

University of Bahrain

College of Science



**Department of
Postgraduate Programs**

Assessing the possibilities of adopting solar energy in Bahrain's economic sectors to achieve sustainable development

Thesis submitted in partial fulfillment of the requirement for the degree
of Master in Environment and Sustainable Development

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Abstract

The need to implement renewable energy programs targeted at lowering carbon emissions and reducing reliance on non-renewable energy sources has been underlined in the assumption that they will contribute to the transition to a green economy and achieve sustainable development. The current study seeks to examine the significance of solar energy adoption and demonstrate the necessity of investing in the development of solar energy systems for economic sectors.

The study's methodology is descriptive and analytical, with a comparative approach to studying experiments from leading countries in solar energy and the transition to a green economy. The data acquired is utilized to identify the most essential lessons learned, which the Kingdom of Bahrain may apply to achieve sustainable growth and a green economy.

The study concludes that the Kingdom of Bahrain can incorporate solar energy into its economic sector, considering the advantages it has in terms of location, funds, technology, and resources. The study recommends that the Kingdom consolidate its efforts and invest in solar energy as soon as possible to achieve sustainable development and thereby shift to a green economy in the economic sectors by 2030.

Keywords: Sustainable Development, Renewable Energy, Solar Energy, Economy, Kingdom of Bahrain.

Dedication

To my unwavering support scheme,

This thesis stands as a testament to the power of love, encouragement, and unwavering belief. Without you, this journey would have been a solitary path, fraught with uncertainties. Your constant presence, words of wisdom, and boundless encouragement have fuelled my determination and guided me through the darkest moments.

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Chapter One

Introduction to the Study

Chapter One

Introduction to the Study

1.1 Introduction

Energy is an imperative for every aspect of economic systems. Most of the contemporary economic activity relies on fossil fuels that are not renewable such as coal, natural gas, and petroleum. Renewable sources of energy, such as wind, solar, and hydroelectric energy, nowadays contribute to a mere ten percent of the world's energy output. For ages, a variety of renewable energy sources have been utilized. Most renewable energy sources are scarcer and/or more costly than standard fossil fuels (Abrar et al., 2023).

Renewable energy suppliers are generally costly due to fundamental features such as high capital magnitude, variable availability, and inadequate net energy ratios. Even though new technologies may reduce prices, renewable energy may not be cost-competitive with market rates for fossil fuels anytime soon unless fossil fuel externalities are considered. In the meantime, improved energy use is critical for every country since the use of energy is necessary to lower any government's expenses. Whenever a municipality expands in size, it needs more energy sources to meet its demands. Furthermore, as cities strive to become "smart," green solar and wind energy will be vital to their success (Delgado, M. et al, 2018).

Modernization has necessitated a continuous shift throughout the globe over time, which means that infrastructure must be altered on a regular basis to keep up with demands. As energy prices grew, buildings, transportation networks, and industries would be modified to use less

energy. Rather than introducing new energy sources, a significant portion of the transition to renewable energy will most likely be completed by reorganizing systems to consume less energy. Because energy conservation is optimal when the marginal cost of energy conservation matches the marginal cost of renewable energy, the higher cost of renewable energy would induce this. Solar photovoltaic (SPV) energy is nearly endlessly accessible and has the greatest marginal cost of any energy source (Li J., et al., 2022).

One of the main concerns is how to deal with the transition to renewable energy by declining the energy cost and the losses of energy while it is used. The current fossil-fuel-dominated energy system will eventually be replaced by a combination of conservation and renewable energy sources. When it comes to climate change, it appears that this should be done sooner rather than later. This sort of energy is seen to be the most effective at increasing a country's economic power and investment. Renewable energy is the key to expanding economic growth and opening a new door to the rest of the globe.

Most of the world's countries have an abundance of renewable energy resources; key stakeholders were contacted to develop a broad scope. The scope viewpoint stresses resource capacity as well as high levels of economic competence, benefits, and technological problems. Waste energy, wind energy, and solar energy have all been investigated in this context. Because renewable energy offers enormous observable advantages, the globe is moving toward building renewable energy projects using current resources (Khare, V. et al, 2016).

All these efforts have resulted in a 70% to 80% decline in the cost of solar and wind energy over the previous five years, while the authorities profit from a reduction in the amount of gas used to create power instead of solar and wind energy. Moreover, utilizing solar panels to generate power emits no greenhouse gases into the atmosphere. Furthermore, because the sun provides considerably more energy than mankind can ever need, solar power is a crucial energy source in the transition to sustainable energy production.

The Kingdom of Bahrain 's policy makers recognized that the country's increasing economy, in addition to increased energy consumption and demand, would gradually lead to the depletion of the country's primary energy supplies. There has been a progressive trend toward energy efficiency and the use of alternative energy sources.

The policy approach of the government is based on both international accords, such as the Paris Agreement, the United Nations Sustainable Development Goals (SDGs), and the League of Arab States Guidelines on Energy Efficiency, and local efforts, such as the Economic Vision 2030. Bahrain has developed a target-based approach to climate change policy, building on the wider goals outlined in the accords, with the goal of realizing the country's energy potential while maintaining cost efficiency. Bahrain Vision 2030 encourages investment in technology that reduces thermal emissions and the discovery of sustainable energy sources, such as solar and wind energy, which are considered renewable, pure, and environmentally friendly. From this concept, the Kingdom has worked to put its efforts towards achieving this objective (BTI, 2022).

1.2 Research Questions

The main research questions are:

- (1) What is the potential of solar energy in Bahrain, and can it be used as the country's energy supply is increasing?
- (2) How appropriate is the use of solar energy in terms of economics and ecology?
- (3) Is there any prospect of satisfying an essential part of the economic sector's energy demand with electricity from solar? and,
- (4) What is the role of solar energy in achieving the goals of sustainable development in the Kingdom of Bahrain?

1.3 Research Objectives

The primary purpose of this thesis is to evaluate the solar energy potential in Bahrain and to justify the need to invest in the development of solar energy systems across all economic sectors.

1.4 Study Methodology

The study employs descriptive, analytical, and comparative approaches to investigate the theoretical foundations of the green economy and renewable energy, as well as to evaluate the models of developed and developing countries' experience in the solar energy sector and the current situation of solar energy and the green economy in the Kingdom of Bahrain. Moreover, it evaluates the feasibility of using solar energy in the economic sector, considering the Kingdom's present and future potential. Finally, the study emphasizes the necessity of depending on solar energy

in the Kingdom's economic sector, with proposals that aid in the transition to a green economy and sustainable development.

1.5 Study Division

The current study is divided into five chapters. Chapter one is the study introduction. Chapter two presents theoretical framework and literature review. Chapter three illustrates experiences in the field of solar energy and the green economy. Chapter four shows solar energy and green economy in the Kingdom of Bahrain. Chapter five includes discussion, recommendations, and conclusion.

Chapter Two

Theoretical Framework and Literature Review

Chapter Two

Theoretical Framework and Literature Review

The current chapter discusses the theoretical framework and the most recent empirical studies, these can show as follows:

2.1 Theoretical Framework

The Earth Summit, which was held in Rio de Janeiro, Brazil, in 1992, provided important aspects as well as a strong vision of multilateral mechanisms to achieve a sustainable future (Haines et al., 2012). The same result was reached after thirty years during the "Rio 20" Conference held by the United Nations on Sustainable Development, where it was emphasized that the green economy is a significant method for achieving sustainable development (Azam et al., 2022).

The emergence of the world's disasters during the past years has encouraged investigating the current economic models and tested their ability to increase economic well-being, social equality, and environmental sustainability. (Lightfoot & Burchell, 2004).

Economic activities typically utilize more resources than the planet can produce sustainably. This activity has resulted in negative externalities such as pollution, climate change, natural resource depletion, and ecological degradation, which imperil the Earth's ability to continue producing wealth and ensuring sustainable production and consumption. As a result of these crises, the concept of "green economy" emerged, with the aim of converting the drivers of economic growth to sustainability. It also calls for refocusing public and private investments, as well as national

and international ones, on emerging green sectors and revising unsustainable patterns of production and consumption (Korkmaz, 2022).

The green economy is dependent on the application of policies that consider environmental dimensions and ensure sustainability in the world's main economic sectors. The energy sector, which incorporates improving the energy efficiency of many sectors through the expansion of renewable energy use and increasing its share of the global energy mix, is the most prominent of these industries. (Qin et al., 2021). To attain this objective, more than fifty percent of the funding for the green investment scenario designed by the United Nations Environment Programme (UNEP) has been allocated. (Victor & Jackson, 2012).

This section illustrates the theoretical foundation of renewable energy and the green economy. The thesis will define the green economy, its characteristics, and its challenges, as well as its transitional mechanisms and sources of funding. In addition, it will emphasize the fundamental concepts of renewable energy and its primary sources. It will conclude by analyzing how renewable energy can facilitate sustainable development and a green economy.

2.1.1 Green Economy

The green economy is the consequence of the improvement of the economic situation with the reduction of environmental risks and the scarcity of ecological life, resulting in the improvement of human equality and social welfare (Chen & Golley, 2014).

According to Tian and Lin (2017), the green economy is an economic growth concept based on ecological economic knowledge and sustainable

development. It is a method of creating a community and a clean environment that raises the economic level, propels the community toward a better life, and maintains a balance in the environment from all forms of environmental diversity (Nelson, 1991).

The concept of the green economy, which promotes growth and sustainable development without harming the environment and provides aid and grants to poor countries in order to advance education, health, and infrastructure, thereby achieving justice and equality, emerged in response to the growing environmental pressures caused by various commitments and activities that serve the economy, particularly in the major industrialized nations (Zhang et al., 2022).

The current economic system may contribute to climate change and the current global crises. Current production and consumption patterns result in resource depletion and are partially responsible for a significant amount of environmental degradation, which will have a negative impact on economic growth and long-term sustainability (Sohail et al., 2022).

Shifting towards a green economy may contribute to achieving sustainable development by considering its economic, social, and environmental dimensions. (Abid et al., 2022). Within the context of global interest in transitioning to sustainable development and a green economy, this topic examines the most important concepts and characteristics of a green economy, as well as the obstacles that impede its transition. In addition, the mechanisms of transition to a green economy and its sources of financing will be discussed.

2.1.1.1 The concept and nature of green economy

The world has not yet come to an agreed definition of a green economy (Loiseau et al., 2016). The United Nations Economic Commission for Europe (UNECE) (2013) defines it as *“an economy that improves human well-being and achieves social justice while significantly reducing environmental risks and ecological scarcity”*. The Commission points out that the green economy can be considered a means of linking the economic, social, and environmental dimensions of sustainable development in a way that achieves long-term economic development by investing in everything that is environmentally friendly and achieves social justice (UNECE/FAO, 2013).

Barua (2022) defines the green economy as *“the state of transition to a low-carbon economy characterized by the use of new and renewable energy within the framework of sustainable environmental practices”* (Barua, 2022, p. 371). This means reformulating and directing government policies and investments towards a range of green sectors such as renewable energy, industry, and clean technology. In addition to green buildings, water, sustainable agriculture, and forests, this transformation helps to avoid water, energy, and food crises and reduces environmental pollutants. Besides, it raises the level of competitive productivity in general (Raza et al., 2022).

The above being mentioned, it is to highlight that there isn't yet a unified definition of the green economy. The United Nations Environment Program (UNEP) defines the green economy as "an economy that results in an improvement in human well-being and social equality, while significantly reducing environmental risks and scarcity of ecological resources" (Victor & Jackson, 2012). This is perhaps the most significant of these definitions. According to Xie and Jamaani (2002), the green economy is an economy in which carbon emissions are reduced and the

efficacy of resource use increases, and in which all social groups are accommodated.

There is no doubt that the 1972 Stockholm Conference for Human Development was the catalyst for environmental concern and the emergence of an awareness of the need to protect the ecosystem. The conference resulted in the formation of the United Nations Environment Program and the establishment of a connection between the environment and development. The General Assembly of the United Nations adopted the World Charter for Nature in 1982, and the Charter emphasized the significance of nature conservation and its diversity. In 1987, the General Assembly issued an environmental perspective that addressed sectoral issues such as population and energy, as well as global environmental issues such as biodiversity, security, and the environment. The 1992 Earth Summit Conference resulted in the concept of sustainable development and the requirement to incorporate environmental protection into development pathways. The Framework Convention on Climate Change and the Convention on Biological Diversity were two of the most significant issues addressed at the Earth Summit (Baste & Watson, 2022).

Japan ratified the Kyoto Protocol in 1997. It was predicated on key mechanisms of joint implementation, sustainable development, and emissions trading (Keong, 2021). In 2002, the World Summit on Sustainable Development was convened in Johannesburg, South Africa, where progress barriers and results since the Earth Summit were evaluated (Lightfoot & Burchell, 2004). The 2012 Rio 20 Conference highlighted the importance of the green economy in attaining sustainable development and reducing poverty (Haines et al., 2012).

The green economy plays a crucial role in achieving sustainable development and eradicating poverty, as it entails an interdependence between the economy, society, and the environment, as well as a shift in production and consumption patterns that preserves resources and reduces ecological degradation (Belad, 2022). It also works to generate new employment opportunities, reduce poverty, and attain social justice (Khan et al., 2021).

According to Blowers (2003), the following are the dimensions of sustainable development considering the transition to a green economy:

- A. Economic dimensions: creating new markets, reducing costs, enhancing performance, utilizing renewable energy sources, and promoting sustainable production and consumption patterns.
- B. Social dimensions: Attention to occupational health and safety, to the poor and marginalized classes, and to individuals with special requirements.
- C. Environmental dimensions: disposal of waste and hazardous emissions, control of the impact on human health, use of renewable raw materials, and disposal of toxic substances.

After decades of ecological deterioration due to the adoption of brown economy policies, sustainable development cannot be achieved apart from the green economy, which requires enhancing the living conditions of individuals without increasing the depletion of natural resources. In order to reduce the overuse of resources, production and consumption patterns must become more sustainable.

The green economy is not viewed as a replacement for sustainable development, as attaining sustainability is dependent on economic

transformation. The brown economy model does not account for social and ecological degradation, depletion of resources, or exclusion. To accomplish sustainability, which is a long-term objective, it is necessary to combine all efforts (United Nations Environment Programme, 2021). The implementation of a green economy should be voluntary, and each nation's action plan should be implemented progressively and within a reasonable timeframe (Kumar, 2017).

2.1.1.2 Green Economy Characteristics

The green economy aims to promote sustainable development by adopting peaceful economic policies that preserve the environment and limit its deterioration as a result of climate change, in addition to striving to reduce the effects of poverty, which is increasing in many countries (Pahle et al., 2016).

A number of the characteristics and benefits of the green economy that contribute to the motivation to transition towards it are listed below:

A. Green economy maintains natural capital

The green economy is not solely concerned with determining the value of natural capital as a factor in human welfare (Ducoing, 2019). In fact, it invests in it to attain long-term economic growth. The UNEP Green Investment Scenario model allocates 2% of global GDP (\$1,300 billion) to initiate the transition to a green economy; a quarter of this value is allocated to natural capital sectors, which include forests as well as freshwater and fisheries. Reducing deforestation is economically feasible for the forest sector and supports agriculture and rural livelihoods. The green economy model suggests that devoting approximately 0.03% of the global GDP until

2050 to paying forest proprietors to preserve them and investing in forest restoration could result in a minimum 20% increase in the value of the forest industry. As the world's population is projected to reach nine billion by the year 2050, there is no doubt that the agricultural sector's greening contributes to sustaining the world's population. The green economy model indicates that by investing between 100 and 300 billion dollars annually in green agriculture until 2050, the value added in green agriculture can increase by more than 10%. Lastly, in the water sector, the problem of scarcity can be addressed by implementing regulations that increase investments in the field of water resource and, as a result, enhance its efficiency, whereas the current approach is anticipated to create a gap between water consumption and water resources. According to the green investment scenario, which assumes annual investments between \$100 billion and \$300 billion until 2050, water demand will decrease by 20% as consumption efficiency increases. Greening the fishing industry, on the other hand, necessitates a reorientation of community expenditures in order to increase fisheries management and financing in order to minimize additional capacity by reducing the number of vessels in order to rehabilitate depleted and overfished fish species. According to the green investment scenario, a one-time investment of \$100-300 billion can reduce overcapacity and increase visit fishing from the current 80 million tons per year to 90 million tons per year by 2050, despite the decrease that will occur over the next decade to allow for the recovery of depleted fish populations (Hafner et al., 2021).

B. Green economy leads to poverty reduction

Without depleting the state's natural resources and assets, the green economy aims to provide diverse opportunities for economic development and poverty reduction (Bird et al., 2022). Greening the agricultural sector and concentrating on small farmers is a strategy for reducing poverty, particularly in developing nations (Sovacool, 2019).

The Dubois (2021) study asserts that investing in sanitation services and clean, usable water in developing countries paves the way for the transition to a green economy, as more than 884 million people lack access to clean water, more than 1.1 billion people lack access to sanitation services, and many children die each year due to the lack of access to clean water. In addition, the green economy model demonstrates that investing 0.16 percent of the global GDP annually helps to maintain global water consumption within sustainable limits.

Renewable energy can play a significant role in reducing poverty, particularly energy poverty, as the green economy seeks to provide energy to the 1.6 billion people who lack access to electricity (Dong et al., 2022). According to international estimates, securing universal access to electricity by 2030 will cost approximately \$756 billion (Wirawan & Gultom, 2021).

Ridderstaat et al. (2022) discovered that the development of the tourism sector can also support the local economy and reduce poverty, given that tourism significantly relies on human resources and employs approximately 8% of the global labor force.

C. Green economy creates jobs and supports community equality

Countries transitioning to a green economy are already experiencing extraordinary job creation under current policies, and the potential can be increased by investing more in green sectors (Unay-Gailhard & Bojnec, 2019). In green investment scenarios, such as investments in the buildings, agriculture, forest, and transportation sectors, the long- and short-term employment growth will exceed the current situation. Furthermore, global employment could increase by up to 4% over the next decade (Ge & Zhi, 2016).

The investigation conducted by Bohnenberger (2022) examined the relationship between the green economy and the global GDP. According to the green economy model, investing approximately 1% of the global GDP to increase energy competence will promote the use of renewable energy and lead to the creation of at least 50% more employment in 2050. In addition, it will provide cost-effective energy and reduce carbon emissions. In order to address the irregularities caused by income and population growth, recycling and waste management employment are projected to increase by at least 10% in the green investment scenario, according to the study.

