949	3559
	12 energy projects	150,396	27,545	64,620,975	349,758	150,396	34,181	13,833	51,861
	FRV project	36,862	6751	15,838,575	85,726	36,862	8378	3390	12,711
	Dutch project	36,863	6751	15,839,005	85,728	36,863	8378	3390	12,711
	Local Company	37,599	6886	16,155,244	87,440	37,599	8545	3458	12,965
	Sheikh Zayed project	67,826	12,422	29,142,944	157,735	67,826	15,415	6238	23,388
	AM Project	29,489	5401	12,670,603	68,579	29,489	6702	2712	10,169
	Air force project	7373	1350	3,167,973	17,147	7373	1676	678	2542
	Risha project	36,869	6753	15,841,583	85,742	36,869	8379	3391	12,713
	Safawi project	37,602	6887	16,156,533	87,447	37,602	8546	3458	12,966
	Philadelphia project	43,190	7910	18,557,541	100,442	43,190	9816	3972	14,893
	Baynounah solar project	172,816	31,651	74,254,225	401,898	172,816	39,276	15,895	59,592
	Azraq 5 MW Project	3687	675	1,584,201	8574	3687	838	339	1271
Total yearly tCO_2 reduction = 1427515 = 1.427515 Mt.									

Table 3 shows the equivalents of the estimated reduced amount of tCO2 in terms of cars and Light trucks not used, liters of gasoline not consumed, barrels of crude oil not consumed, people reducing energy use by 20%, acres of forest absorbing carbon, hectares of forest absorbing carbon, tons of waste recycled. The lower amounts of the previously mentioned things, the lower pollution, the lower gas emissions due to the combustion process, and accordingly, the lower climate change observation.

Based on Table 3 and amongst the investigated projects, it is manifest that the expanded Maan wind project and Baynounah solar project stand ahead of the rest. In terms of achieving our goals and making a significant impact, these two projects are rising above all others, proving themselves to be the Titans. In other words, while all the projects were commendable and impressive in their own right, these two aforementioned projects rose above the fray, delivering unparalleled value and impact. Figures 12 and 13 show the tCO_2 reduction from the expanded Maan wind project and Baynounah solar project, respectively.

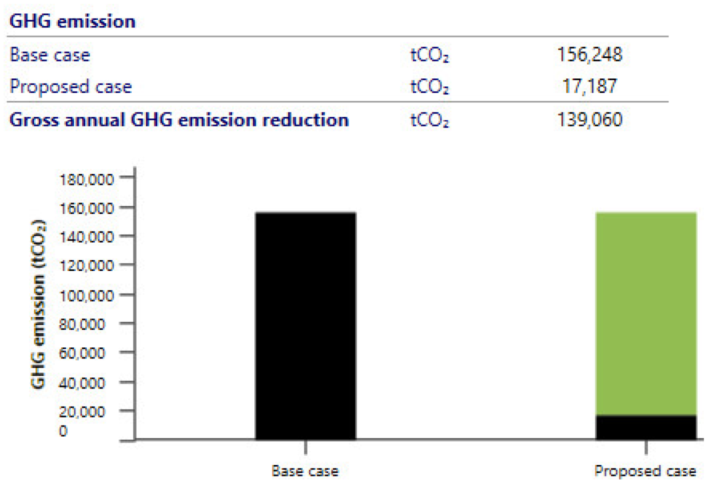


Figure 12. tCO_2 reduction from the expanded Maan wind project.

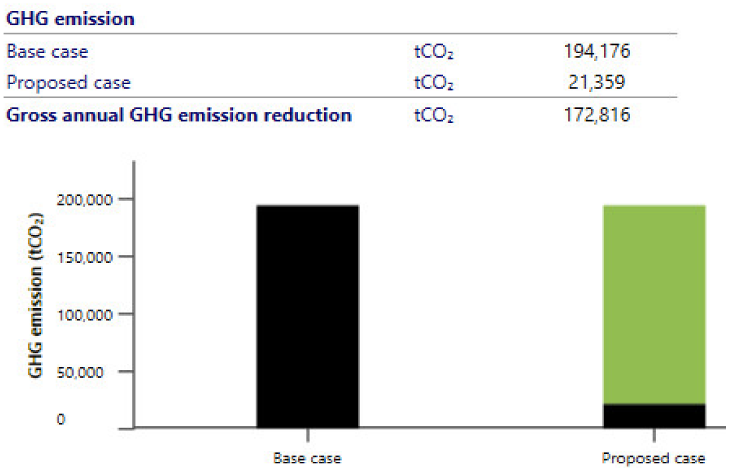


Figure 13. tCO_2 reduction from Baynounah solar project.

As mentioned before, the core of the climate change phenomenon that is met nowadays is the increase in CO_2 emissions due to several activities conducted by several sectors. Based on Table 3, it is plain that the yearly reduction in tCO_2 due to replacing the traditional energy sources by wind projects equals 753,302, while the tCO_2 reduction from PV projects equals 674,213. The overall mitigated carbon dioxide due to renewable energy projects equals 14,27,515 = 1.427,515 Mt. Hereby, to understand the role of renewable energy projects in climate stabilization, the plot of this research lies in assuming that the amount of mitigated CO_2 is not mitigated and produced from fossil fuel for electricity generating.

Table 4 links the average temperature with the corresponding CO_2 emissions during the same year in Jordan. It is worth mentioning that these listed amounts of megatons (Mt) of CO_2 are due to electricity generated from fossil fuels. The aim of linking the temperature with the emitted CO_2 from fossil fuel on the same plot is to estimate an equation that can be used to study to which level the existence of CO_2 affects the temperature rising in Jordan. Figures 14 and 15 clarify the situation of temperature increment, based on the data inserted in Table 4, in case the CO_2 emissions were not controlled. The temperature increases along with time as CO_2 emissions increase continuously. The average temperature and the CO_2 emissions are linked together, where the CO_2 emissions are the causing factor of temperature rising. In other words, the increase in temperature is a function of the CO_2 emissions from fossil fuel burning for electric energy generating purposes.

Table 4. Average temperature [62] and CO_2 emissions in Jordan [63].

Year	Average Temperature °C	CO_2 Emissions (Mt)
1990	18.78	10.087
2005	19.29	20.321
2020	19.92	23.510
2021	20.36	24.297

Furthermore, based on Table 4 it can be noticed that the increment in both CO_2 emissions as well average temperature jumped obviously from 1990 to 2005 as in this period, RETs environment was not existed in Jordan as these days, which justifies the usage of fossil fuel as the main source for energy. While from 2005 to 2020, several renewable energy projects were constructed in Jordan, which contributed to minimizing the CO_2 emissions, where the increase was moderate, as clear in Table 4. Nevertheless, over only one year, from 2020 to 2021, the average temperature and CO_2 emissions increased due to the industrial revolution in conjunction with the increase in the population.