To conserve resources, the employment associated with greening the water and fishing sectors will inevitably alter. According to current trends in exorbitant water consumption, it is anticipated that the water industry will have 20 to 25 percent fewer jobs in 2050 than projected. The greening of the fisheries sector will result in employment losses due to the desire to reduce fishing activity, but some jobs will return to growth by 2050 when fish species are restored (Wang et al., 2022).

D. Green economy replaces fossil energy with clean energy

Increasing the availability of energy from renewable sources and limiting its depletion reduces the likelihood that fossil fuel prices will rise. Two-thirds of global greenhouse gas emissions are currently attributable to the energy sector, and the costs of adaptation associated with climate change are expected to reach between 50 and 170 million dollars by 2030, of which more than half will be borne by developing nations. As importers of petroleum, a number of these nations face challenges resulting from the price of fossil fuels (Ringel et al., 2016). Consequently, investing in renewable energy sources can considerably improve energy security and, by extension, economic and financial security, as well as contribute to the reduction of carbon emissions caused by the use of fossil energy, thereby facilitating the transition to a green economy (Amigues & Moreaux, 2019).

E. Green Economy supports a more sustainable standard of living

Approximately fifty percent of the world's population currently resides in urban areas, which account for seventy-five percent of carbon dioxide emissions (Liu & Dong, 2021).

Fageda et al. (2022) discussed how the trend of urbanization exerts pressure on public health, freshwater resources, and the sanitation system, which typically results in inadequate infrastructure supplies, poor environmental performance, and higher public health fees. Gavrilidis et al. (2022) study highlighted the importance of encouraging green cities as it increases energy efficiency and reduces carbon emissions. Green cities are characterized by abundant facilities for housing, employment, trade, and entertainment and are subject to limits to prevent overcrowding.

Liu et al. (2020) study indicated that the building sector is one of the largest contributors to the world's emissions, with the equivalent of 8.6 billion tons of carbon dioxide, due to the fact that one-third of the final use of global energy occurs inside buildings. Therefore, the construction industry is responsible for at least one-third of global resource consumption and twelve percent of total fresh water consumption. In addition, the sector contributes approximately 40% to the generation of solid waste, as it is anticipated that the environmental footprint of the construction sector will increase to 15.6 billion tons of carbon dioxide by 2030, accounting for approximately 30% of total energy-related carbon emissions.

The study by Guo et al. (2022) discussed how the construction of new green housing and the development of existing buildings that consume a great deal of energy and resources can result in substantial energy savings, as investments of between 300 and 1,000 billion dollars per year until 2050 can result in a global energy savings of nearly one-third.

Working towards greening the building sector can also lead to enhancing productivity in the use of water, land, and materials, as well as reducing waste (Jiang & Payne, 2019).

Yao et al. (2021) claimed that the transportation sector is responsible for half of the world's consumption of liquid fossil fuels and 25% of the world's energy-related carbon releases.

The green economy model shows that investing 0.34% of global GDP annually until 2050 in the transport sector can lead to minimizing petroleum-based fuels by 80% while increasing employment by 10% (Aminzadegan et al., 2022).

Sikder et al. (2022) study indicated that the related social and environmental costs, such as air pollutants, accidents, and accumulation, are estimated at 10% of GDP, which is more than the funding needed to pave the transition towards a green economy.

F. Green Economy maintains sustainability of natural resources

According to the study by Liang et al. (2022), the green investment scenario provides long-term growth from 2011 to 2050 and helps to prevent significant negative risks, such as the effects of climate change, increased water scarcity, and the loss of ecosystem services. Increasing scarcity of energy and natural resources will constrain global economic growth under the current approach, whereas the green investment scenario obtains higher annual growth rates over time, as shown graphically in Figure 1.

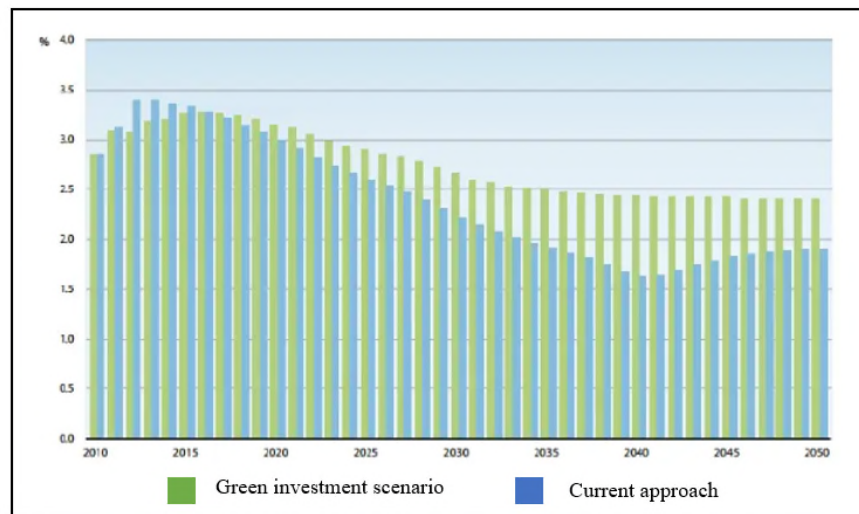


Fig. 1: Projected trends for the annual rate of global GDP growth between years 2010-2050
(Liang et al., 2022)

In terms of energy, primary demand is expected to return to its present levels by 2050, which is 40% lower than expected under the current approach. In the coming decades, supply and demand side measures will

reduce energy prices below the normal current approach prices, thereby reducing the vulnerability of the global economy to potential energy price disruptions.

Since more than half of the green investment scenario is devoted to increasing energy efficiency in various sectors and expanding the use of renewable energy, it is anticipated that the annual volume of energy-related carbon emissions will decrease to 20 percent in 2050 from the current level of approximately 30 gigatons under the green investment scenario. Following the current course of action, carbon emissions are projected to reach nearly 50 gigatons by 2050. Figure 2 shows the energy carbon emissions under the green investment scenario compared to the current approach in gigatonnes of carbon dioxide.

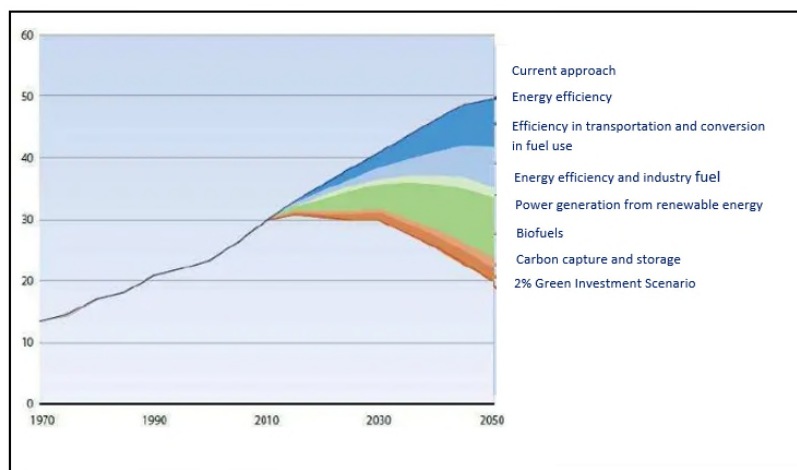


Fig. 2: Energy carbon emissions under the green investment scenario compared to the current approach in gigatonnes of carbon dioxide

(Liang et al., 2022)

2.1.1.3 Challenges of the transition towards a green economy

The transition to a green economy is gathering momentum and advancing at a rapid pace, but it faces numerous obstacles that impede its progress and impede the availability of a framework to promote sustainable

development (Mundaca et al., 2016). The following is a summary of these obstacles:

A. Global crises challenges

Numerous crises have swept the globe, endangering the entire global economy and plunging millions into destitution, particularly in the developing world. These crises have weakened the efforts made to attain development goals and thus contributed to further ecological deterioration and resource depletion. They have become a burden on sustainable development economics and a barrier to the transition to a green economy. Simultaneously, they are viewed as catalysts for such a transformation in order to mitigate the effects of these crises and guarantee the stability of the global economic and ecological system. These crises include the global financial crisis, the climate change crisis, and the natural resource crisis, which includes the food crisis, the fuel crisis, the dearth of fresh water, and the sanitation crisis (Candelon et al., 2020).

Although the causes of these crises are distinct, they all share a common trait: the misallocation of resources. In recent decades, capital has been spent on sectors that contribute to resource depletion and the increase in greenhouse gas emissions without parallel investment in renewable energy fields, nor has much been invested in sustainable agriculture, ecosystem protection, or biodiversity (Pacca et al., 2020).

B. Funding challenges

The process of transitioning to a green economy necessitates vast financial resources, and securing these resources is one of the most

significant and formidable obstacles to this metamorphosis (Wang et al., 2022).

According to the research conducted by Licastro and Sergi in 2021, financing is essential for the development of productive assets for the poor, the creation of new employment opportunities in sectors of the economy based on natural resources, and the expansion of low-income groups' access to development infrastructure supplies, such as renewable energy sources, clean water, and sanitation services.

There is no doubt that the private sector cannot accomplish the necessary transition to a green economy on its own. Instead, governments must play a crucial role in financing the scientific research initiatives required to develop clean energy technologies and renewable sources and make them more efficient and less expensive. Governments, investors, donors, significant financial institutions, and the international community must ensure the transition to a green economy is adequately financed (Kolcava & Bernauer, 2021).

C. Economic challenges

Numerous nations around the globe are afflicted by a variety of economic issues, as evidenced by the observable decline in many economic indicators, such as low rates of economic growth, high rates of inflation, and unemployment, as well as the deterioration of public budget deficits, deficits in the balance of payments, and the accumulation of debts, as well as other economic issues that transform in the absence of successful sustainable development plans. There is no doubt that the situation of these indicators has worsened as a result of the 2008 global financial crisis, and if the effects of this crisis persist, the decrease in development aid to the

least developed countries and the decrease in remittances of workers abroad and foreign direct investment will lead to a decline in the levels of public investment, which may have a negative impact on economic growth and impede the transition towards a green economy.

D. Political challenges

Political obstacles impede the transition to a green economy and the promotion of sustainable development in every nation (Swainson & Mahanty, 2018). These challenges can be classified as either external or internal. The pressures put on national internal affairs by major powers and financial institutions serve as an example of external political challenges. As for the internal political challenges, they are represented by instability, low economic indicators, and the slow implementation of national policies and plans intended to shift to a green economy (Agheli & Taghvaei, 2021).

E. Environmental challenges

Due to the pursuit of rapid economic progress and material affluence at the expense of the optimal exploitation of natural resources, the entire planet is confronted with a variety of environmental problems that threaten both current and future generations. Due to the ineffective incorporation of environmental considerations into sectoral policies, environmental problems such as air and water pollution caused by the industrial, energy, and transportation sectors, as well as soil degradation and insufficient treatment of industrial and sewage water, are escalating. Choi et al. (2016) suggest that reorienting investments in a manner that enables preserving the productive assets of the poor and locating sources of economic growth and employment may be one of the strategies for overcoming these obstacles.

The green economy scenario is a viable option for addressing these multiple challenges simultaneously in all nations, particularly in low-income nations (Gunay et al., 2022).

F. Commercial challenges

The study by Cosbey (2012) discussed how many nations, particularly developing nations, fear that the transition to a green economy will result in the imposition of unnecessary tariff or non-tariff barriers, or the imposition of taxes or bans on products that do not adhere to the environmental performance standards that developed nations can apply. Possibly the obstacle impeding the transition to a green economy in this regard is the impact of compliance with environmental standards, which necessitates the restructuring of industries or the modification of production methods, on the competitiveness of businesses, resulting in productivity losses and employment opportunities.

G. Technological challenges

In terms of modern technology, the disparity between developed and developing nations is unquestionably vast. Technology and technical knowledge are significantly more advanced in the West, and this knowledge is rarely transferred to developing nations. To implement sustainable development programs and to plan for the use of renewable energy sources such as solar energy, wind energy, and others, technical requirements are necessary. Therefore, it is essential to overcome these obstacles in order to ensure that developing nations are at least aware of the technologies that can facilitate green growth (Raihan & Tuspekova, 2022).

H. Standard Challenges

When making an all-encompassing plan to switch to a green economy, it's important to spell out the methods and measuring tools that will be used to judge the progress made and the choices that were made, since the different sectors involved have different goals. It's also important to come up with rules for what the green economy does so that the results can be tracked. Some indicators, including environmental assessment, resource conservation, and pollution reduction, as well as job creation and economic growth, can be used to measure the performance of green economy activities (Fabozzi et al., 2022). China's use of what it calls the green GDP to measure economic development while taking environmental factors into account can serve as a model for other countries.

2.1.1.4 Mechanisms of transition to a green economy

The transition to a green economy has the potential to steer global development in a new direction that promotes sustainability, economic stability, and environmental stability (Cui et al., 2022). The principles of a green economy firmly establish the concepts of economic development, social justice, and environmental sustainability; however, appropriate policy measures and mechanisms are necessary to ensure the success of the transition to a green economy (Barua & Aziz, 2022). These mechanisms include:

A. Establishment of a sound legislative framework

Ali et al. (2021) study indicated that a disciplined legislative framework should create incentives that drive economic activity toward a green economy and overcome obstacles to green investments. Therefore, improper behaviors can be controlled either by setting minimum standards

or banning certain activities altogether. Standards can be effective tools for achieving environmental goals and enabling markets for sustainable goods and service, contributing to the transition towards a green economy.

B. Prioritize government investment and spending in areas which supports green sectors

Newbery (2016) study claimed that green subsidies, such as price support measures and tax incentives, as well as subsidies in the form of direct grants and loans, can be used to work rapidly to avoid the loss of natural capital and to encourage nascent green industries such as the renewable energy industry in the framework of building comparative advantage and driving employment and long-term growth.

The same area was explored in (Winfield & Dolter, 2014) study as the study highlighted how tax incentives can help boost investment in the green economy and mobilize private finance. Government spending should be time-bound; for instance, once subsidies are applied, it can be difficult to eliminate them because recipients of subsidies will exert pressure to continue receiving subsidies; therefore, subsidies must be phased out over time to encourage innovation (Hussain et al., 2022).

C. Reducing government spending in areas that deplete natural resources

Most forms of support represent a heavy burden for many countries of the world at the economic and environmental levels, as they encourage the depletion of resources and ecosystem degradation (Xia et al., 2022). Nagy et al. (2021) study indicated that subsidies can reduce the profitability

of green investments; for example, fossil fuel subsidies pose a major burden to the development of renewable energy technologies such as solar and wind energy. It is estimated that phasing out all forms of fossil fuel subsidies could reduce global demand for primary energy by 5.8 percent and reduce buried gases by 6.9 percent.

D. Expanding the establishment of sustainable public procurement programs

By virtue of their scale and rule-making function, public procurement can foster markets for eco-friendly, green products that make efficient use of resources. Sustainable public procurement is a key pillar of the transformation to a green economy, estimated at more than \$4 trillion per year, and accounts for a significant portion of the GDP in some nations, such as 47% of the GDP in Brazil. In countries such as the United Kingdom and Germany, sustainable public procurement has helped reduce the carbon footprint by 25% (Rodriguez-Plesa et al., 2021).

E. Strengthening the role of the private sector and civil society

The transition to a green economy necessitates changes in business practices, as the private sector must take social and environmental norms into account when conducting activities. In addition, regulatory regulations and mechanisms for reducing pollution, food emissions, and water pollution should be considered (Kolcava & Bernauer, 2021).

According to Klausen and Winsvold (2019) study, civil society can play a significant role in facilitating the transition to a green economy by

assisting entrepreneurs to take advantage of the green economy's specialized markets and financial resources.

F. Using VATs and market-based tools to encourage green innovation and investment

Cannas (2017) found that in a market economy, a VAT policy can stimulate green investment. In the transportation industry, for instance, negative savings such as pollution and health harm are not reflected in the costs, which discourages green investment. Typically, the costs associated with waste treatment and disposal are not reflected in the prices of products and services in the waste industry. To counteract this, the price of the product or service should include the cost of negative savings. This is accomplished via corrective VAT or specific fees. The two varieties of environmental-related VAT are "polluter pays" and "user pays." The former is concerned with the producer or consumer being responsible for the production of pollutants, while the latter is responsible for charging fees for the extraction or use of natural resources.

A study by Amand (2014) revealed that market-based tools such as "tradable license systems" can be used to address a variety of environmental problems. Unlike value-added tax, which sets a price for pollution and then allows the market to determine the level of pollution, tradable licensing systems cap the allowable level of pollution and then let the market determine the price.

G. Promote sustainable production, consumption, and efficient use of resources

The transition to a green economy entails the promotion of sustainable production and consumption patterns, which contributes to the promotion of economic and social development within the context of the capacity of ecosystems to support such development by addressing the relationship between environmental degradation and economic growth. A green economy also necessitates a comprehensive foundation of resource efficiency to prevent the degradation of the ecosystem and deal with the massive depletion of resources (Huang & Zhao, 2022).

H. Investing in capacity building, training, and education

Capacity-building, training, and skill-enhancement programs are required to prepare a qualified workforce for the transition to a green economy, as this process involves some degree of economic restructuring and necessitates certain actions to ensure a fair transition for workers impacted by the change. Consequently, it will be necessary to provide the essential assistance to transform workers in certain sectors into new jobs commensurate with the transition to a green economy (Dai et al., 2017).

I. Strengthening international governance

International environmental agreements can facilitate and stimulate the transition to a green economy by establishing institutional and legal frameworks that strengthen international governance and contribute to overcoming global environmental obstacles. The United Nations Framework Convention on Climate Change and its Kyoto Protocol, the multilateral environmental agreement with the greatest impact on the

transition to a green economy, cannot be overlooked because it has successfully stimulated growth in a number of economic sectors, such as renewable energy production and energy efficiency technologies, in order to reduce greenhouse gas emissions (Ofori et al., 2022).

2.1.1.5 Sources of financing for the transition towards a green economy

It is difficult to arrive at a comprehensive estimate of the amount of financing required for the global transition to a green economy, but the volume of this funding is substantial, and current estimates focus on what the world needs to reduce carbon emissions and attain target levels. The IEA Blue Map scenario is predicated on halving energy-related carbon emissions by 2050, which would require annual investments of more than \$46 trillion. The World Economic Forum and Bloomberg New Energy Funding estimate that the annual investment in new energy will need to increase to \$500 billion in order to limit the global temperature increase to less than two degrees Celsius (Gunnarsdottir et al., 2021).