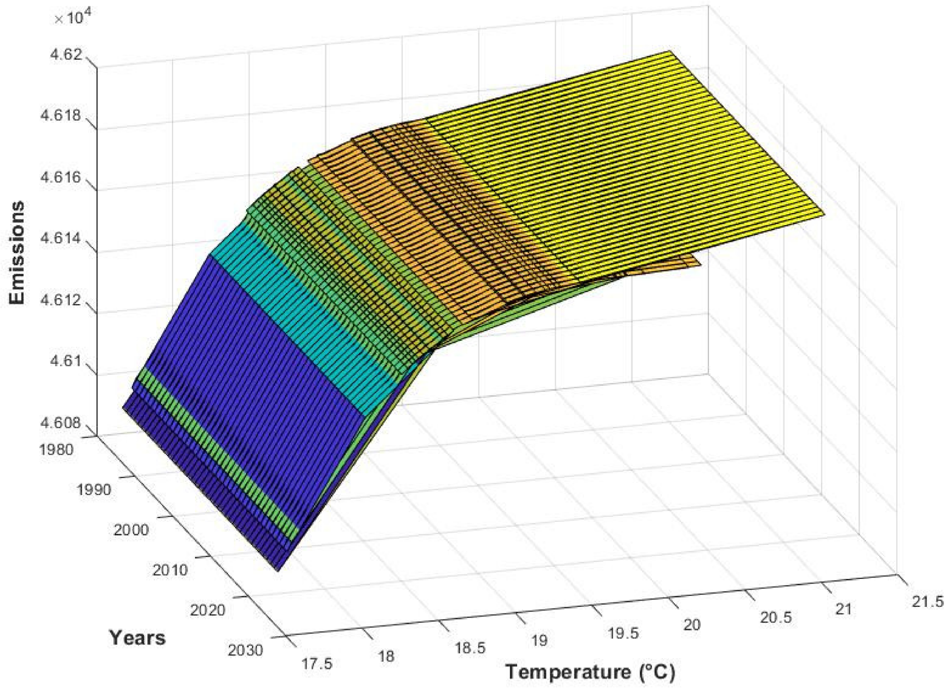


Figure 14. Clarification of how the emissions and the temperature increases with time.

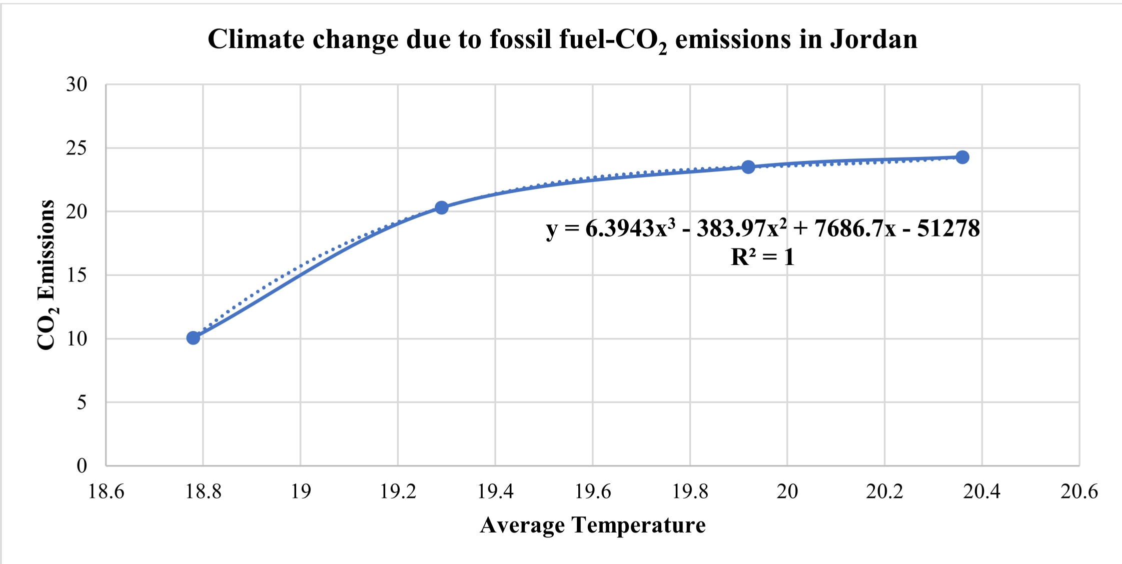


Figure 15. Climate change in Jordan due to CO_2 emissions.

Based on Table 4, it is unequivocal that the produced CO_2 from fossil fuel burning in 2021 is 24.297. However, to investigate the contribution of renewable energy projects in tackling temperature rising, a reduced amount of CO_2 will be added to that produced from burning fossil fuel, as pointed out previously.

The relationship that links the temperature with the CO_2 emissions from fossil fuel, which is the core of this research, is clarified in Equation (2). Consequently, based on the following formula, which is obtained with the aid of Figure 15, the unreal temperature (avoided one) that clarifies the contribution of a renewable energy project can be determined and, accordingly, the difference between the actual temperature, listed in Table 4, and the avoided temperature depicts the effectiveness of renewable energy projects. To achieve the research objective, this process is summarized in merely three steps, as clarified in Figure 16.

$$y = 6.3943\,x^3 - 383.97\,x^2 + 7686.7x - 51278 \quad (2)$$

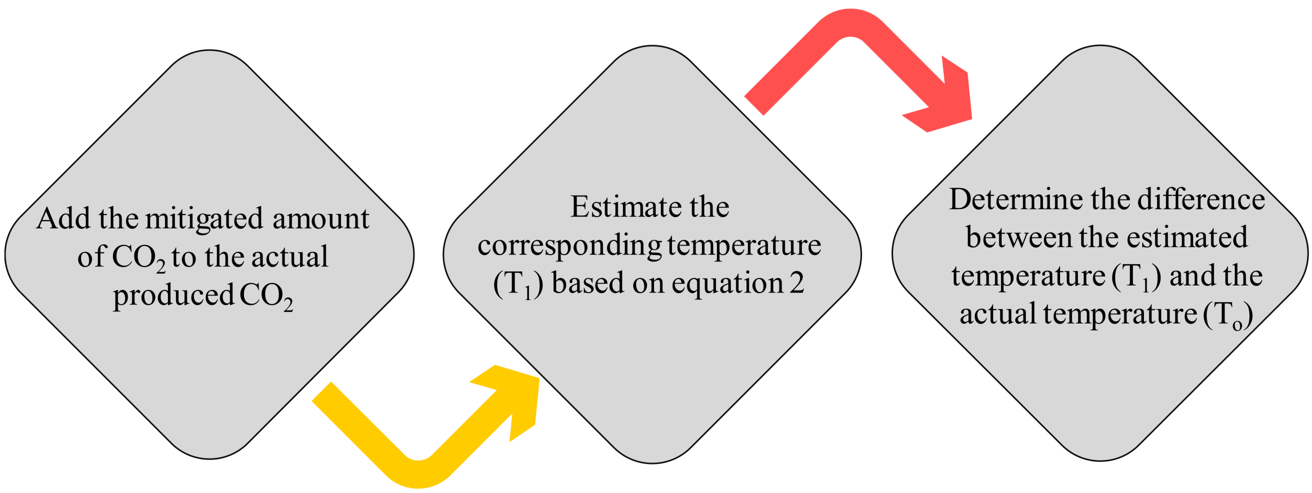


Figure 16. Deep understanding of how renewable energy projects contribute to mitigating temperature rising in Jordan.

Based on Equation (2), it is manifest that the amounts of the tCO_2 produced from burning the fossil fuel for electricity generation purposes in the years 1990, 2005, 2020, and 2021 that are represented in the y-axis are linked with the average temperature in the same mentioned years, which are represented in the *x*-axis. The role of this equation is to estimate the average temperature in 2021 in case of the absence of wind and solar PV projects. Moreover, Equation (2) is a cubic equation where three roots are expected to be found. Only the real number will be considered, while the complex ones will be ignored. And finally, this equation gives an accepted estimation as the coefficient of determination, R^2, which is a statistical measure that indicates how well the equation fits the data points.

According to Equation (2), temperature estimation in the absence of renewable energy projects has been conducted for 2021 since it involves the most recent data. If the produced energy from renewable energy projects were produced from fossil fuel, the CO_2 emissions would have become 24.297 + 1.427515 = 25.724515 Mt, and the correspondence temperature would have been, based on Equation (2), 20.751 °C instead of 20.36 °C for the year 2021. Thus, the existing renewable energy projects mitigate the temperature rising by 0.391 °C each year.

Accordingly, from 2021 to 2030, the operation of renewable energy projects, wind and solar, in Jordan will mitigate an increase in the temperature to 3.9 °C. The obtained value is reasonable and can be justified because of the industrial revolution, where several technologies that depend on electricity emerged. Consequently, the generation of electricity must be increased. As evidence, based on Table 4, it is clear that from 2020 to 2021, the temperature increased significantly. However, the period is only one year, while from 1990 to 2005, the increment in temperature was less than 1° C despite the long period. Moreover, population growth contributes to requiring more electricity to be generated.