The report "Towards a Green Economy", issued by the United Nations Environment Program (UNEP), analyzes the potential macroeconomic implications of investing more than \$1.3 trillion annually over the coming decades, and more than half of this investment will be allocated to raising energy efficiency in various sectors, especially buildings, industry, and transport, as well as expanding the use of renewable energies. The remaining half of the investment is devoted to enhancing waste management and a variety of natural capital-based industries, including agriculture, fisheries, and others. The financial services and investment sectors are poised to provide the majority of the

financing required to transition to a green economy. Long-term institutional investors, such as pension funds and insurance companies, are becoming increasingly interested in minimizing environmental, social, and governance risks, and commercial banks are taking these risks into account when designing green financial products (United Nations Environment Programme, 2021).

The role of public transformation in giving a strong impetus to the transition to a green economy and encouraging private financing cannot be ignored, and this role has been demonstrated by the fiscal stimulus packages launched by the Group of Twenty in response to the financial crisis, in which \$552 billion out of a total of \$3.3 trillion has been allocated to support green investments (Droste et al., 2016).

Subsidy and value-added tax (VAT) policy reforms can be used to facilitate green public investments. Subsidies in the energy, water, fisheries, and agriculture sectors, for instance, lower prices and encourage the exploitation of their respective natural capitals, thereby imposing a recurring burden on the general budgets of the countries. Removing this subsidy and taxing the use of energy and natural resources can increase efficiency and free up resources for green investments. In particular, eliminating subsidies in these four sectors could save between 1 and 2 percent of global GDP annually, which could be used to pay for the transition to a green economy (Bohringer et al., 2022).

The United Nations Program to Reduce Emissions from Deforestation and Deforestation (REDD) can be an important tool for advancing the green economy in collaboration with other program mechanisms, such as the REDD+ partnership. Donor donations to the

program and its partnership, as well as the facilities of the Carbon Forest Partnership, the Global Environment Facility, and the Forest Investment Program, have reached five billion dollars, and these grants can be considered as sources of funding for the transition towards a green economy (Golub et al., 2021).

Ngo et al. (2022) study claimed that development finance institutions at the global and national levels play a pivotal role in supporting the green economy, and these institutions paralyze regional development banks and bilateral assistance development agencies, such as the German Development Bank KfW, the AFD Bank of France, the National Development Banks, and others. Finally, stable capital markets with high flexibility, supported by productive information for investment and financial intermediation, will have an important role to play in providing the capital needed to shift towards a green economy.

On the basis of the preceding analysis, it is to be noted that the energy sector can be considered the leading sector for the transition to a green economy, including the allocation of more than half of green investment to increase energy efficiency and expand the use of renewable energies, despite the fact that renewable energies are the global focus of attention; consequently, the second section of this chapter focuses on clean renewable energy as the leading sector for the transition to a green economy.

2.1.2 Clean renewable energy as a leading sector for the transition towards a green economy

Energy has a close relationship with economic activity and growth rates due to its role as the foundation and backbone of all lifestyles (Yue et al., 2022). As fossil energy sources are known to be depleted, to have a high cost of exploitation, and to have a negative impact on the environment, including the deterioration of the ecosystem, humans are still in the process of searching for new sources of energy to meet their expanding requirements (Mohsin et al., 2021). Renewable energy is the best option for attaining sustainable development and transitioning to a green economy, as the world has clearly recognized the threat to the environment posed by the use of fossil energy, which results in environmental pollution (Yang et al., 2021).

To clarify the relationship between renewable energy and the green economy and its role in achieving sustainable development, light will be shed on the concept of renewable energy, its significance, and its main divisions, as well as a brief review of its most important sources, before concluding with an analysis of the role of renewable energy in achieving sustainable development and the transition to a green economy.

2.1.2.1 Renewable Energy (Basic concepts)

In the modern era, humans are aware of the possibility of benefiting from natural phenomena to generate energy, such as the sun, wind, water, and others, which are renewable and permanent, which contributes to meeting the growing demand for energy as well as being clean and not polluting the environment, thereby contributing to the transition towards a green economy (Sherif et al., 2022).

A. The concept of renewable energy and its status

There are many definitions of renewable energy, as the International Energy Agency defines it as “energy that can be derived from natural phenomena such as the sun and wind and which is determined at a rate greater than the rate of its consumption” (The International Renewable Energy Agency, 2022). The Intergovernmental Panel on Climate Change defines it as “energy obtained from energy streams” (Renewable Energy Sources and Climate Change Mitigation—Special Report of the Intergovernmental Panel on Climate Change, 2011).

Edenhofer and Seyboth (2013) study defined it as technologies that do not produce carbon, such as solar energy, wind energy, hydropower, and geothermal energy, as well as technologies that do not affect carbon dioxide emissions, such as biomass.

Renewable energy can be defined as energy derived from natural phenomena that are renewed and never implemented, and whose use does not result in environmental pollution or damage to the ecosystem or biodiversity (Kim & Park, 2022).

Since the middle of the twentieth century, the world has pondered the future of energy when oil, natural gas, and coal are depleted due to increased consumption (Ilechukwu & Lahiri, 2021). Moreover, fossil fuels pose a significant threat to the environment because they impair the ecosystem and increase greenhouse gas emissions. Therefore, renewable energy is now humanity's best option for preserving the environment, exploiting natural phenomena, and progressively securing energy for sustainable development (Shrestha et al., 2022).

B. The importance of using renewable energy

The world extracts vast quantities of fossil energy sources daily to meet its diverse requirements, which are dependent on these depleted sources, which threatens their depletion and the occurrence of more environmental pollution (Xie & Jamaani, 2022). Hence, the need has become urgent to expand the use of renewable energy, given its paramount importance, which can be listed as follows:

1) Achieving energy security

The 1973 oil crisis posed a great danger to the pro-Israel industrial economies during the Glorious October War, where the Organization of Arab Petroleum Exporting Countries announced an oil embargo to push Western countries to force Israel to withdraw from the occupied Arab lands, and the members of the Organization of Petroleum Exporting Countries agreed to use their influence to raise oil prices. Hence, the great powers realized the danger of oil dependence on Arab countries and worked to secure their energy economy by paying attention to renewable energy and encouraging research and development in its field (Alpanda & Peralta-Alva, 2010). This was reinforced by the financial crisis in 2008, which negatively affected the global energy sector, as well as the impact of revolutions and political conflicts in many oil-exporting countries such as Iraq and Libya on the global oil market, which emphasized the importance of renewable energy in securing energy (Mukhtarov et al., 2018).

2) Achieving environmental security and reducing pollution

Fossil energy, which dominates the global energy mix, has caused many environmental problems, such as global warming, acid rain, and others. Perhaps the expansion of the use of clean renewable energy contributes to reducing pollution and ecological degradation that result from fossil energy, thus contributing to the transition towards a green economy (Zheng et al., 2022). The Kyoto Protocol indicated the need to conduct research on renewable energy and carbon dioxide sequestration technology, as well as advanced and environmentally sound technologies, to develop and increase their use in order to reduce environmental pollution (Miyamoto & Takeuchi, 2019).

3) Supporting the national economy and promoting sustainable development

The expansion of renewable energy use has a positive effect on the economies of all nations that adopt this strategy. Renewable energy has provided more than 7.6 million jobs, playing a significant role in the creation of employment opportunities and the support of the global economy (Mukhtarov et al., 2018). Renewable energy sources as a whole produce nearly 2.5 million jobs, or one-third of all jobs, with the solar photovoltaic industry leading the way in terms of employment opportunities. (Smolović et al., 2020).

The importance of renewable energy can also be seen when a country with a large renewable energy potential is able to meet its own energy requirements and export the surplus to other nations. These countries will

limit their imports of fossil fuels in order to avoid the effects of the rise in crude prices (Akintande et al., 2020).

The report "The Global Framework for Tracking Sustainable Energy for All" confirmed that 1,6 billion people lack access to electricity, preventing them from carrying out their daily activities. According to the report, nearly 2.7 billion people rely on wood, coal, animal dung, and other sources of household fuel, which causes escalating waves of pollution that wreak havoc on human health and kill approximately 4 million people annually (Matraeva et al., 2022). Providing energy services to everyone who lacks them is a requirement for reducing poverty and promoting sustainable development, and renewable energy is progressively contributing to this goal (Solarin & Shahbaz, 2013).

2.1.2.2 Renewable Energy Division

The study by Peddakapu et al. (2022) discussed the diversity of renewable energy sources, which can be categorized according to several criteria, such as the modernity criterion, which is subdivided into traditional and new energy, and the economic feasibility criterion, which is subdivided into economic and non-economic energy. These two categories can be described as follows:

A. Renewable energy divisions according to the modernity criterion

- 1) Conventional renewable energy: It is represented in biomass energy, which took a place before the advent of oil, and through which biodiesel, ethanol and others can be produced. Despite the continuous developments in the fields of energy use, this type is still the only source of energy for many of the world's population.

- 2) New renewable energy: Which includes solar energy, wind energy, hydropower and geothermal energy.

B. Renewable energy divisions according to the economic feasibility criterion

- 1) Economic renewable energy: It is energy that is already used, and its economic and technical feasibility has been confirmed. It includes solar energy, wind energy, hydroelectric energy, thermal energy, and biomass.
- 2) Uneconomical renewable energy: It is energy that is still in the process of experiments and studies, such as energy from hydrogen.

2.1.2.3 Renewable Energy Sources: Concept, Uses, Advantages and Challenges

The capacity to use renewable energy sources without causing their depletion distinguishes them from other energy sources, which include some of humanity's oldest energy sources (Mayer et al., 2021).

Solar energy, wind energy, hydropower, geothermal energy, and biomass energy, all of which are derived from the sun, are the economic sources of renewable energy that are presently used on a global scale.

A. Solar energy

Solar energy, also known as solar radiation, is the energy emitted from the sun's beams, primarily in the form of heat and light, and it is the byproduct of nuclear reactions occurring within our nearest star, the sun. If

the current energy in the world is harnessed and utilized properly, it may be sufficient to satisfy all future energy needs (Ramful & Sowaruth, 2022). The significance of solar energy stems from the fact that sunlight promotes the evolution of living organisms and is responsible for the processes of photosynthesis in plants that produce food and biomass, in addition to their function in water and wind energy (Nilson & Stedman, 2022).

In addition to the use of greenhouses to increase the temperature, solar energy is crucial for land cultivation, crop production and growth, and food preservation through drying. In addition, solar energy is responsible for the so-called group of renewable energy sources, the most important of which is, and it is noticeable that the importance of solar energy is increasing as a source of renewable energy because it is not decreasing and is non-polluting, at a time when it has become apparent that the levels of fossil fuels, oil and coal, as well as natural gas, are decreasing (Gaonwe et al., 2022).

1) The concept and nature of solar energy

Solar energy is an infinite source of pure, renewable energy. Two fundamental technologies for the production of solar energy, photovoltaic conversion and thermal conversion, are able to convert solar energy into electrical energy and thermal energy. Using photovoltaic solar cells, photovoltaic transformation involves converting solar radiation directly into electrical energy. This mechanism is utilized in a variety of applications, including solar roofing, solar illumination, and solar pumps. As for the thermal conversion of solar energy, solar collectors are intended to convert solar radiation into thermal energy. Thermal materials are utilized for heating, water heating, and the production of electricity, among other purposes (Oudes et al., 2022).

Franco (2018) study highlighted that in 1973, in the wake of the global oil crisis, a UNESCO conference was held in Paris entitled "The Sun in the Service of Humans", where it stressed the need to expand the use of solar energy to overcome oil dependency. This conference was followed by the first European program on research and development in the field of renewable energy by the European Commission in France in 1974. The decade of the eighties and nineties witnessed a huge boom in the field of solar energy, which was evident through the studies and research conducted in this field, in addition to the wide applications of solar energy in many countries around the world.

2) Solar energy uses

Historically, solar energy was utilized in humid regions to heat water, dry crops, etc. Currently, solar energy is utilized in numerous domains and industries. The production of electricity through solar thermal technology and photovoltaics is one of its most varied applications. Solar energy is also utilized to heat water for residential and public use, industrial processes, illumination, cooling, and air conditioning. The production of photovoltaic cells has increased significantly in recent years. Global photovoltaic solar energy capacity is estimated to be 177 gigawatts, and Germany and China are at the top of the list of countries producing photovoltaic cells. Spain and the United States dominated the global market for concentrated solar thermal energy. The total global capacity of solar thermal energy was approximately 4,400 gigawatts (Neupane et al., 2022).

More than two million people in developing nations use the solar-powered purification and desalination of water to treat potable water. In wastewater remediation, solar energy is used to remove toxins from polluted water through photolysis (Kan et al., 2021). Solar energy can also be used to circulate water with solar pumps, dry crops, and dehydrate organic manure, among other agricultural applications. Solar energy is also used to illuminate streets, main roadways, and squares, as well as remote villages located far from the public network (Prăvălie et al., 2019).

3) Advantages and challenges of using solar energy

As an inexhaustible renewable energy source that is also clean and does not pollute the environment, solar energy is of great interest to a great number of countries around the globe. It is considered an available energy that is not monopolized by any nation, in addition to being secure and silent when used (Li & Huang, 2020). However, it faces obstacles that impede the expansion of its exploitation, such as the high initial costs of its use and the lack of funding sources, as well as technological obstacles such as the problem of energy storage, the erosion of solar collectors, and the issue of clouds and dust (Devabhaktuni et al., 2013). These benefits and considerations will be discussed in greater detail in subsequent sections of this thesis.

B. Wind Energy

Wind ranks second in global studies and applications as an alternative energy source, after solar energy, as work is underway in many countries to develop its use in the field of electricity generation, where

wind energy is converted into mechanical energy and then into electrical energy, as wind energy is used on land or at sea (Santa Catarina, 2022).

1) The concept and nature of wind energy

Since the beginning of time, humans have used wind energy, which is one of the oldest and most prevalent forms of energy. This energy is produced by the wind and is generated by three factors: the temperature difference between the poles and the equator, the Earth's rotation on its axis, and the difference in the amount of solar radiation absorbed by land and sea. These three mechanisms interact in a complex manner to generate winds throughout the world. Wind velocity is directly proportional to altitude; the greater the height above the earth's surface, the greater the wind velocity (Pourebrahim et al., 2021).

2) Wind energy uses

Since ancient times, wind energy has been used to power sailing ships and operate windmills to grind grain and pump water. Due to their scale and capacity, these turbines were used to generate electricity in the modern era (Zheng et al., 2016). As a consequence of industrialization and the advent of the petroleum age, the use of wind turbines declined until 1970, when it reached its lowest point and was restricted to remote areas. However, after the 1973 global oil crisis and the subsequent rise in oil prices, the trend returned to using wind energy to generate electricity, and this use grew significantly in the 1980s in response to the growing concern over pollution issues caused by the use of fossil fuels (Mizuno, 2014).

3) Advantages and challenges of using wind energy

There are numerous benefits associated with the use of wind energy, as it is a renewable and clean source of energy that does not produce any greenhouse gases that are harmful to the environment. Wind energy is also considered an available source of energy that can be exploited and utilized in accordance with each country's climate and terrain (Cruz, 2022). Wind farms can also be used for agriculture and livestock, and turbines can be deployed in the depths of oceans and seas in addition to on land (Chang et al., 2022).

Irfan et al. (2019) study discussed the number of advantages that wind energy enjoys, which makes it a strong competitor to fossil energy in the near future. However, there are challenges that hinder the expansion of its use, such as the high initial costs of its exploitation, in addition to the problem of energy storage and the problem of intermittency, as the wind does not always blow when electricity is needed to be produced. The turbines' rotation also generates a significant quantity of noise, making their installation in populated areas difficult. Some birds are impacted by the establishment of wind farms as a result of collisions with the arms of the turbines, particularly if the farms fall within the seasonal migration routes of birds.

C. Water Energy

Water is one of the most abundant substances on the earth's surface and one of the basic elements present on the planet. It is also one of the most essential elements for human survival (Liu et al., 2020).

Hydroelectricity is generated by the accumulation of water in high mountains as a result of precipitation, which then cascades into water bodies, transforming the mountains into waterfalls. Since falling or

descending water contains kinetic energy, it is possible to convert it into electrical energy (Adun et al., 2022).

1) The concept and nature of hydropower

Hydropower is defined as the energy resulting from waterfalls or the production of energy through the use of gravitational force as a result of falling water, and it is one of the most extensively used renewable energy sources in the production of electricity. The sources of hydropower can be divided into two major categories: those associated with sea and ocean surfaces and those associated with rivers (De Silva et al., 2022).

Kim et al. (2022) study revealed that there are numerous forms of energy that can be extracted from seas and oceans, including tidal energy, wave movement energy, and thermal energy. It is also possible to utilize the water descending from natural waterfalls that intercept rivers or artificial waterfalls by constructing dams on rivers in order to power the turbines that generate electricity.

2) Hydropower uses

Since ancient times, humans have utilized the seas, oceans, and rivers for numerous purposes, including food production, transportation, and commerce. Additionally, humans used them to operate water mills, sea cranes, and other machinery. China and Brazil topped the list of hydropower-producing countries. In the modern era, hydropower was primarily used to generate electricity, as the total global hydropower capacity is estimated to be 1,055 gigawatts, and China and Brazil topped the list of hydropower-producing countries (Kumar & Saini, 2022).

3) Advantages and challenges of using water energy

Hydropower plays a leading role in the field of generating electricity from renewable sources on a global scale due to its multiple advantages, as it is renewable and clean energy that does not pollute the environment, in addition to the multiple advantages of building hydroelectric panels, such as flood control and water flow rate management during the different seasons and irrigating neighboring agricultural lands, among others. Finally, hydropower is capable of handling peak demand. When the demand for electricity is low, the dam stores larger quantities of water, which later provides more flow when required (Shokri & Sanavi Fard, 2022).

Despite these benefits, hydropower is not completely exploited due to the high initial costs of exploiting it and the lack of investments, as the majority of hydropower needs are located in developing countries that are unable to invest in it to the required extent. The establishment of water stations may alter living patterns, as the construction of dams and reservoirs leads to population migration and a shift in the nature of labor, such as from farming to fishing. Hydroelectricity can destabilize ecosystems, alter river systems, elevate temperatures, and impede fish migration (Achhari & El Fadar, 2020).

D. Geothermal Energy

Geothermal energy is considered buried energy in the depths of the earth, and it exists in the form of a stock of hot water or steam and hot rocks, but the heat presently exploited is hot water and hot steam, while the hot rock fields are still under research and development. The geological

components of the earth's interior must contain fissures and water or water vapor aquifers in order to produce thermal energy (Guan et al., 2022).