5.2. Water Consumption Outcomes

Any met problem can be solved by having a clear understanding of what is the reason for the resultant problem. Similarly, to effectively address water scarcity and manage water governance at all levels, it is essential to have a clear understanding of the underlying causes. This understanding can then be used to develop sustainable, efficient, and effective approaches to integrated water management that foster cooperation, community building, and peaceful resolution of conflicts.

Jordan's water situation is complex and relatively unsustainable, with increasing demand for freshwater exceeding the availability and pollution of surface and groundwater resources. Additionally, Jordan is facing significant challenges with water scarcity and pollution and heavy reliance on importing water through trade [14]. Besides, Jordan is facing a severe water shortage due to its dependence on highly variable annual precipitation, and the potential impact of climate change on freshwater resources is a significant concern as it could exacerbate the existing water scarcity. It is essential to consider the effects of climate change in the management and sustainable use of available water resources [38].

Most of the power plants used for electricity generation in Jordan depend on Natural gas sources, which require 600 gallons/MWh for cooling [15]. Hereby, the quantity of the saved water is determined for the renewable energy projects by assuming that if each renewable energy project is replaced with a traditional power plant with the same production level, how many gallons or m^3 of water will be required, as clarified in Table 5.

Table 5. Quantities of saved water due to renewable energy farms' implementation.

Year	Wind Ventures		PV Ventures	
	Energy Output (MWh)	Water Consumption Reduction (Gallons)	Energy Output (MWh)	Water Consumption Reduction (Gallons)
2017	449,100	269,460,000	591,300	354,780,000
2018	449,100	424,200,000	836,200	501,720,000
2019	874,900	524,940,000	1,341,200	804,720,000
2020	13,78,800	827,280,000	1,645,200	987,120,000
2021	15,95,500	957,300,000	2,162,600	1,297,560,000
Cumulative water consumption reduction from 2017 to 2021 due to wind and solar projects = 6.9491 $\times$ 10^9 gallons				

Based on the previous outcomes, the amount of saved water from the aforementioned renewable energy farms in Jordan equals 6.9491 $\times$ 10^9 gallons. In other words, if the energy produced from the existing renewable projects is produced from traditional energy sources, an amount of water equal to 6.9491 $\times$ 10^9 gallons will be required for cooling purposes in thermal power plants. Thus, the effectiveness of renewable energy projects is proven from both the climate change phenomenon and water consumption points of view. However, one gallon is equivalent to 0.00378541 m^3 [64]. Ergo, the contribution of wind and PV projects in Jordan in water consumption reduction in terms of m^3 is clarified in Figure 17.

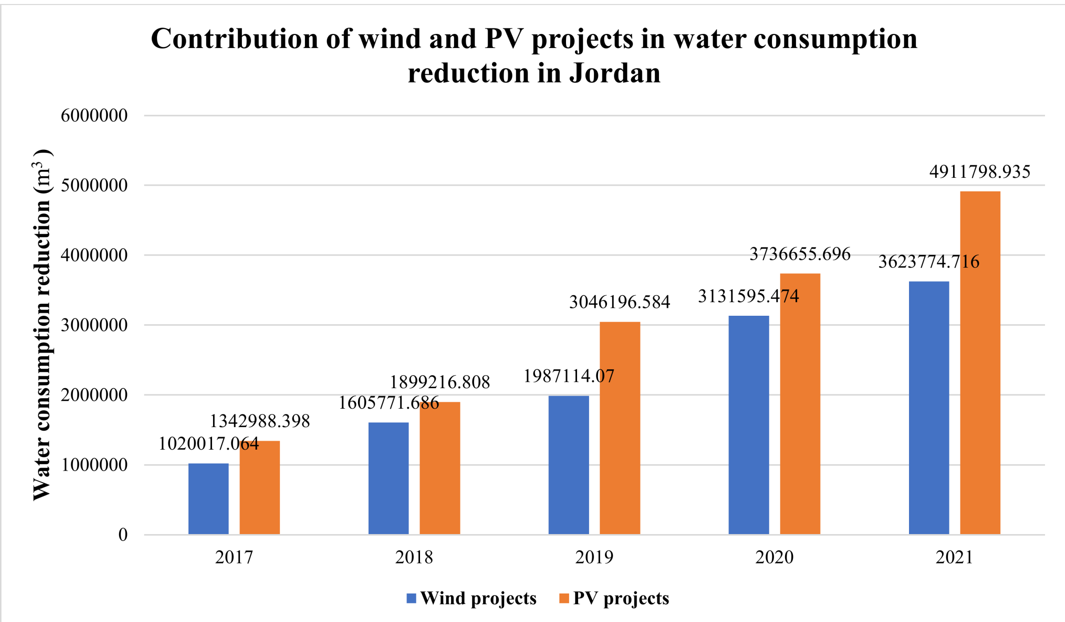


Figure 17. Role of wind and PV projects in Jordan in water consumption reduction.

6. Future Situation Estimation

The population in Jordan in 2030 will be about 11.9 million [65], and the corresponding expected demand for energy (Electrical Energy needed) in the same year is 28,230 GWh [66], while the demand in 2021 has been recorded to be 17,380.17 GWh [67]. Hence, the difference between 2040 and 2021 is 10,849.83 GWh. Table 6 clarifies the number of emissions that will be produced in the absence of renewable energy projects (Scenario 1) and with the existence of renewable energy projects (Scenario 2). However, since natural gas is the most used fuel in Jordan, a comparison has been conducted between generating electricity from natural gas, wind, and PV technologies. Assuming that this demand growth will be covered by the wind with a percentage of 40% and by the PV with a percentage of 60%.

Table 6. Emissions of tone CO_2/GWh.

	Scenario 1	Scenario 2	
Emissions tCO_2	Natural gas 5,424,915	Wind 112,838.232	PV 553,341.33

Thus, the contribution of RE projects in covering the growth of demand in 2030 will appear in producing 666,179.562 $tCO_{2,}$ while covering the increase in demand by natural gas will contribute to emitting 5,424,915 tCO_2. Hence, the reduction in the emissions equals 4,758,735.438 tCO_2 = 4.758735438 Mt. Accordingly. The existing renewable energy projects are reducing the production of CO_2 with an annual amount of 1.427515 Mt, and in the future, if the increase in demand in 2030 is covered by renewable energy projects (40% from wind and 60% from solar PV) an amount of reduction which is equal to 4.758735438 Mt is likely. Hereby, the cumulative decrease in the aforementioned renewable energy projects from 2021 to 2030 is equal to 1.427515 × 10 = of 14.27515 Mt, bearing in mind the likely reduction in 2030 due to covering the difference in demand by the renewable energy projects, which is equal to 4.758735438. Hence, the total reduction in CO_2 emissions in 2030 due to renewable energy projects would be about 19.033885438 Mt.

Referring to Figure 18, which has been plotted based on Table 4, the expected emissions of CO_2 due to fossil fuel burning in 2030 is equal to 28.554 Mt. However, if the covered amount of energy by renewable energy is replaced with fossil fuel, the reduction amount of CO_2 will not be reduced. In other words, instead of having only 28.554 Mt, the reduced amount of CO_2 by renewable energy projects will be added.