1) The concept and nature of geothermal energy

Geothermal energy, or internal heat energy, means that heat is stored under the surface of the earth and that heat flows out from the ground through contact, heat transfer, hot mineral springs, and erupting volcanoes. It can be extracted from the ground using technical methods, and dry steam is considered the finest method due to its high thermal capacity and lack of corrosion-causing properties (Spijkerboer et al., 2022).

2) Geothermal energy uses

Goedkoop and Devine-Wright (2016) state that increasing geothermal energy's contribution to meeting the world's energy requirements is contingent upon future technological advances, research, and exploration. Geothermal energy's most widespread application is the generation of electricity. It is also used to heat buildings via central heating systems, in which water heated near the earth's surface is piped directly into buildings and factories for heating. In addition, it has agricultural and industrial applications in recovery with hot springs, which contain natural minerals that treat a variety of diseases and are the foundation of medical tourism. The use of hot mineral springs for cookery has been documented (Mahbaz et al., 2020). The United States and the Philippines topped the list of countries generating thermal energy. The total global geothermal capacity is estimated to be 12,8 gigawatts (Limberger et al., 2018).

3) Advantages and challenges of using geothermal energy

Geothermal energy is one of the renewable sources that has attracted the attention of many developed nations due to the benefits it offers. As well as to devise means to transport or store it, compared to the use of fossil fuels, and they are abundant enough to generate enormous amounts of electricity in the future. Geothermal energy is a crucial source of national income because it supports underground tourism and hospitalization (Ratio et al., 2020).

Benediktsson's (2021) study revealed that despite the advantages that geothermal energy possesses, which qualify it to be at the forefront of renewable energy sources in the future, it suffers from some drawbacks that may hinder its widespread adoption, such as the high initial costs of its exploitation and the corrosion of drilling tools, as well as the danger of dealing with heat violently leaking to the surface of the earth, as well as the problem of noise associated with its operation. As the geothermal well system can only extract 10% of the heat in the well to the surface of the earth, and thermal stations use 10% of this amount, the percentage of geothermal heat at a site that is actually used may not exceed 1%.

E. Biomass energy

Biomass comprises all generated waste that can be utilized through recycling or reuse processes, which, in addition to reducing the volume of waste, can contribute to energy production (Lu et al., 2022).

1) The concept and nature of biomass energy

Biomass energy refers to the energy that can be derived from plant and animal materials and waste by converting them to liquid or gas through chemical processes or pyrolysis (Liu et al., 2022). It can also be utilized by

burning it directly and utilizing the resulting heat to heat water or generate steam that can operate turbines and generate electricity. Biomass can be converted into fuels for internal combustion, such as ethanol and biodiesel (Ma et al., 2022).

2) Biomass energy uses

Biomass is one of the earliest forms of energy on which humans have relied, as it has been utilized primarily in the form of combusted wood for heating and lighting homes and other outdoor spaces. Currently, liquid, gaseous, and solid materials are used to produce electricity, heat, and power using biomass energy. Also used for transportation is biomass. Biomass derived from cellulosic vegetation is used to produce ethanol, which can replace petroleum in internal combustion engines. The use of biogas for heating and cooking represents the final application of biomass (Anupong et al., 2022).

The global capacity for biomass energy is estimated to be 93 gigawatts, and the United States and Germany are the leading producers (Limberger et al., 2018).

3) Advantages and challenges of biomass energy use

Biomass energy has numerous environmental benefits, as it is considered a renewable, pure energy that does not pollute the environment and also limits global warming. Additionally, it contributes to the development of the rural economy and the improvement of the rural standard of living. In addition, it helps create employment opportunities (Thornley et al., 2019). The idea of using biomass energy is based on a simple and uncomplicated technique in which waste is burned in

incinerators to produce enough heat to heat the water in the boilers, which is then converted into steam and sent to the turbines (Jiang et al., 2022).

The study by Buffi et al. (2022) noted that despite the advantages that biomass energy has as a renewable energy source, there are obstacles to expanding its use as the initial costs of exploiting it rise. For example, producing 10% of the world's gasoline demand could result in the loss of 50% of the corn crop, in addition to the high cost of transportation and storage. Biofuel crops compete with food production for the use of agricultural land, and they require a substantial amount of fertilizer and irrigation water. Finally, the use of biomass energy is hindered by the high cost of agricultural crops, as the conversion of maize, wheat, and sugar, for example, into fuel raises the cost of food commodities and land.

2.1.2.4 The role of renewable energy in achieving sustainable development

Energy and its services are fundamental to achieving the economic, social, and environmental dimensions of sustainable development, particularly in terms of reducing poverty and altering unsustainable patterns of production and consumption, as well as conserving and managing resources to ensure the reduction of energy's negative impacts on the environment (Wang et al., 2022).

Jha et al. (2022) study highlighted that the role of renewable energy in achieving sustainable development can be analyzed by reviewing the importance of energy in general and renewable energy in particular for sustainable development. In addition to focusing on the relationship of renewable energy with the backward dimensions of sustainable

development, challenges that hinder renewable energy in achieving sustainable development should also be addressed.

A. Renewable energy as an entry point for sustainable development

Energy is essential to human life, and it plays an important role in achieving the economic, social, and environmental dimensions of sustainable development, as its supply is a key factor in advancing production and achieving stability and growth, thereby creating more job opportunities and contributing to improving the standard of living, reducing poverty, and lowering unemployment (Ahmed et al., 2017). Therefore, energy was selected as one of the five main areas included in the "Water, Energy, Health, Agriculture, and Biodiversity" initiative, which was submitted by the General Secretariat of the United Nations to contribute to the preparation of the World Summit on Sustainable Development held in Johannesburg, which sought to concentrate efforts in the aforementioned areas to contribute to the achievement of sustainable development (Mulopo, 2022).

As a result of the global energy crisis, there is a growing interest in renewable energy sources that do not pollute the environment and consider all aspects of sustainable development (Lightfoot & Burchell, 2004). In addition to alleviating poverty, preserving the environment, and achieving sustainable development, there is a growing emphasis on the availability of future potential and opportunities for renewable energy sources to contribute to meeting the global demand for energy. During the previous two decades, numerous renewable energy technologies have been developed. Renewable energy technologies have reached the level of application, particularly in the field of small and medium capacities in

remote areas, where some renewable energy sources have proved to be extremely cost-effective while others are still in the research phase. However, these technologies are not yet extensively used to provide energy services, and obstacles, such as high initial costs, continue to impede their widespread adoption (Ghimire & Kim, 2018).

The technical benefits and economic viability of renewable energy systems are heavily influenced by time and location. Due to its availability and widespread distribution in many countries around the world, solar energy in particular can rank second after fossil energy, followed by wind energy. Modern methods of utilizing biomass are one of the most promising sources for providing the fuel and electricity required to satisfy the energy needs of rural areas (Apergis & Payne, 2010).

B. Renewable energy and the backward dimensions of sustainable development

Three of the Johannesburg Plan's ten energy-related issues involved the connection between energy and sustainable development. Renewable energy contributes considerably to achieving these objectives, which are common goals and fundamental requirements for sustainable development (Alao et al., 2021).

1) Poverty alleviation and development of new and remote communities

Achieving sustainable development in the face of a growing population necessitates the improvement of individual lives, particularly in impoverished regions. The Johannesburg Summit urged all nations to improve the provision of services and energy resources that are economically viable, socially acceptable, and environmentally sound,

considering the unique circumstances of each nation. This is accomplished by managing and preserving the available resources in a manner that enables meeting the basic needs of housing, strengthening the supply of rural electricity and energy networks and providing them with appropriate energy systems for development, expanding the use of renewable energy and cleaner types of liquid and gaseous fuels, and reducing the negative effects of production and energy consumption on human health and the environment (Kayakutlu & Mercier-Laurent, 2017).

In addition to the aforementioned measures, renewable energy provides a solution for poverty alleviation and the development of new and remote communities by supplying them with renewable energy products such as solar heaters for water heating and solar pumps for use in agricultural activities such as desalinating seawater or water wells powered by renewable energy (Zhao et al., 2022).

There is no doubt that the contribution of renewable energies to attaining this contributes to reducing energy and water poverty, as well as to the development of new and remote communities.

2) Changing unsustainable patterns of production and consumption

Current production and consumption patterns in numerous sectors result in the depletion of natural resources. Moreover, it has been linked to ecosystem degradation and environmental pollution. The energy sector is one of the sectors characterized by unsustainable production and consumption patterns, as well as the resulting inefficiency, waste, and depletion of resources in response to population growth and development needs (Stockhausen et al., 2012).

As a result of the above, the Johannesburg Plan urged all countries to reform unsustainable patterns of energy production and consumption in order for countries to make better use of existing resources. Furthermore, the strategy underlined the importance of implementing economically feasible and ecologically appropriate energy pricing regulations, as well as increasing the use of renewable energy, which is distinguished by sustainable production and consumption patterns (Lightfoot & Burchell, 2004).

3) Reducing the negative effects of energy on the environment

The twenty-first century agenda centered on the relationship between energy and the environmental dimensions of sustainable development, particularly those related to the protection of the atmosphere from pollution resulting from the use of energy in various economic and social activities, particularly in the industrial and transportation sectors. Emphasis has been placed on policies to reduce the negative effects of the energy sector on the environment, considering the equity in the distribution of energy sources, through the expansion of the use of renewable energy and increasing the proportion of its contribution to the global energy mix, in addition to supporting research and development programs necessary to raise the efficiency of energy use. Lastly, accomplishing integration between the policies of the energy sector and those of other economic sectors, particularly the transportation and manufacturing sectors (Cong et al., 2022).

The Johannesburg Plan included a set of policies to combat global warming, which is one of the most detrimental effects of energy on the environment, emphasizing the need to expand the use of clean renewable energy to reduce carbon emissions by creating the appropriate climate for the development of renewable energy technologies and the dissemination of their applications in a variety of fields, as well as encouraging the private sector to participate in their development and securing the necessary financing. Renewable energy technologies are deemed promising for meeting energy demand and preserving the environment, thereby contributing to the transition to a green economy (Ekolu, 2020).

4) Challenges that hinder renewable energy in achieving sustainable development

The relationship between economic growth and the increase in energy consumption and greenhouse gas emissions is close. Renewable energy can help eliminate this relationship, thereby contributing to sustainable development. The lack of human and financial resources in this field, the low level of public awareness of the available capabilities and systems that can be used appropriately, and the absence of research and development processes pertaining to the renewable energy system are all obstacles (Mosta et al., 2021).

Perhaps the formulation of sound policies on renewable energy, the mobilization of human and financial resources, the expenditure of global funds on research and development, and the propagation of a culture of using renewable energy would aid in overcoming these obstacles.

C. Renewable energy as a mechanism for the transition towards a green economy

The green economy is characterized by the use of new and renewable energy within the framework of sustainable environmental practices, where energy is obtained from its clean, naturally renewable sources, such as solar energy, wind energy, hydropower, and others, as opposed to the brown economy, which relies on depleted fossil energy sources that pollute the environment and are not sustainable, such as coal, oil, and natural gas (Ge et al., 2022).

The United Nations Environment Program's 2011 report "Towards a Green Economy" demonstrated that investments by public and private institutions in the major economic sectors that are powered by renewable energy sources can result in long-term economic growth. During the years 2010–2050, the medium- and long-term outlook exceeded the standard business approach. In addition to gradually securing energy, protecting the environment from pollution, and achieving sustainable development, the green economy model demonstrates that investing 1% of the global GDP to increase energy efficiency in various sectors and expand the use of renewable energy will generate many job opportunities. The total number of jobs under the green investment scenario will increase by more than 20% compared to the conventional business model by 2050, while also reducing carbon emissions and attaining a high economic growth rate (Zhang et al., 2022).

Greening the energy sector requires replacing investments in fossil energy sources with investments in clean energy sources and gradually improving energy efficiency in order to reduce carbon emissions, thus

contributing to the transition towards a green economy (Koasidis et al., 2022).

When the social costs of fossil energy technologies are considered, such as the costs of droughts, hurricanes, flooding, pollution, and acid rain, renewable energy technologies become more competitive. The existence of a future carbon market and price as a result of reaching a global agreement on carbon emissions is a powerful incentive to invest in renewable energy. It is anticipated that replacing investments in fossil energy with investments in clean energy will triple the share of renewable sources in power generation by 2050. Given the total energy balance, renewable sources can provide more than 25 percent of total fossil resources, followed by the gradual elimination of carbon emissions, thereby contributing to the transition to a green economy (Li et al., 2022).

The enabling conditions favor and encourage the brown economy, which relies significantly on fossil energy that pollutes the environment. Subsidizing this energy is without question a significant barrier to the development and application of renewable energy technologies. As a result, gradually eliminating subsidies and then increasing the use of renewable energy sources may be wise strategies for lowering global demand for fossil fuels. This contributes to the transition to a green economy by substantially reducing carbon emissions (Wurlod & Noailly, 2018). The transition mechanisms and facilitating conditions for a green economy can pave the way for the success of public and private investments in transforming the global economy into a green economy (Yang et al., 2022).

With approximately one-third of the world's population lacking access to electricity, linking the mechanisms of energy systems and building a sustainable economy becomes a necessity imposed by the future, compelling each country to seek to secure its current and future energy needs and preserve the environment by expanding the use of renewable energies, particularly solar and wind energy, as most countries in the world have enormous potential in at least one of these areas (Tao et al., 2020).

Figure 3 graphically represents the global capacity for energy production during the period from 2012 to 2030 in gigawatts.

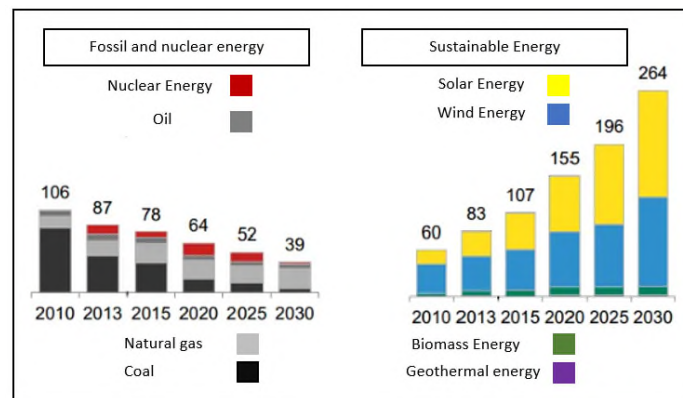


Fig. 3: Global capacity for energy production during the period of year 2010 – 2030 in gigatonnes
(International Energy Agency, 2020)

The upward trend of global capacities generated from renewable energy is clearly superior to the downward trend of global capacities produced from depleted fossil fuels and nuclear energy.

Solar energy is one of the driving forces behind the transition to a green economy (Bruno & Bevilacqua, 2022). The sun is a sizable source of clean, renewable energy that is not subject to governmental control and does not harm the environment. Rather, it is one of nature's gifts. The

energy that can be obtained from sunlight in 105 minutes is sufficient to meet the world's energy requirements for an entire year, exceeding them by approximately 5,000 times. As a result of innovation and global spending on research and development, its cost of exploitation is also constantly declining, allowing it to compete with fossil energy, whose prices are gradually increasing due to rising demand, and countries are moving toward eliminating subsidies (Wu et al., 2022).

2.2 Literature review

Numerous previous studies have focused on the topics of green growth, sustainable development, and environmental sustainability. Some of these studies are listed below:

Green growth, according to Green and Mills (1978), may have good benefits on the economy, society, and environment while also being a cost-effective approach to better the future of growing nations.

Thornton (2001) clarified that abandoning economic growth is a necessary condition for addressing the environmental crisis and that green growth is not certain or a quick way to achieve energy security and end poverty in developing countries, but rather the opposite. It may be less quick to achieve its desired goals compared to traditional growth strategies.

National Renewable Energy Laboratory (2007) report, which was done by ECONorthwest's Portland office for the National Renewable Energy Laboratory, was mainly completed to present estimates of the potential benefits should the Solar America Initiative's (SAI) PV installation goals be achieved. The SAI (Solar America Initiative) goal is to install 5–10 GW of photovoltaic (PV) systems in the U.S. by 2015 and 70–100 GW of PV

systems in the U.S. by 2030. In this analysis, benefits were calculated for both high and low scenarios for the SAI goals based on the target installation costs and amount of PV installed. The scope of the report did not cover aspects such as estimating customer needs for solar and determining the optimal market mechanism that will drive installation cost reductions. The aspects researched in the report included environmental, energy, and economic benefits. In order to estimate the benefits, the analysis assumed that the SAI meets its PV installation goals. In terms of the benefits of energy, the report confirmed that PV installation will actually lead to a significant amount of electricity generation resources, which will then displace generation from more traditional sources. Moreover, in terms of the economic benefits, the report highlighted that reaching the goal of installation can stimulate a huge amount of economic activity as resources are directed toward solar-related industries. Another economic benefit would be an increase of \$2.9 to 9.1 billion, and 16,000 to 45,000 new jobs would be created. Furthermore, the successful completion of installing the PV through the SAI will lead to a reduction in the demand for natural gas, which will help reduce the price of natural gas in return. Finally, in terms of the environmental benefits, the analysis showed the health benefits that are expected as a result of solar generation goals. These benefits are summarized in reducing fossil fuel and fired electricity generation as well as reducing emissions (SO₂, CO₂, and NO_x).

Gautam et al. (2009) used a descriptive and analytical approach to test the validity of the hypothesis of the study, which is based on the fact that new and renewable energies can be invested in Nepal to compensate for the shortage of traditional energy sources. The study found that the future of renewable energy is promising, as it was shown through a comparison between conventional energy and new and renewable energy that

renewable energy equipment systems began to spread at the commercial level despite the relatively newness of this energy, and that the greatest spread is for wind energy as its cost has already begun to harmonize fossil energies.

Tim et al. (2010) examine how environmental factors and economic growth based on the green economy interact. The study demonstrated that environmental progress and economic growth based on the green economy must coexist. The study also demonstrated that sensible environmental regulations, which are a key component of green economy policies, can spur economic growth. The study also showed that economic growth, which is closely related to environmental health, boosts investment, generates employment, and raises output at both the industrial and natural resource levels. The study, which used a descriptive analytical approach, concluded that implementing green economy policies has a number of unintended consequences related to environmental awareness, which has clearly resulted in advancements in all spheres of life, particularly the economic one.