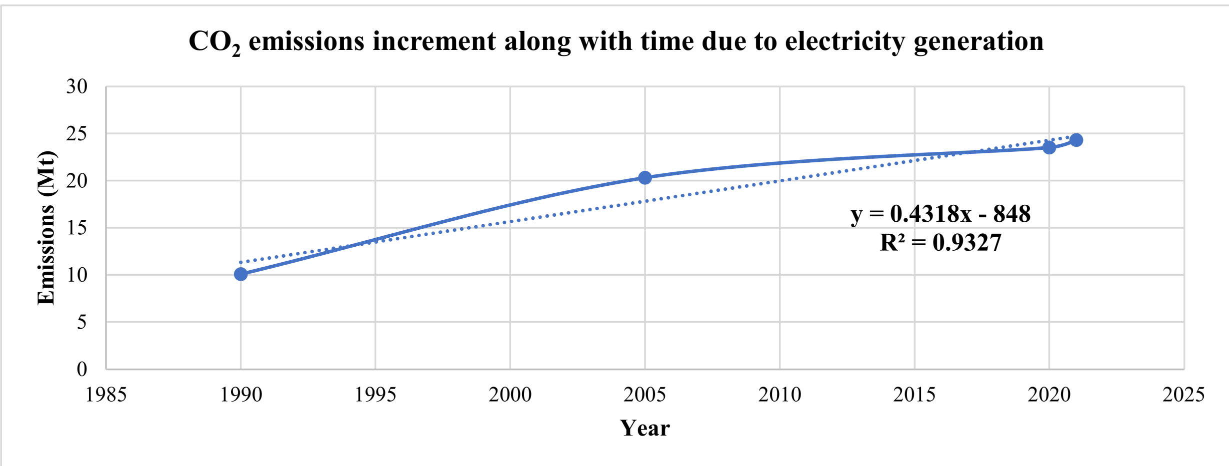


Figure 18. The amount of emitted CO_2 due to generating electricity.

Hence, with the absence of renewable energy projects, the emitted amount of CO_2 in 2030 will be 28.554 Mt + 19.033885438 Mt = 47.587885438 Mt. Accordingly, based on Equation (2), the temperature would be 21.623 °C, but based on Figure 19 that also has been plotted based on Table 4 the temperature in 2030 is expected to be 20.576 °C, which means that if the growth in demand in 2030 is covered by implementing some new renewable energy project in conjunction with the already existing renewable energy projects, an amount of temperature increasing avoidance in 2030 will be equal to 1.047 °C in that year.

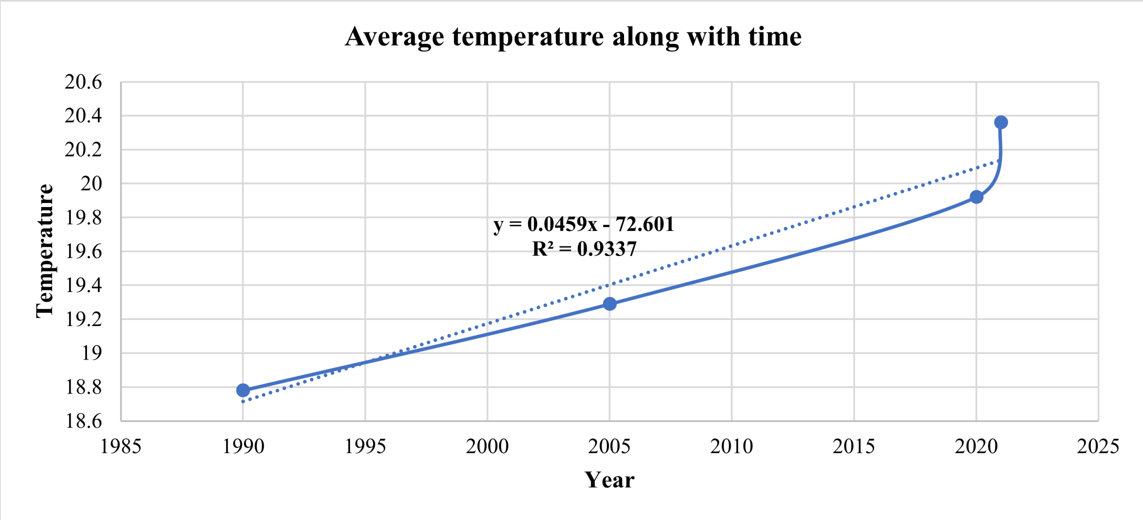


Figure 19. Variation of temperature along with time.

However, regarding the water consumption reduction, it is mentioned how covering the growth in demand by the renewable energy projects in Jordan affects the water consumption situation in Jordan. As mentioned in the previous section, the difference in demand between 2030 and 2021 equals 10,849.83 GWh. If this growth is decided to be covered by natural gas, the most used one in Jordan, an amount of water for cooling purposes will be required that is equal to 6.5×10^9 gallons, while neither in the wind nor in PV technologies, the water will be required. In other words, the amount of saved water will likely be 6.5×10^9 gallons if generating electricity from natural gas is replaced by wind or PV projects.

$$y = 0.4318x - 848 \tag{3}$$

It is manifest that Equation (3) represents a linear equation, which links the amount of CO_2 in Jordan along with the years to estimate the number of emissions in the future. The high R^2 value suggests a strong correlation between the variables, allowing for accurate predictions and further relationship analysis.

$$y = 0.0459x - 72.601 \tag{4}$$

Similarly, Equation (4) links the average temperature in Jordan along with the years to estimate the amount of the expected temperature in the future. As mentioned before, the high R^2 value suggests a strong correlation between the variables, allowing for accurate predictions and further analysis of the relationship.

7. Conclusions

This paper addressed the pressing and multifaceted issue of climate change, a phenomenon arising from the retention of solar irradiation within the atmosphere, primarily due to the presence of various greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons CFC-11 ($CC1_3F$) and CFC-12 ($CC1_2F_2$). The study investigated the significant contributions of wind and photovoltaic (PV) projects in Jordan between 2015 and 2021. In particular, it examined the reduction in CO_2 emissions achieved by replacing conventional power plants, predominantly reliant on natural gas, with renewable energy sources, ensuring equitable capacity comparisons.

The findings revealed that wind and PV farms in Jordan have made substantial strides in reducing CO_2 emissions. When replacing a conventional power plant dependent on natural gas with renewable energy sources, a noteworthy reduction in tCO_2 emissions was observed. Additionally, the study highlighted the water consumption reduction resulting from the transition to wind and solar energy, indicating that 957,300,000 gallons were saved by wind projects and 1,297,560,000 gallons by PV projects in 2021.

To enhance the study's efficacy, a simulation for the future, specifically projecting to the year 2030, was conducted. The simulation assumed that 40% of the growth in energy demand would be met by wind energy, while the remaining 60% would be covered by solar energy instead of fossil fuels. The outcomes demonstrated that such an approach would result in an estimated reduction of 112,838.232 tons of CO_2 emissions from wind energy and 553,341.33 tons from solar energy. Additionally, it was projected that 6.5×109 gallons of water could be conserved if renewable energy were to fulfil the growth in energy demand.

Lastly, the paper presented two scenarios regarding future energy demand growth. The first scenario assumed conventional power plants would meet the demand, while the second scenario considered adopting wind projects to cover 40% of the growth and PV projects to cover 60%. These scenarios underscored the importance of embracing renewable energy sources to address climate change challenges effectively.

Author Contributions: Conceptualization, A.A.-Q. and H.D.; methodology, A.A.-Q. and H.D.; software, H.D.; validation, H.D.; formal analysis, A.A.-Q. and H.D.; investigation, A.A.-Q. and H.D; resources, H.D.; data curation, H.D.; writing—original draft preparation, H.D.; writing—review and editing, A.A.-Q.; visualization, A.A.-Q., A.M.A.M.; supervision, A.A.-Q.; project administration, A.A.-Q.; funding acquisition, A.A.-Q. and A.M.A.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors would like to thank Yarmouk University for the support in this research study.

Conflicts of Interest: The authors declare no conflict of interest.

Symbols and Abbreviations

GHG	Greenhouse gases	tCO_2	Tons of carbon dioxide.
IPCC	Intergovernmental Panel on Climate Change	*Mt*	Megaton
WG3	Working Group III	*MWh*	Megawatt hour
RETs	Renewable Energy Technologies	*GWh*	Gigawatt hour
GDP	Gross Domestic Product	ρ	Air Density
tCO_2	Tons of carbon dioxide.	V	Wind Velocity

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