Min (2010) aimed to highlight the role of the carbon tax as a tool for achieving a green economy and to clarify its feasibility in the political context, social justice, environmental and economic effectiveness, and the extent to which there is a relationship between the green economy and the carbon tax. In his study, the researcher relied on surveys, interviews, and questionnaires. The study concluded that the carbon tax generally fits the current political context in Ireland. The environmental and economic effectiveness and social justice of the carbon tax are linked to the political orientation of the government, and in social justice, the energy, transport, agriculture, and rural communities sectors are the most affected by the

carbon tax, while the environmental effectiveness of the carbon tax Carbon is difficult to produce in the short term, and the researcher recommended increasing the environmental effectiveness of the carbon tax by spreading awareness about its importance, convincing the public of its feasibility, and making it socially equitable across each sector.

Alnaser and Alnaser (2011) listed the major renewable energy projects (mainly solar and wind) in the six GCC countries. The total capacity of these projects exceeds 600 MW. Among these projects is the establishment of the first zero-emission house (green house) in the Middle East, constructed in Bapco residence town (Awali) in Bahrain. The study highlighted that several projects in Building Integrated Photovoltaic and Building Integrated Wind Turbines are already established in GCC countries, as all GCC countries are planning to construct PV plants with large capacity. Due to the vast growth of development in infrastructure and investment in energy, electricity consumption in the GCC countries increased at a fast rate, 12.4% from 2005 to 2009. The study recommended that the GCC countries increase their electrical capacity by 60,000 MW, which represents 80% of the current installed capacity, to meet their demand in the future, as this rate is much higher than the world average due to the high electricity consumption rate. This means that there is a need to build 50 more gas-fired power generator plant turbines (each rated at 1400 MW). The study also discussed that the GCC countries have realized that depending on gas will not be the solution due to a shortage of resources and environmental impact; hence, diversity in electricity production is a must, and this can only be achieved by using renewable energy resources.

Stambouli et al. (2012) aimed to present a case study of solar energy in Algeria, in which the author touched on the uses of energy and its

ecological effects, highlighting in their study the relationship between economic development and sustainable development, leading to sustainable local development and the economic feasibility of using renewable energy. Finally, the author presented the development of solar energy, its fields of use, and its role in achieving sustainable development in Algeria.

A report of the original submission to the G20 Development Working Group by the AfDB, the OECD, the UN, and the World Bank assumed that green growth is necessary to achieve sustainable development and does not replace it (A Toolkit of Policy Options to Support Inclusive Green Growth, 2013).

Song (2013) claimed that for green growth to happen, environmental policies must be put in place that take environmental factors into account when making economic decisions. These policies should change energy systems, look for new ways to produce, supply, and use energy that are sustainable, include natural capital in economic calculations, and set prices for external environmental factors.

Ansari et al. (2013) create a structural model of the obstacles that India faces when putting solar power plants into operation. It has been determined that there are thirteen pertinent obstacles to installing solar power systems. An interpretive structural modeling (ISM) technique-based structural model of these obstacles to building solar power systems in India has been established after it was discovered that these barriers are related to one another in various circumstances. Barriers have also been categorized using MICMAC analysis according to driving power and reliance. There is one top-level barrier and six bottom-level barriers that have been discovered. The study offered several strategies for getting rid

of these obstacles. The study made clear that in order to prioritize and manage resources effectively and efficiently and enable the installation of the greatest number of solar power projects in India, organizations and government bodies would benefit from a better understanding of these constraints.

The 2014 Clean Energy Ministerial and International Renewable Energy Agency Report was written to add to the theoretical foundation for characterizing and comprehending the socioeconomic impacts of a large-scale deployment of renewable energy. The macroeconomic effects—which encompass a wide range of advantages like welfare, GDP, value added, and rising employment rates—were the primary emphasis of the report. A country would typically have a medium to high likelihood of creating value at the beginning of its renewable energy development, as the report's findings underscore the reality that these positive benefits actually depend mostly on the level of development of the nation's renewable energy sector. A robust quantitative analysis of the anticipated socioeconomic effects of solar and wind energy deployment was the instrument or method utilized in this report to evaluate the value creation prospects. This is necessary to enable well-informed policy choices. This tool makes sure that the public is informed of pertinent statistics and data and that the efficacy of policies is tracked. Additionally, in order to use this instrument, the countries must demonstrate that they have the institutional capacity to handle the data as well as the financial means to collect it. Additionally, in order to use this tool, it is necessary to first define and comprehend the variables that must be evaluated, such as GDP, employment, and so forth, as well as their primary attributes, which may include (net or gross; regional, national, or sub-national; obtained through simulation or optimization, etc.). Subsequently, the nation must determine whether the necessary inputs—resources, funds, data, time, and expertise—are truly

accessible. Policy decisions should be based on evaluating the influence of wind, solar, and energy deployment on value creation, according to the study's recommendations, which state that policymakers in the nation should apply value creation based on the state of renewable energy deployment at the moment and the local conditions.

Lukas (2015) utilized cross-sectional data for 60 nations in 2014 to study how the green economy contributes to sustainable development, job growth, and the eradication of poverty. The study concluded that while the average per capita national income index shows a favorable relationship between the green economy and economic growth, the global green economy index shows a negative relationship between the two. The study also revealed a substantial decline in the green economy's ability to lower unemployment and raise employment rates, but it did contribute to the reduction of poverty. The report advocated for more public and private spending with the goals of lowering carbon emissions, improving energy efficiency, and slowing down environmental deterioration.

The aims of the 2015 study from the United Nations Environment Program and United Nations Development Program were to clarify the role of the green economy in poverty eradication and to provide policymakers with a viable strategy to aid in the formulation and implementation of green economic projects. According to the report, in addition to building the poor's ability and protecting them from the harmful impacts of shocks and climate change, we must also allow the private sector to flourish and promote environmentally responsible industrial practices. The study's findings confirmed that the link between green economy efforts and poverty reduction is not always automatic. Furthermore, a poorly managed transition to a green economy has the potential to exacerbate poverty and

inequality. The study also reaffirmed the importance of integrating poverty-reduction policies so that they are thoroughly researched, well-integrated, and consider the circumstances of various nations and stakeholders while attempting to make up for lost time and lessen any unfavorable effects on the poor, as well as developing a long-term funding strategy and a monitoring and evaluation system.

Vaghefi et al. (2015) aimed to identify the extent to which the Malaysian economy is proceeding on the path of sustainable growth and the prospects for calculating the green GDP of Malaysia. Green GDP is in the process of theoretical study worldwide. The study also highlighted that no country has moved from traditional GDP to green so far due to a lack of data and an underestimation of economic losses. The study recommended the necessity of linking the environment and the economy to reach sustainable development through the inclusion of natural capital as an important economic asset. The study also stressed the need to achieve sustainable economic growth by promoting low consumption patterns, low inputs in production, and low emissions in all economic sectors. Moreover, the study recommended amending the national accounts from the traditional image to the green one through the establishment of a national database, the development of the accounting system, and the collection of more accurate and comprehensive data. Vaghefi et al. (2015) also carried out a study that year with the goal of determining the extent to which the green economy can improve economic life in Islamic nations by reducing poverty. The study explained how the green economy contributes to improving the economic situation of the countries that adopt it, whether developed or developing countries. The researcher recommended the necessity of adopting integrated strategies for the green economy in Islamic

countries to contribute to addressing many of the problems that these countries might be facing.

Schneide (2015) aimed to determine the relationship between the green economy and economic growth, employment creation, and poverty alleviation in Thailand in light of climate change and the lack of economic resources. The researcher conducted an analytical and standard study of the economic system in Thailand from 1994 to 2014 and drew the conclusion that the economic system based on random policies far removed from modern economic systems, such as the green economy, caused the economy to deteriorate. The study revealed that the succession of governments and the adoption by some of them of green economy policies and strategies resulted in significant economic growth, which led to the creation of more employment opportunities. The study revealed that adopting economic policies founded on the green economy significantly contributed to Thailand's economic revival. These relationships among the variables of the study were not strong in all the employed models, but they indicated the existence of a relationship between those variables. In order to accomplish an economic renaissance in developing countries, the study recommended adopting the green economy as an integrated economic system.

Aceleanu et al. (2015) aimed to investigate the unemployment situation in Romania, particularly juvenile unemployment. The researchers emphasized that human resources, the foundation of all progress and prosperity, have a significant impact on the sustainable development of any nation. In light of this, the researcher sought to identify the most effective means for addressing the unemployment problem. In the study, the researcher took an analytical approach by analyzing economic data before

and after the implementation of green economy policies. The study confirmed that the use of contemporary labor policies is connected to a planned economic reality founded on the green economy, which aims to eliminate the causes and effects of unemployment. Finally, the study confirmed that sustainable development founded on a green economy leads to prosperity and increases youth investment.

Bowen and Kuralbayeva (2015) sought to determine the employment impact of green growth. Using descriptive analytics, the researcher analyzed data pertaining to employment and economic conditions in numerous nations. The study revealed a number of claims and counterclaims regarding whether green development increases or decreases employment opportunities. It is currently impossible for policymakers to evaluate contradictory claims regarding the quality and quantity of green jobs, as the complete effects of environmental policies on employment pose a formidable obstacle. The study recommended conducting a comprehensive analysis of the impact of green policies in developing nations, accelerating international efforts to develop unified statistical standards for measuring green jobs, compiling national statistics on green jobs in countries, conducting a regular assessment of the rate of demand for workers in environmental services and resource management, assessing market impacts, and evaluating the potential work of green growth econometrics.

Eco-Union et al. (2016) intended to evaluate the green economy strategies developed by countries surrounding the Mediterranean by analyzing and evaluating the development strategies of the aforementioned nations. Nonetheless, it was observed that a number of sectors in these nations have not established objectives that align with the objectives of the

green economy and that there is no specific and comprehensive strategy for the green economy and sustainable development. According to their respective strategies, some nations, such as France, Italy, Morocco, Portugal, and Tunisia, have progressed towards a green economy. The study concluded that the countries of the Mediterranean basin still have a long way to go to implement the principles of green economy in their economies. In spite of this, these nations lack genuine implementation mechanisms. According to the study, many Mediterranean countries have not yet developed national strategies and policies that contemplate the green economy. The study recommended that countries improve their strategies by developing a common vision, goals, and specific procedures to monitor implementation progress, discontinuing support for unsustainable practices, avoiding the waste of natural resources, and increasing funding for the green economy through the establishment of green banks and a review of tax policies.

Martinez-Zarzoso and Grunewald (2016) attempted to identify the primary strategies that can contribute to the development of a green economy in three Latin American economies: Brazil, Chile, and Mexico. The researcher employed a descriptive analytic strategy to compare the green development strategies and accomplishments of the three nations. The study concluded that the three countries have made remarkable progress by identifying the institutions and systems required to pave the way towards a green economy; however, it is too early to assess whether initiatives and policies related to a green economy have been fully implemented and whether progress towards a green economy has resulted in an increase in welfare while preserving the environment.

Paramati et al. (2017) looked at the impact of renewable and non-renewable energy consumption on agriculture, industry, services, and overall economic activities (GDP) through a committee of the Group of Twenty countries. The study found a long-term relationship between the variables. Long-term resilience indicates that the consumption of renewable and non-renewable energy has a significant positive impact on economic activities in all sectors as well as on overall economic output. It also indicates that the impact of renewable energy on economic activities is greater than that of non-renewable energy. The study suggests directing policymakers to develop effective policies to transfer domestic and foreign investments into renewable energy projects. This ensures low carbon emissions and sustainable economic development across the G20.

In their study, Sharifzadeh et al. (2017) employed both descriptive and analytic methods to examine the relationship between the UK's economic development and the rising demand for electrical energy. In light of varying development rates, standard analysis was also used to estimate the future demand for petroleum products used in electricity generation. The study concluded that there are compelling reasons for the United Kingdom to concentrate on new and renewable sources of energy, the most significant of which is the scarcity of their natural resources of fossil energy in relation to the needs of future development. The study determined that nuclear energy is the most effective energy source for meeting future energy demands, followed by wind and solar energy. However, solar energy is the most profitable source.

Ahmed et al. (2017) highlighted Saudi Arabia's high annual per capita electricity consumption of 9000 kWh. This utilization is concentrated in the residential sector, and it is projected to double by 2025. Economic and environmental pressures necessitate a modification of energy consumption patterns through energy efficiency strategies. Currently, the stakeholders in the construction industry (contractors, investors, architects, and developers) do not rank energy conservation and other sustainable measures among their top priorities. In order to create a sustainable built environment, the conventional design process must be modified, and building energy modeling (BEM) must be incorporated from the outset. This study sought to quantify the energy and environmental savings that can be achieved by incorporating BEM into early-stage design decision-making. This was accomplished by conducting an industry survey to ascertain the current scope of BEM and to identify the technical and non-technical barriers to using BEM in the building designs of Saudi Arabia.

Alnaser and Alnaser (2019) evaluate the impact of the Bapco 5 MW solar PV grid-connected project on Bahrain's energy mix production and renewable energy outlook. Environmental impacts, economic impacts, business impacts, research impacts, and, most notably, the creation of green employment were highlighted in the study as some of the project's many positive outcomes. This initiative helped attract developers and investors to invest in Bahrain, particularly in the renewable energy sector, by demonstrating that Bahrain utilizes intelligent, environmentally friendly technology, as Bapco technology can power approximately 500 houses at 10 kW. The study also addressed numerous other topics, including greenhouse gases, the impact of particulates on the performance of installed PV, and the dependability of PV. In addition, the study revealed

that this implementation reduced CO₂ emissions by approximately 8,000 tons per year, assuming that 1 kWh of natural gas emits 1 kg of CO₂.

Amran et al. (2020) employ the inductive method to conduct a comprehensive review of prior studies pertaining to the subject of the study in order to determine the evolution of concepts pertaining to renewable energy. In addition to the inductive method, the variables of the study were analyzed deductively to clarify the role of renewable energy in achieving sustainable development. Using a standard model, the relationship between the role of renewable energy in accomplishing sustainable development was examined using the standard approach. In the study, the researcher also utilized the statistical program (EViews 7) to analyze and evaluate the impact of independent variables on the gross domestic product of the examined countries. The study recommended making the most of the current potential to improve the future, preserving and properly utilizing the existing energy supply, and preventing waste.

The Economic Times (2020) News article, which was published in the Economic Times, discussed the primary findings in the Environmental Performance Index report. In collaboration with the World Economic Forum, a team of researchers from Yale and Columbia universities created this report. Investing in the transition to renewable energy sources can have a positive effect on GDP, according to the report. In addition, the report explained that the adoption of renewable energy will result in the creation of approximately 7.19,000 new jobs and will contribute to the improvement of human welfare. According to World Bank findings, resource-efficient greening of India's economy and low emissions can be attained with minimal impact on GDP growth, as reported in the news article.

Sharif (2021) assessed the dynamic impact of solar energy consumption on ecological footprints by employing quantile-on-quantile (QQ) regression in the context of the top ten solar energy-consuming countries. The empirical analysis of the study demonstrates that, with the exception of India and the United Kingdom, the use of solar energy reduces ecological footprints at various quantiles for all sample countries. At higher quantiles of solar energy and lower quantiles of ecological footprint, the overall relationship is more pronounced. The bidirectional quantile Granger-causality analysis confirms that the ecological footprint has a positive feedback effect on solar energy. The empirical evidence presented in the study suggests that solar energy should be incorporated into the agenda for sustainable growth.

An article written by Mayur Misra highlighted that solar power has proven that it can be a solution to many of the world's problems in terms of energy, as it can actually help countries balance their economic security, energy security, and environmental sustainability. The article discussed how solar energy can have many benefits for any country, as it enjoys a low maintenance cost, reduces energy costs, is environmentally friendly, and increases property value. The article finally highlighted that due to the high demand for solar installation and the low prices, the capacity of solar power in India has grown from a meager 10 MW solar energy generation capacity in 2010 to around 30 GW in 2019 (Misra, 2021).

Gebreslassie (2021) used a descriptive and analytical approach to evaluate the reality of energy in Ethiopia. The study examined the possibility of local manufacturing of solar application technology and the viability of utilizing some solar energy system applications in Ethiopia. According to the study's findings, the current global energy system that

relies on fossil fuels cannot meet future energy demand. Consequently, there is worldwide interest in solar energy sources. In addition, the study concluded that there are insufficient policies and legislation to encourage solar energy investment in Ethiopia, as well as a lack of local manufacturing capabilities for solar equipment.

Majeed et al. (2021) analyzed the impact of disaggregated energy consumption, natural resource abundance, and economic globalization on environmental quality for GCC countries from 1990 to 2018. The study employed econometric techniques of the second generation. The primary findings of the study indicated that economic globalization and renewable energy aid in reducing emissions, whereas the profusion of natural resources enhances environmental quality. The focus of the study was on the role of energy intensity and green economic factors in achieving sustainable economic growth in Gulf states.

Despite the relative support of a large number of studies on the impact of green growth on energy sustainability and achieving sustainable development, there are many studies that discuss that the impact of green growth on the energy sector is uncertain, as the increasing demand for energy will lead to more use of fossil fuels, which are less expensive than renewable energy sources that require high production costs, and therefore green growth will face a challenge (Eicke & Weko, 2022).

Ofori et al.'s (2022) recent study conducted in Africa proved that green growth indicators have a weak impact on the energy sector in Africa, using long-term data for the period 1996–2013. This can be attributed to the fact that clean energy-based industries are not fully developed in Africa, the majority of Africa's exports are from extractive industries that

use low technologies to reduce environmental pollution, and strict adherence to environmental laws and regulations in Africa is conspicuously absent.

The objective of Raihan and Tuspekova's (2022) study clarifies the role of green national accounts in assessing economic development and the reality of Mexico's transition to a green economy. A mechanism that incorporates all sectors of the economy and begins with the most polluting sectors, using green economic incentives and green economy mechanisms, is proposed. The researcher recommended the need to support the green transformation process by increasing green investments, the need to provide the necessary support for this, and the need to raise awareness of the importance of the green economy, focus the transformation process on the most dynamic sectors with the impact of other sectors, increase investment in the renewable energy sector, take into account social costs when pricing goods and services, and create new ways to measure the green economy.

Sohail et al. (2022) emphasize the importance of implementing the policies and curricula advocated by the green economy. The researcher employed the descriptive analytic method in his study. The conclusion of the study was that the green economy plays an important and effective role on all environmental, social, and economic levels. The study found that in order to make things better, we need to create national and regional plans for energy efficiency, a national industrial policy that supports low-carbon industries and research, ongoing investments in transportation and water, a partnership between the public and private sectors to back green investments, and a portion of our tax money to go toward these things.

Ma and Cheok's (2022) explain the significance of adopting a green economy in establishing employment opportunities, preserving natural capital, and assisting developing nations in achieving food security and basic services such as water supply and disposal, as well as protecting natural resources. During his research, the author employed the descriptive analytical procedure. The study concluded that the transition towards a green economy necessitates reform of policies and legislation. The green economy is a new driver of economic development by creating green employment opportunities. Small and medium-sized businesses must also be redirected to meet the needs of the green economy in order for their green products to be commercially viable. The researcher advocated for the existence of enabling conditions for the green economy, such as the reform of legal regulations, policies, financial support, incentives, and legal and market structures, as well as the need to rehabilitate national small and medium enterprises as a major economic driver and to align their operations with the principles of the green economy.

Anam et al. (2022) discussed Bangladesh's rising energy demand, which is a result of the country's accelerated population growth and economic expansion. Therefore, solar energy has significant potential in Bangladesh's energy portfolio. The study identified and assessed the primary factors influencing the sustainable development of solar energy in Bangladesh, a developing economy in South Asia. The study used an integrated approach to find 12 factors that affect the growth of solar energy. It then used the best-worst method (BWM) to rank them by how important they were and the ISM-MICMAC to look at how they related to each other. Findings indicate that favorable geographical location in terms of solar irradiation, government policy toward sustainable renewable energy, the need to reduce greenhouse gas emissions, and the presence of large bodies

of water are the most influential factors in the sustainable development of solar energy in Bangladesh. This research is anticipated to make a systematic contribution to the literature on sustainable solar energy development, which will benefit both decision-makers and end-users.

EzzEldin et al. (2022) discussed the national renewable energy target of 5% by 2050 that Bahrain has established due to the high environmental and energy demand caused by the expansion of Bahrain's construction industry and residential buildings. The primary objective of the study was to examine the viability of installing rooftop photovoltaic systems in Khalifa Town residential structures. Using the software PVsyst and AutoCAD, this evaluation of the rooftop area and modeling of the PV system were conducted. Installing 17 kW PV panels on each of the 1,724 villas will help produce 44,953 MWh of solar electricity annually, which is sufficient to meet approximately 43% of the town's total electricity requirements. This installation will reduce CO₂ emissions by 34,794 tons, or approximately 21% of the total CO₂ emissions for the city. The study indicates that the payback will be 9.6 years if the government purchases each kWh of solar electricity for only 29 fils. The establishment of a feed-in tariff policy will also determine the payback period and, as a result, create more green employment and boost local PV manufacturing.

Tutak and Brodny (2022) discussed results on the degree of renewable energy use in selected sectors of the economy and households in the European Union countries between 2000 and 2019. The impact of the use of renewable energy sources on economic indicators and on the consumption of energy from conventional sources was also determined. Due to the different levels of economic development and wealth of countries, the study referred to groups of “old” and “new” European Union

countries. The study showed the concentration and dynamics of change in the consumption of renewable energy in the studied sector and households for individual countries and their groups. The Kohonen artificial neural networks were used to analyze similarities between the European Union countries in terms of the use of energy from renewable energy sources in the sectors studied. In addition, correlations were established between economic and environmental parameters for the whole economy, industry, and agriculture, forestry, and fishing sectors and the consumption of energy from renewable energy sources, as well as the impact of this energy consumption on the consumption of conventional energy. The study's results showed a significant increase in the consumption of energy from renewable energy sources in the European Union countries in the studied period, as well as significant differences in the use of this energy among the studied countries, their groups, and sectors. Also, it was found that renewable energy source-based energy consumption has a positive impact on economic growth, the reduction of greenhouse gas emissions, and the reduction of conventional energy consumption in practically all European Union countries. The results obtained indicate that this impact is greater in the “old” than in the “new” European Union countries. The methods used in the study were based on statistical data from the Eurostat database. These data covered the consumption of renewable energy in economic sectors and EU households. The sectors covered included the industry sector, transport sector, agriculture, fishing and forestry sector, commercial and public services sector, other sectors, and households.

Shang et al. (2022) indicated that the United States of America suffers from a large deficit in energy sources, despite the fact that it consumes about 25% of the total global fossil fuels annually and depends mainly on the import of oil from abroad, which negatively affects national

security and its economy. The study highlighted that the only source of fuel that could secure energy production in the United States for at most a century is coal, but its use represents a significant threat globally. Therefore, the study recommended moving towards the use of renewable energy, especially solar energy, to ensure energy production and partially preserve the environment.

Wang and Huang (2022) used the descriptive approach to emphasize that all countries in the world need to develop low-carbon economies in order to save the planet from climate change and its negative impacts and to create a future in which sustainable development is achieved. The study concluded that there are challenges to structural adjustment and the shift to a green economy that political actors agree on, such as a lack of political management and leadership, as well as a lack of comprehensive and understandable policies and efficient institutions in some nations.

Luan and Lin (2022) used the descriptive, quantitative, inductive, and deductive approaches, as well as the comparative approach, to test the hypothesis that the private sector will accept and invest in the solar industry, enabling it to manufacture the components of solar projects in China locally. The study found that there is a weakness in the sources of funding directed to solar energy investments, whether from the government or private sector. The study also summarized the lack of comprehensive strategies to finance renewable energy projects in China. Finally, the study monitored the intention of China towards the use of nuclear energy despite the risks of the explosion of nuclear reactors and the high costs of burying the waste from those reactors.

These studies concur on the vital and important role of the green economy at all economic, environmental, and social levels for humans in particular and the ecosystem in general, as well as the importance of striking a balance between economic growth and preserving natural resources and making optimal use of them without harming environmental components in order to preserve the rights of future generations. Some previous studies addressed the mechanisms of enabling the green economy on the ground, with some studies emphasizing the importance of developing the education and training sector to keep up with the needs of the green economy and others emphasizing the need to link small and medium-sized enterprises to the green economy because of their significant role in many economies around the world. To comply with the state's transition to a green economy, there was also a focus on the necessity of a gradual structural shift in a number of sectors.

On the other hand, numerous previous studies have also highlighted the vital and positive role of solar energy and its contribution to the green economy in achieving economic growth and job creation, thus contributing to the reduction of poverty and unemployment in both developed and developing nations.

Several previous studies advocated for the adoption of realistic, implementable, and consistent with international standards and agreements integrated strategies for the green economy. Several previous studies have examined how to measure the progress of the green economy by modifying the traditional national accounts and constructing the green national accounts, which incorporate the cost of environmental degradation into the calculation of the gross domestic product. Other studies corroborated the difficulty in studying the relationship between green growth and employment due to the lack of specific measurement frameworks for green

jobs and the inability to determine the effect of the green economy on regular jobs in the green economy. Nevertheless, it was evident from the aforementioned studies that solar energy adoption is essential, especially given the high electricity consumption. Even the slightest increase in any renewable energy category, such as solar photovoltaics, contributes to an increase in the gross domestic product of a country.

Chapter Three

Experiences in the field of solar energy and the green economy

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The present chapter focuses on the most significant foreign experiences with solar energy and the transition to a green economy to draw lessons from them.

The first section shows two examples of developed-nation experiences that have achieved a breakthrough in the utilization of solar energy: The United States of America and the Federal Republic of Germany. Section two illustrates two models of developing-country experiences, namely the People's Republic of China and the United Arab Emirates, where each strives to employ solar energy to prevent ecological degradation and excessive carbon emissions.

3.1 Models of the experiences of developed countries in the field of solar energy and the green economy

Developed countries are among those with an interest in research, development, and technical knowledge related to the solar energy industry (Keeley & Matsumoto, 2018). This is in light of the efforts of many nations to exploit their available solar energy potentials in order to contribute to meeting the demand for energy and reducing carbon emissions. In this section, the experiences of the United States of America and the Federal Republic of Germany will be addressed, since both countries are the forerunners among established nations in the use of solar energy and the transition to a green economy (Sueyoshi & Goto, 2014), as follows:

3.1.1 The experience of the USA

As a result of its increased vulnerability to climate change and its negative effects, the United States has become aware of the grave peril that threatens its security and exacerbates ecological degradation. As the energy sector is the largest contributor to greenhouse gas emissions, the state has devised strategies for adopting clean energy technologies that reduce greenhouse gas emissions and contribute to the transition to a green economy. Innovators and investors in the United States have made remarkable strides in developing and disseminating clean energy technology in recent years, with the support of the US government and its energy security and environmental protection policies. The United States has maintained its leadership in the market for concentrated solar thermal energy, ranking first in the world in terms of investment and second in the world, after China, in terms of total solar heating capacity, which has reached 16.7 gigawatts. With capacities of up to 18.3 gigawatts, it ranked fifth in terms of the total installed capacity of photovoltaic solar energy, behind Germany, China, Japan, and Italy (Pickett et al., 2020). The country's experience with solar energy has demonstrated the importance of creating favorable conditions for the development of renewable energy sources. The USA has realized that establishing robust policy frameworks is crucial for the widespread deployment of solar energy. The USA has also invested heavily in research and development (R&D) and has worked on collaboration between the government, private sector, and research institutions. Moreover, the USA has worked on educating the public about the benefits of solar energy and promoting awareness, which has been vital for its acceptance and adoption (Ginsberg & Fthenakis, 2018).

1) Solar potential in the USA

The United States of America has vast solar potential, as many states, particularly those in the southwest, experience a great deal of solar radiation. Approximately 2,700 hours of sunshine are averaged annually in the United States of America (Grossmann et al., 2014). Arizona is the sunniest state in the United States, receiving the equivalent of 1,9 billion megawatts per hour of solar radiation, with an annual average of 3,806 hours of sunshine (Majumdar & Pasqualetti, 2019).

2) Solar energy projects in the United States of America

The United States of America has more than 1,950 solar power stations, ranging in large, medium, and small sizes, in addition to tens of thousands of solar roofs that cover the roofs of buildings (Johlas et al., 2020). Table (1) and Table (2) represents the most important stations.

Table (1): The most important photovoltaic solar power stations in the United States of America

Station	State	Capacity / MW (Megawatts)
Solar Star Projects	Rosamond - California	579
Topaz Solar Farm	San Luis Obispo - California	550
Desert Sunlight Solar Farm	Riverside - California	550
Agua Caliente Solar Project	Yuma - Arizona	290
Copper Mountain Solar Facility	Boulder City - Nevada	250
California Valley Solar Ranch	San Luis Obispo - California	250
Antelope Valley Solar Ranch	Los Angeles - California	230
Mount Signal Solar	Imperial Valley - California	206
Centinela Sola Energy Project	Imperial Valley - California	170
Mesquite Solar Project 1	Sonoran Desert - Arizona	150

Table (2): The most important solar thermal energy stations in the United States of America

Station	State	Capacity / MW (Megawatts)
Ivanpah Solar Electric Generating System	Mojave Desert- California	392

Solar Energy Generating Systems (SEGS)	Mojave Desert- California	354
Solana Parabolic Trough plant	Maricopa - Arizona	280
Mojave Solar Project	Barstow - California	250
Genesis Solar Energy Project	Blythe - California	250
Crescent Dunes Project	Tonopah - Nevada	110

3) Solar energy as a mechanism for the transition towards a green economy in the United States of America

The energy sector in the United States is the primary source of greenhouse gases (Laird, 2011). Approximately fourteen states in the United States are devising programs and strategies related to clean renewable energy, particularly solar ones, in order to reduce carbon emissions and transition to a green economy. Within the framework of the United States plan on climate change, the US Department of Energy has allocated approximately 53 million dollars to support 40 institutions specializing in research, development, and innovation in the field of solar energy in order to reduce the production costs of solar energy, which are reflected in its prices and degree of spread (Song et al., 2018).

The US Department of Energy's "SunShot" initiative aimed to make solar energy prices competitive with fossil energy prices by working to reduce solar energy prices by 75% between 2010 and 2020. This contributed to increasing solar energy's contribution to meeting the demand for electricity in the United States of America, reducing approximately 28% of greenhouse gas emissions by 2050, and then contributing to the transition to a green economy (Ho et al., 2014).

In an effort to transition to a green economy and reduce carbon emissions, the United States has sought to apply and benefit from

renewable energy technologies, particularly solar energy, in a manner that ensures energy security and prevents ecological degradation. Consequently, the country has been able to inaugurate a large number of photovoltaic and thermal solar energy stations, which contributes progressively to achieving its green economy transition strategy (Crespi et al., 2019). The United States' total solar capacity contributes to the transition to a green economy by reducing carbon emissions by approximately 16.8 million metric tons per year (Crespi et al., 2019).

3.1.2 The experience of Germany

Germany's per capita carbon emissions are among the highest in the European Union, given that its economy is one of the largest in Europe. (Weber & Cabras, 2017). This prompted the German government to develop plans to increase renewable energy's share of electricity production to 50 percent by 2030. It is possible that the early 1990s subsidy policy increased the economic attractiveness of the use of clean energy, particularly solar energy, as the government began implementing the feed-in tariff program, which guarantees a fixed tariff for the use of solar energy per kilowatt hour for more than 20 years, with a 5% tariff reduction for new systems (Azevedo et al., 2021).

Germany has occupied the leading position in the world in the installed capacities of solar photovoltaic energy for several consecutive years, as the total installed capacity reached 38.5 gigawatts distributed over about 1.5 million photovoltaic systems throughout the country, starting from solar roofs on rooftops to large solar power stations, which made it superior to its international competitors in the field of solar energy such as China, Japan, and Italy. This raises the percentage of the contribution of renewable

energies in the energy structure in Germany to more than 31%, and the government aims to reach the percentage to 35% by the end of the current decade. Germany has been a global leader in solar energy deployment, and its success can be attributed to several key factors such as: Feed-in Tariffs, enacting the Renewable Energy Act (EEG) in 2000, implementing a net metering policy, investing significantly in research and development for solar energy technologies and finally fostering a culture of public awareness and acceptance of solar energy (Weber & Cabras, 2017).

Figure 4 shows the installed capacities of photovoltaic solar energy exceed those of other energy sources in Germany.

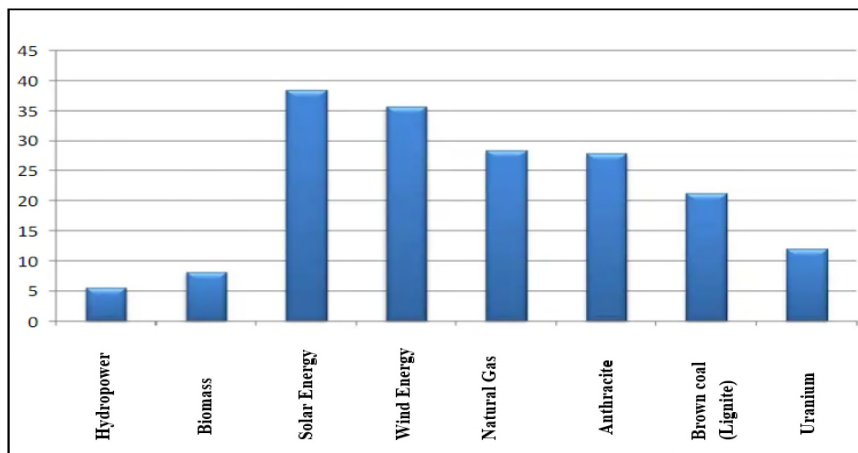


Fig. 4: Germany's net installed energy capacity (In Gigawatts)
(Wehrmann, 2022)

In addition, approximately two-thirds of Germany's current primary energy consumption is dependent on imports of coal, natural gas, and uranium; therefore, the shift toward the use of renewable energies will contribute to a reduction in German imports of fossil and nuclear energy, which will have a positive impact on the state's trade balance, in addition to avoiding fluctuations and high oil and gas prices (Lux et al., 2022). Additionally, it lessens the economic mobilization of countries that

produce oil and safeguards the environment from contamination due to the use of fossil fuels (Ferguson-Cradler, 2022).

As a consequence of the 2011 Japanese nuclear disaster at Fukushima, a new evaluation of the safety and security of German nuclear reactors was conducted. Accordingly, eight of the seventeen oldest nuclear reactors were shut down, and the German Parliament approved a timeline according to which the remaining reactors will be shut down by 2022, after which Germany, which generates 17% of the world's nuclear power, will abandon nuclear energy. In exchange, solar and wind energy use is expected to rise (Weber & Cabras, 2017).

1) Solar potential in Germany

The annual average number of hours of sunshine in Germany is approximately 1,550 (Ramirez Camargo et al., 2018). Therefore, Germany is not deemed a sunny country. Its solar radiation is approximately one thousand kilowatts per square meter per year, and it increases as one travels south (Schnaars, 2022). Bavaria is the German state with the highest average number of sunshine hours, which can reach 1,709 hours per year (Ziegelmann et al., 2000).

Additionally, Germany relies on the production of solar energy through photovoltaic solar energy technology, as this is the most prevalent method. On sunny days, photovoltaic panels can cover up to 35% of the country's total electricity demand, and on national holidays, this number can reach 50%. There is also solar thermal energy technology in Germany, but it is less prevalent than solar photovoltaic technology (Wainer et al., 2022).

2) Solar energy projects Germany

Numerous solar energy projects exist in the Federal Republic of Germany, as photovoltaic panels are dispersed throughout all German states in the form of large, medium, and small stations, in addition to the solar roofs dispersed on the roofs of government, residential, and commercial buildings, which contributes to the reduction of high carbon emissions and the subsequent transition to a greener economy. (Kockel et al., 2022). Table (3) shows the most important stations.

Table (3): The most important photovoltaic solar power stations in the Federal Republic of Germany

Station	State	Capacity / MW (Megawatts)
Meuro Photovoltaic Power Station	Brandenburg	166
Neuhardenberg Solar Park	Brandenburg	145
Templin Solar park	Brandenburg	128.5
Briest Solar park	Brandenburg	91
Finow Tower Solar park	Berlin	84.7
Eggebek Solar park	Holstein-Schleswig	83.36
Senftenberg Solar park	Brandenburg	82
Finsterwalde Solar park	Brandenburg	80.7
Lieberose Photovoltaic park	Brandenburg	71.8
Alt Daber Solar park	Brandenburg	67.8

3) Solar energy as a mechanism for the transition towards a green economy in Germany

The Federal Republic of Germany is taking on a global leadership position in climate policies and the reduction of global warming, as the country is committed to the Kyoto Protocol, agreements to enhance biological diversity and reduce carbon emissions, and programs to expand the use of renewable energy (Sheykhha et al., 2022). Germany is

considered one of the first industrialized nations to realize that a clean economy based on natural resources is the best engine of progress, and it was able to reduce the volume of carbon emissions by 25% by 2012 compared to its theory in the 1990s; thus, it was able to reduce the volume of emissions at a greater rate than required by the Kyoto Protocol, which required Germany to reduce its emissions by 21% from their size in the 1990s (Eerma et al., 2022). In 2013, renewable energy in Germany contributed to the elimination of 146 million kilograms of carbon dioxide, thereby reducing carbon emissions (Croonenbroeck & Hennecke, 2020).

Figure 5 shows the percentages of the contribution of renewable energy sources to reducing carbon emissions in the Federal Republic of Germany in 2013.

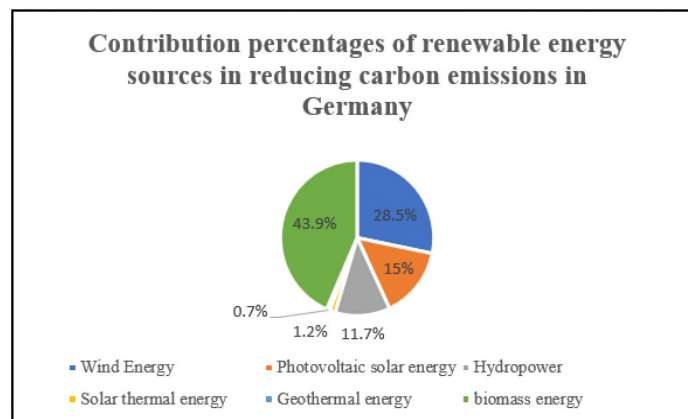


Fig. 5: Contribution percentage of renewable energy sources in reducing carbon emissions in Germany
(Wehrmann, 2022)

The plan for transitioning to a green economy includes a long-term objective to reduce carbon emissions by 80 percent by 2050, with renewable energies contributing 80 percent to electricity generation in the same year, and then achieving a quantum leap in the process of transitioning to a green energy-based clean economy. While the

government aims to produce 35 percent of its energy requirements from renewable sources by 2020 and 50 percent by 2030 (Eerma et al., 2022).

The German Federal Environment Agency “Umweltbundesamt” has outlined a three-pronged transition strategy to a green economy. First, all nations strive to maximize their use of renewable energy sources. Second, the state-to-state exchange of available renewable energies ensures that each state's deficit is offset by the surplus of the other states. Finally, energy imports from neighboring countries are minimal. The Authority believes that carbon emissions can be reduced to their lowest levels using this strategy (Sheykhha et al., 2022).

3.2 Models of the experiences of developing countries in the field of solar energy and the green economy

The innovation of modern technology and investment in research and development are no longer the exclusive domain of developed nations, nor is the use of renewable energy their exclusive domain. Rather, developing countries seek to increase the proportion of renewable energy in their energy structure, thereby contributing to the gradual security of energy and limiting the associated ecological degradation (Ghosh et al., 2022). In this section, the experiences of the People's Republic of China and the United Arab Emirates will be discussed, as they are among the developing nations with the greatest increase in their carbon footprint but also among the nations seeking to expand their use of solar energy in order to transition to a green economy, as follows:

3.1.1 The experience of China

China has sought to achieve its goal of rapid development over the past several decades, growing by an average of 10% per year and becoming the second largest economy in the world. However, this rapid growth has resulted in pressures such as the deterioration of the ecosystem and the increase in greenhouse gases, as China is currently the largest contributor to global greenhouse gas emissions. In comparison to 2005 levels, the government was able to reduce its carbon emissions by 40% to 45% by 2020, and it plans to increase its consumption of renewable energy to 15% in the near future (Huang et al., 2022).

In 2009, the government announced that it would support solar energy systems by bearing about 70% of the prices of those systems in order for this industry to grow, making it competitive with energy generated from fossil fuels, particularly coal, in the future. China dominated the list of countries investing in renewable energy as a whole by the end of 2014 and now has approximately a quarter of the world's renewable energy capacity. China ranked first in photovoltaic solar energy investments and second in total installed capacities, behind the Federal Republic of Germany, with capacities of up to 28.2 gigawatts (Li et al., 2019). China currently produces approximately two-thirds of the world's photovoltaic panels and ranks first in solar thermal capabilities. Both the photovoltaic and solar heating industries have created a large number of new jobs in China (Hu et al., 2022).

China's success in becoming a global leader in solar energy deployment can be attributed to its ambitious renewable energy goals, substantial investments, and favourable policies. China has worked to establish ambitious renewable energy goals, including specific goals for solar energy installation capacity. This industry lacks a long-term vision. In addition,

the Chinese government implemented a variety of policies to encourage the development of solar energy, including feed-in tariffs, subsidies, and tax incentives. Additionally, China has made substantial investments in research and development (R&D) for solar energy technologies. In addition, China acknowledged the significance of constructing the necessary infrastructure to support the deployment of solar energy. This included investments in transmission lines and grid enhancements to facilitate the increasing incorporation of renewable energy sources. China took advantage of its manufacturing prowess to realize economies of scale and reduce the price of solar panels. China was able to make solar energy more affordable and accessible by becoming the world's largest manufacturer of solar panels, thereby lowering prices globally. China actively engages in international collaboration and partnerships in order to learn from the experiences of other nations and impart its own expertise. This knowledge and technology exchange have contributed to the global development of solar energy. Lastly, China's approach to long-term planning provided investors with stability and predictability, which helped to attract significant domestic and international investments in solar energy projects. This stability nurtured industry confidence and facilitated its rapid expansion (Huang et al., 2020).

1) Solar potential in China

Most Chinese provinces receive an abundance of solar radiation, as the sun beams brightly in China. More than two-thirds of the country's land area receives approximately 2,200 hours of annual sunshine on average. The annual average number of hours of daylight in Qinghai Province is 3,500, making it the province with the most sunshine. The solar radiation in China is approximately 5,860 megajoules per square meter per year, and

depending on its solar capabilities, approximately 90% of China's needs can be met (Huang et al., 2022).

2) Solar energy projects in China

China's total installed photovoltaic solar capacity reached 28.2 gigawatts by the end of 2014, and the country can produce about 25 billion kilowatt-hours of electricity annually using photovoltaic panels, of which 80% comes from major stations and 20% from solar roofs on government, residential, and commercial buildings. (Dai et al., 2022). Nonetheless, the solar thermal energy sector's contribution to China's electricity production is limited (Teng et al., 2022). In this context, Table 4 shows the most important stations.

Table (4): The most important photovoltaic solar power stations in the Republic of China

Station	State	Capacity / MW (Megawatts)
Longyangxia Hydro - Solar Station	Shanghai	480
Huanghe Golmud Power Plant	Golmud - Shanghai	200
Gonghe Industrial Park Phase 1	Gonghe - Shanghai	200
Xiangshui Solar Station	Jiangsu	100
Chengde Park, Phase 1,2	Chengde - Hebei	100
Jiayuguan Power Plant	Jiayuguan - Gansu	100
Ningxia Qingyang Solar Park	Ningxia	100

Table (5): The most important solar thermal energy stations in the Republic of China

Station	State	Capacity / MW (Megawatts)
Erdos Solar Power Plant	China's Inner Mongolia Autonomous Region	50
Jinshawan Solar Updraft Tower	Wuhai - China's Inner Mongolia Autonomous Region	27.5

Delingha Supcon Tower Plant	Delingha - Shanghai	10
Badaling Solar Power Tower	Beijing - Shanghai	1.5
Dahan Solar Power Tower	Badaling Yanqing - Beijing	1

3) Solar energy as a mechanism for the transition towards a green economy in China

The Chinese economy is the largest energy consumer in the world, as it relies heavily on fossil fuels to meet nearly 90% of energy demand, and coal accounts for more than 70% of China's energy structure, leading to water and air pollution and a significant increase in greenhouse gas emissions (Dai et al., 2022). In 2008, the World Health Organization ranked seven Chinese cities, including Beijing, among the ten most contaminated in the world due to the excessive use of coal in industrial processes, which accounts for 80 percent of carbon emissions in China (Runqing et al., 2012). The expansion of renewable energy use is anticipated to play a significant role in reducing carbon emissions and contributing to the transition towards a green economy. Therefore, the government aims to increase the proportion of renewable energy in China to 15 percent by 2020 and 30 percent by 2050 (Wu et al., 2022).

According to the "Development Plan for the Emerging Renewable Energy Industry" report, China aims to invest between 2 and 3 trillion Chinese yuan in renewable energy sectors, excluding hydroelectric power, by 2020. This has helped China achieve its goal of reducing carbon emissions by 40% to 45% by 2020 from 2005 levels (Wu et al., 2022). The green economy in China creates a new path for economic growth; this growth includes the creation of many green jobs and the strengthening of the balance of payments through the expansion of exports of renewable

energy products, particularly solar and wind energy (Yu-Ling Hsiao et al., 2021). With the goal of preventing ecological deterioration and China's belief in the need to transition to a green economy, the nation has endeavored to use solar energy extensively by launching a large number of photovoltaic and thermal solar power stations (Chen et al., 2014).

3.1.2 The experience of the UAE

Since the foundation of the United Arab Emirates in 1971, energy and natural resource concerns have been intimately tied to the country's development and growth (Qamar & Janajreh, 2016). Today, sustainable energy has become a central component of the nation's efforts to foster economic, social, and environmental growth, as well as the primary driver of sustainable development and environmental protection. The UAE holds a prominent position in the global energy sector, which is experiencing growth and rising demand, and it can maintain its leadership position in this vital sector by diversifying its energy mix to include renewable energy sources, as investment in these sources is essential for countries whose economies are highly dependent on fossil fuels. Currently, the UAE is a global leader in solar energy, and climate change matters. These efforts culminated in the UAE hosting the International Renewable Energy Agency's headquarters in Abu Dhabi. With a total capacity of 100 megawatts, the UAE is ranked fourth in the globe in terms of the total installed capacity of concentrated solar thermal energy, behind Spain, the United States of America, and India. Abu Dhabi and Dubai aimed to generate 7% of their electricity from renewable sources by the year 2020 (Salameh et al., 2022).

The UAE's leadership has a distinct vision for renewable energy and sustainable development. The UAE understood the potential of solar energy and established ambitious goals to diversify their energy balance and reduce their reliance on fossil fuels. The UAE has made substantial investments in research and development to advance solar technologies. This allowed the country to develop efficient and cost-effective solar technologies. To promote solar energy adoption, the UAE fostered robust partnerships between the public and private sectors. This partnership enabled the development of large-scale solar initiatives and attracted international companies and expertise to the region. In addition, the UAE has invested in the infrastructure required for the integration of solar energy into the grid. This involved the construction of solar parks, the establishment of transmission networks, and the implementation of smart grid technologies. The UAE has also implemented solar energy deployment-supportive policies, regulations, and incentives. These included feed-in tariffs, net metering, customs duty, and tax exemptions for renewable energy equipment. The sector attracted investment due to the sector's clear and consistent regulations, which provided certainty and fostered investment. Through training programs, partnerships with educational institutions, and collaboration with international organizations, the country also aimed to develop indigenous expertise and knowledge in solar energy. This contributed to the development of a competent workforce and innovation in the renewable energy industry. Finally, the UAE actively engaged in international collaborations and partnerships to exchange knowledge, share best practices, and leverage global expertise in solar energy. The UAE recognized solar energy's economic benefits in addition to its environmental sustainability. It fostered the development of a robust solar industry, attracting investments, creating employment, and

enhancing the nation's competitiveness in the renewable energy sector (Abuzaid et al., 2022).

1) The solar potential of the UAE

The UAE is characterized by their mild climate, which provides an ideal environment for the production of solar energy, as the country receives an average of ten hours of sunlight per day (Ghaith & Abusitta, 2014). The UAE experiences approximately 350 days of sunshine a year, making it one of the countries with the highest solar potential. The total solar radiation received by the country is approximately 6.5 kilowatt hours per square meter per day, making the UAE a solar energy resource-rich nation (Eveloy & Ahmed, 2022).

2) Solar energy projects in the UAE

Solar energy can be generated in the UAE through solar photovoltaic technology as well as solar thermal energy (Ghaith & Abusitta, 2014). Table (6) shows the most important stations.

Table (6): The most important current and future photovoltaic and thermal solar energy stations in the United Arab Emirates

Station	State
Shams 1 solar thermal power station	Abu Dhabi
Sheikh Bin Rashid Al Maktoum Solar Photovoltaic Complex	Dubai
The ten-megawatt solar photovoltaic plant	Abu Dhabi
Noor 1 solar photovoltaic plant	Abu Dhabi

Noor 1 solar photovoltaic plant	Abu Dhabi
Floating islands of photovoltaic solar energy	Ras Al Khaimah

Masdar City is an excellent example to reference, as it can be evaluated for internal implementation. Based on Abu Dhabi Economic Vision 2023, the emirate intended to transform its economy from one based on natural resources to one based on knowledge and innovation, so it established the "Masdar Initiative" as a special economic zone. It works to ensure that the renewable energy sector can play a crucial role in this diversification of the knowledge-based economy (Ibrahim, 2016). Through its five integrated units, the Masdar initiative endeavors to elevate Abu Dhabi's standing as a global center of excellence in the energy sector (Griffiths & Sovacool, 2020). The first element consists of the Masdar Institute of Science and Technology, an academic institution for postgraduate research that focuses on alternative energy science and engineering, environmental technologies, and sustainability. The second division, "Masdar Investment," aims to construct a portfolio of leading renewable energy firms and prospective clean technologies. It also aids in the growth and development of some businesses by providing the necessary capital and expertise. The third division, Masdar Carbon Management, is responsible for managing initiatives that reduce carbon emissions by increasing energy efficiency, importing waste heat, and capturing and storing carbon dioxide. The fourth division, "Masdar Energy", develops and operates renewable energy initiatives and participates in numerous international renewable energy projects. Abu Dhabi's "Masdar City" is the location of the fifth facility. Since 2006, its establishment has been in progress. The city encompasses approximately 6 square kilometers (Ibrahim, 2016).

Masdar City obtains all of its energy from renewable sources, particularly solar energy. The walls of the Masdar Institute are comprised of airbags made of a plastic material that insulates against the air's heat, and the roof of the institute is covered with photovoltaic panels that generate electricity while shading the building and the roadways (Griffiths & Sovacool, 2020). As part of its solar energy utilization strategy, Masdar City utilizes solar-powered electric vehicles. The "ten-megawatt solar power generation" facility was inaugurated in 2009 in Masdar City on an area of 210,000 square meters, with a total capacity of ten megawatts and approximately 88,000 photovoltaic panels. The plant supplies the construction works in Masdar City with the necessary electricity, and the surplus, which constitutes 40%, is transmitted to the local Abu Dhabi electricity network. This station contributes to the transition to a green economy by annually reducing carbon emissions by approximately 15,000 metric tons (Elchalakani et al., 2014).

3) Solar energy as a mechanism for the transition towards a green economy in the UAE

The UAE is one of the world's top energy consumers due to its population growth, industrial and commercial expansion, and economic and social development. It is also the second-largest electricity consumer in the Gulf region, after the Kingdom of Saudi Arabia, accounting for 19% of total consumption (Abuzaid et al., 202). The UAE has recognized the danger of excessive energy consumption, which results in a high carbon footprint and ecosystem degradation, as well as the depletion of oil resources and the negative impact of the increasing import of natural gas

on the balance of payments, as natural gas accounts for approximately 97% of its energy structure. In accordance with its energy strategy, the state aims to produce 24% of its electricity requirements from oil energy sources by 2021 (Rahman et al., 2021).

Dubai's dearth of substantial natural gas reserves forces it to import the majority of its fuel requirements from international markets in order to generate electricity. The Ministry of Environment and Water launched the "Environmental Footprint in the UAE" initiative in 2007 and announced the "Dubai Integrated Energy Strategy 2030" in 2011, which calls for reducing dependence on natural gas by increasing the production of electricity from other sources, such as clean coal, nuclear energy, and solar energy (Abuzaid et al., 2022), as represented graphically in Figure 6.

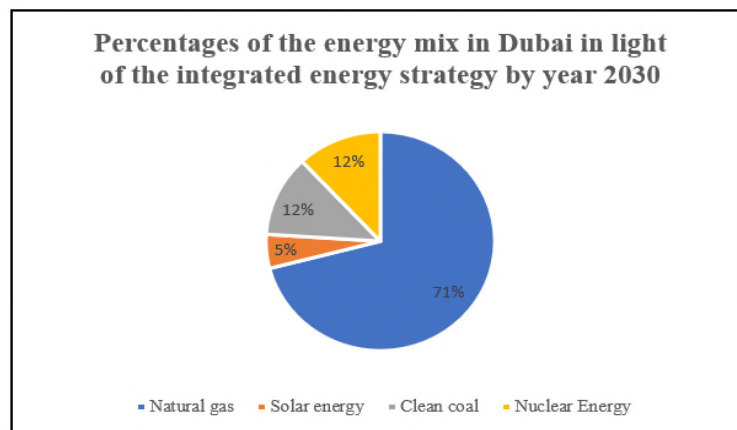


Fig. 6: Percentages of the energy mix in Dubai in light of the integration energy strategy by year 2030
(Abuzaid et al., 2022)

To achieve Dubai's aim of meeting 5% of its electricity needs with solar energy by 2030, the Sheikh Mohammed bin Rashid Al Maktoum Complex will be inaugurated by 2020. Dubai has targeted a 16% reduction in carbon emissions from all sectors by 2020. In the context of its efforts to become the world's capital of the green economy, 50% of this goal is contingent on the expansion of solar energy use (Khan et al., 2021).

The energy sector in the Emirate of Abu Dhabi is the largest contributor to greenhouse gas emissions, which amounted to approximately 99 million tons in 2010, with the energy sector alone accounting for 72 percent. This has led to a significant increase in attention to environmentally harmful gas emissions in recent years within the framework of the "Green Economy for Sustainable Development" initiative, as Abu Dhabi seeks to reduce carbon emissions from electricity production operations (Islam et al., 2009).

In order to shift towards a green economy based on clean energy and reduce carbon emissions, the UAE has sought to launch many of its solar power plants, which contribute to the transition towards a green economy (Khan et al., 2021). As mentioned previously, Shams 1 solar thermal power plant contributes to reducing carbon emissions by about 175 thousand metric tons annually, and Sheikh Mohammed bin Rashid Al Maktoum Solar Photovoltaic Complex contributes to reducing carbon dioxide emissions by about 14 thousand metric tons annually. It is to highlight the fact that the solar roofs spread on some buildings contribute to reducing carbon emissions, such as those used by the Dubai Electricity Authority with a capacity of 700 kilowatts, as well as some residential and commercial buildings in the Equestrian Square in Dubai with a capacity of up to 600 kilowatts, and the roof of the Masdar Institute building is covered with solar roofs in the Emirate Abu Dhabi with a capacity of 1 gigawatt. The country is still continuing its plans and projects related to the use of solar energy, and that is by launching more stations such as Noor 1 and Noor 2 for photovoltaic solar energy in Al Ain, Abu Dhabi (Islam et al., 2009). Masdar City is considered the first city in the world to be completely devoid of carbon emissions and the closest city to a green economy, as it

relies entirely on renewable sources. CO2 emissions in the UAE and thus contributes to the transition towards a green economy (Griffiths & Sovacool, 2020).

The lesson learned from the experiences of the four countries are summarized below:

- A. United States of America: The USA's experience with solar energy has underscored the importance of combining supportive policies, research and development, public-private partnerships, grid integration, and public awareness to drive its successful implementation. These lessons can be a guide towards the transition to a more sustainable and renewable energy future.
- B. Federal Republic of Germany: Overall, the key lesson from Germany's experience with solar energy is the combination of strong government policies, such as feed-in tariffs, supportive regulatory frameworks, and consistent incentives, coupled with public awareness and acceptance which can create an environment conducive to the rapid growth and adoption of renewable energy technologies.
- C. People's Republic of China: It is important to note that China's experience is unique and may not be directly applicable to every country due to varying factors. Nonetheless, the lessons learned from China's success in applying solar energy can still be valuable in terms of developing the renewable energy sector.
- D. United Arab Emirates: The UAE's successful application of solar energy highlights the importance of long-term vision, supportive policies, infrastructure development, capacity

building, and international cooperation. These lessons can be valuable for the adoption of solar energy and transition to a more sustainable energy future.

Chapter Four

Solar energy and green economy in the Kingdom of Bahrain

Chapter Four

Solar energy and green economy in the Kingdom of Bahrain

Oil and natural gas have dominated the economy of the Kingdom of Bahrain for a number of decades. The Kingdom, along with the Gulf Cooperation Council (GCC) nations, was concerned about the long-term sustainability of its hydrocarbon revenues, as oil and gas reserves would eventually deplete; this prompted the government to develop strategies to diversify the Bahraini economy and to encourage investments in clean energy to promote green economy (Hamdi & Sbia, 2013). From this prospect, this section will provide an overview of the Kingdom's location, sustainable energy agenda, a summary of the Kingdom's position in regards to solar energy and the green economy, the current solar technology and investment in clean energy projects, the potential of solar energy in the Kingdom of Bahrain and the Kingdom's economy.

4.1 Location

The Kingdom of Bahrain is located at 26.24°N and 50.8°E. It is in the region of the earth between latitudes of 40°N and 40°S; that region is referred to as the “solar belt”, where an abundant supply of solar irradiation falls. Bahrain has a strong solar energy performance indicator due to its abundant insolation (EzzEldin et al., 2022). The Direct Normal Irradiance (DNI), which is helpful for Concentrating Solar Thermal Power (CSP) systems, is about 2,050 kWh/m²/year, while the Global Horizontal Irradiance (GHI), which specifies the average energy yield from photovoltaic power systems, is about 2,120 kWh/m²/year. Bahrain enjoys abundant insolation, which results in a high solar energy performance indicator (Solar Resource Maps of Bahrain, n.d.).

The high rate of expansion in economic activities and population has led the country to witness a high rate of annual growth in electricity consumption. From this perspective, the need to invest in and develop renewable energy, especially solar energy, has emerged (“Bahrain Economic Quarterly, Q1,” 2022)

4.2 Bahrain's Sustainable Energy Agenda

The Kingdom of Bahrain is dedicated to meeting its national and international commitments in regards to the development of sustainable energy as per Figure 7.

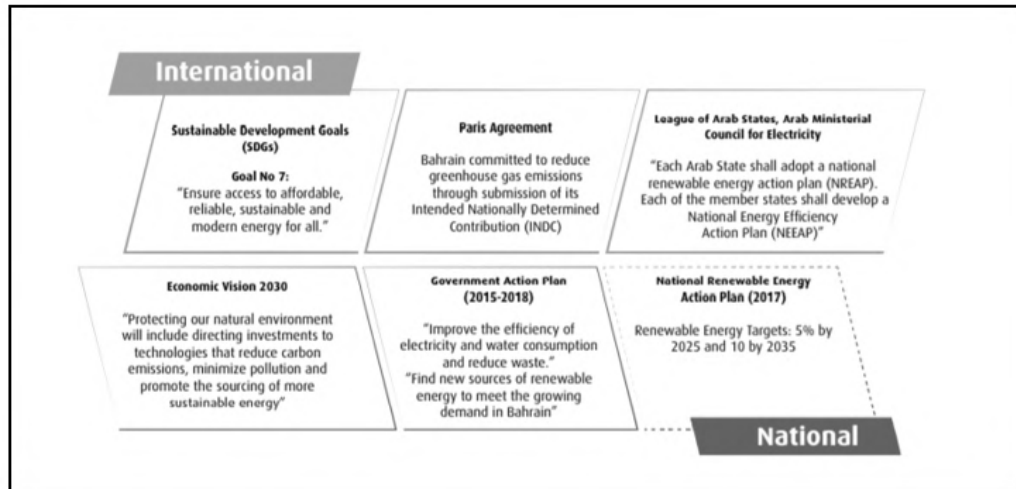


Fig. 7: Bahrain's International and National commitments
(National Renewable Energy - Action Plan (NREAP), 2017)

4.3 Solar energy and Green Economy in the Kingdom of Bahrain

To assess the ability to adopt solar energy in Bahrain's economic sector in order to achieve sustainable development, it is necessary to understand the significance of the green economy in Bahrain, which the United Nations Environment Program defines as an economy that improves human well-being and social equality while significantly reducing environmental risks and ecological resource scarcity (Munawwar & Ghedira, 2014). It is also known as an economy that reduces carbon emissions, improves the efficacy of resource use, and distributes resources fairly among generations (Bachbellerie, 2012).

Since the modern global capitalist economy has let people down many times, its crises are happening faster and more often, and globalized capitalism hasn't been able to find radical solutions to these problems, like markets collapsing, food prices going up, water shortages and bad quality, and changes in the weather, people are becoming more interested in this idea and how it can be used. Based on this importance, the World Council for the Green Economy (WGEO) was established in the United States of America in 2004 with the aim of promoting green investment, consolidating green culture, maximizing resource efficiency, and preserving the right of future generations to a decent life in various parts of the world (Pillai & Naser, 2018). Numerous regional and international conferences and forums have been held to examine its various contents, including the 2019 Middle East and North Africa Forum on Green Economy, which took place in the Kingdom of Bahrain from (2-4) July, 2019, and was organized by the Supreme Council for the Environment and the World Council for Green Economy. It aimed to introduce the significance of the green economy and expand its role and scope of work in achieving sustainable development, which includes three main areas: the theme of improving regulatory rules and public policy frameworks to reduce the risks of green investment, the theme of encouraging innovative green investment through partnerships between the public and private sectors, and the theme of advancing capacity development at the national level for comprehensive environmental management (Lunning, 2022).

On the executive level of the Kingdom's directions towards green economy, on February 27, 2020, the Labor Fund “Tamkeen” signed a joint cooperation agreement with a number of banks in the Kingdom to expand support services within the scope of the enterprise financing program, in order to enable institutions wishing to obtain financing for the purchase

and installation of solar panels to generate energy, in addition to subsidizing the cost of auditing solar energy accounts in a way that encourages companies and small and medium enterprises to take the initiative to invest in sustainable and clean energy projects (Tamkeen Launches the Solar Financing Scheme as Part of Its Tamweel Scheme to Help Organizations Save on Energy – Tamkeen, 2020). This agreement falls within the goals of sustainable energy based on two main objectives: increasing the utilization of renewable energy, raising energy efficiency, and rationalizing its consumption (Lunning, 2022). Moreover, this agreement will contribute to achieving the national goals adopted by the Government of the Kingdom of Bahrain to reach 5% of renewable energy out of total energy by 2025 and 6% of energy efficiency improvement (Pillai & Naser, 2018).

The repercussions of the Corona pandemic (Covid-19) came to enhance the importance of the green economy and the inevitability of expanding its adoption and adopting sustainable development practices for various economic sectors in the Kingdom, including the financial and banking sector, which plays a major role in finding the appropriate financing base for green economy projects (Hesselman et al., 2021).

The Kingdom of Bahrain has been keen to pay attention to renewable and alternative energy sources based on a national strategy aimed at raising the efficiency of energy use, saving an estimated 230 million dinars by 2025, as well as ensuring optimal utilization of its climatic conditions and benefiting from the comparative advantage offered by solar energy, and then contribute with other state agencies in efforts to protect the environment and then confirm the country's commitment to achieving sustainable development goals (Bachbellerie, 2012).

4.4 Overview of the current solar technology and investment in clean energy projects

One solar panel needs an area of 2.5 square meters, which can produce 500 watts, so the annual production of the panel is 1,650 kilowatts, and the life span of the system is 20 years. For example, when installing 80 solar panels on an area of 200 square meters with an investment of 16 thousand dinars, it can generate 66,000 kilowatt-hours of electric energy annually (EzzEldin et al., 2022).

From the above concept, the use of solar panels in homes and companies has led to reducing the value of the electricity bill and achieving a high rate of savings in the regular electricity consumption bill, estimated at 30% or more according to the size of the station and consumption rates (Alnaser & Alnaser, 2011).

4.4.1 The application of Solar technology

- A. In its second phase, the initiative aims to install solar panels on the roofs of 20 schools, up from 8 schools in its first phase, in order to reduce the cost of conventional electricity by an estimated 20 to 30 percent. (Alsabbagh, 2019).
- B. Beginning in January 2018, the Net Metering system enabled individuals and consumers to install solar energy systems on their homes or businesses, connect them to the government grid in accordance with the requirements of the Electricity and Water Authority, and benefit from the solar-generated electricity to cover a portion of their electricity consumption needs. Bahrain has taken a

number of steps to motivate and encourage citizens to participate in these national initiatives, including replacing the solar energy produced and returning it to the Electricity and Water Authority for a bill reduction. By installing two meters, one for the conventional electric network and the other for moderating the consumption process and calculating solar energy consumption. The charge will include both its consumption from the government network and its solar energy consumption. The distinction between the two is known as net metering (*Net-Metering Resolution & Typical Self-Declaration*, n.d.).

C. The Sustainable Energy Authority was successful in persuading the banking sector to provide financing solutions that contribute to enabling individuals and investors to participate in solar energy-generated electricity projects, citing the fact that the "National Bank of Bahrain and Bank of Bahrain and Kuwait" provide financing loans for the cost of installing solar energy panels to generate electricity for homes. The loan will be granted for a duration of seven years and at preferential interest rates. Coordination is ongoing with a number of other financial institutions in order to present soft financing options for these environmentally friendly initiatives ("The Kingdom of Bahrain-National Energy Efficiency-Action Plan (NEEAP)," 2017).

D. Bahrain aims to obtain 250 megawatts from renewable energy sources by 2025 (EzzEldin et al., 2022). However, more than 187.5 megawatts have been achieved over the past three years, making renewable energy a promising area for investment in partnership with the private sector. Notably, foreign firms have entered Bahrain's renewable energy sector in a manner that contributes to achieving sustainable economic development, diversifying

investment sources, and injecting capital, which is reflected in rising economic growth rates (Alsabbagh, 2019).

- E. The Sustainable Energy Authority intends to increase its share of Bahrain's total energy production by implementing future expansion initiatives in renewable energy (Pillai & Naser, 2017). As there are two factories in Bahrain that produce solar panels and work to provide 40 megawatts of clean solar energy annually, the Authority is also working to meet the needs of the Bahraini market for solar energy by providing a suitable work environment for solar energy projects in order to keep up with development and invest in solutions that achieve growth within the framework of sustainability on all levels. Moreover, the Majid Al Futtaim project to install the largest central solar energy system with a voltage of 6.2 megawatts on the Bahrain Mall and the Bahrain International Circuit project to install solar energy systems on the roofs of car parks to produce approximately 3.5 megawatts of clean energy, as well as the joint venture with the Ministry of Labor and Social Development, are among the most prominent renewable energy projects that demonstrate this cooperation and integration (*Bahrain News Agency*, 2021).
- F. In addition, another accomplishment was the opening of the Batelco Solar Park, which has the capacity to generate 1,600 megawatts per hour of renewable energy and will help reduce carbon emissions by 900 tons per year (Batelco, 2021).
- G. Furthermore, solar energy is used to power the Electricity and Water Authority's water transmission and distribution stations. This station is considered to be the first station of the Electricity and Water Authority to be supplied with clean electric energy generated by solar panels installed on the facades and roofs of the station's

buildings. These solar panels contain 1,316 solar cells that generate approximately 407 kilowatts of clean electric energy, which is sufficient to meet the station's needs. In this field, sophisticated computer programs have been used to develop a simulation model that determines the optimal placement of solar panels and their vertical and horizontal angles (*Renewable Energy*, n.d.).

- H. Bahrain has recently issued an invitation to bid for the construction of a 72-megawatt solar power facility in the southern region of Sakhir. It is anticipated that the solar power plant will meet the energy requirements of the Bahrain International Circuit, the University of Bahrain, the Bahrain International Exhibition and Convention Center, and the Dana Theatre. In addition to the land allocated for these facilities, the solar panel station will be constructed on rooftops, car parking canopies, and electric vehicle charging stations (Bahrain Launches Tender for 72 MW of Solar, 2022).
- I. In addition to the aforementioned, some of the most significant stations identified for the application of solar energy systems include: Sheikha Mozah School, which has a capacity of solar systems on the roofs of its buildings and parking lots, with a capacity of 1 megawatt, as well as Bahrain airport, which has a capacity of 1 megawatt (Ognnews, 2020). Another solar station is located at King Hamad University Hospital, with a capacity of 4 megawatts. Bahrain Defense Force Hospital, which has a production capacity of 542 kilowatts. Ramli project, with a total of 600 solar panels installed on lighting poles. St. Christopher's School has a capacity of 1.25 megawatts. Cooperation has been made with Bapco to integrate solar energy solutions into new fuel supply stations starting from the design stage, as well as the Busaiteen waterfront project, which was

launched recently and is operated using solar energy. The government is also in the process of benefiting from the landfill in the Hafira region, as solar panels will be installed to produce 100 megawatts by the private sector, and it is expected to achieve positive returns for the investor and the government as the government will receive a low electricity tariff (*Bahrain News Agency*, 2021).

Interest in clean energy projects began with the Kingdom's accession as a permanent member of the International Renewable Energy Agency (IRENA) since its inception in 2009, as Bahrain recently participated in IRENA's tenth conference in Abu Dhabi, and the establishment of a sustainable energy unit in 2013, which contributed to a greater awareness of energy sources (Lunning, 2022). Renewable energy, which is less expensive and better equipped to combat climate change, also contributes to meeting development needs and keeping up with the global transformation of investment in alternative energy fields. (*Bahrain Stands Fifth in Green Energy Increase | the DAILY TRIBUNE | KINGDOM of BAHRAIN*, 2022).

By issuing Royal Decree No. 87 in October 2019, which includes the establishment of a specialized authority concerned with natural energy sources of a permanent and continuous nature, Bahrain has taken concrete steps in a short period of time to implement its directives regarding the use of renewable energy sources (Alsabbagh, 2019). The trend toward renewable energy has also been reflected in the policies and programs that have been implemented over the past few years, particularly with the 2017 publication of the National Plan for the Use of Renewable Energy and

Energy Efficiency, which included numerous initiatives that are being implemented in numerous projects (Lunning, 2022). In addition, a national committee was established to monitor and implement these initiatives, and it was successful in identifying the country's natural resources and the most efficient means of sustaining and exploiting them (*Bahrain Stands Fifth in Green Energy Increase | the DAILY TRIBUNE | KINGDOM of BAHRAIN*, 2022).

The Kingdom of Bahrain has embarked on its investment in renewable energy initiatives on more than one track. In addition to cooperating with experts and studies of the United Nations Development Program to transfer and localize expertise and experiences, it has sought to foster partnerships with national and international institutions capable of working in the areas of sustainability and increasing energy efficiency (Lunning, 2022). It collaborated with significant corporations to invest in related projects and worked with local banking institutions to contribute to the financing of renewable energy projects (Pillai & Naser, 2017).

The most important steps taken to promote clean and renewable energy are the standards for the efficiency of all types of cars and electrical appliances (Bahrain Research Group, 2022). These standards were approved, along with rules for installing solar panels on the roofs of homes and buildings, especially government buildings. These rules went into effect in 2018 and helped many people and businesses use solar energy. In addition, efforts are being made to construct a solar power plant with a total capacity of 100 megawatts, which is expected to be operational this year, as well as issuing a guide for building green houses, lighting specifications, supporting the central cooling project in the Gulf of Bahrain, certificates of accreditation of renewable energy systems to measure the efficiency of optimal use of energy sources, and cooperation between "Tamkeen" and

the New Energy Authority (*Tamkeen Launches the Solar Financing Scheme as Part of Its Tamweel Scheme to Help Organizations Save on Energy – Tamkeen, 2020*).

These awareness-raising and implementation efforts have resulted in the attempts of some private institutions and individuals to benefit from the feasibility of alternative energy projects and increase energy efficiency, including the project of the Agency for Agriculture and Livestock to operate solar panels in the facilities of its agricultural reserves and green houses and to allow building owners to own their solar energy projects, which it is hoped will reduce total electricity consumption by an average of 20% (Pillai & Naser, 2017).

All of these steps and accomplishments contribute to the accomplishment of the national plan to increase energy efficiency and the national plan for renewable energy, both of which were approved in 2018 and include a number of goals, such as setting a national goal to rely on renewable energy in Bahrain by 5% of the energy sources in the Kingdom by 2025, so that this percentage reaches 10% by 2035, noting that the plans and goals will assist Bahrain in achieving its sustainable development objectives (“Bahrain Economic Quarterly - Q1,” 2022).

4.4.2 Adoption of solar energy theme by the government and commercial companies

Commercial and industrial businesses and institutions frequently use solar energy to lower their electricity bills, which account for a sizable portion of their overall costs and expenses. This is especially true now that solar energy costs have decreased thanks to scientific advancements, allowing businesses to recover their investment within seven years. The water tariff for non-domestic accounts is 750 fils per unit, whereas the electricity tariff for non-domestic accounts is 16 fils per unit for up to 5,000 units and 29 fils per unit for more than 5,000 thousand units. (*Bahrain News Agency*, 2021).

Renewable energy is distinguished by its reliance on resources that can generate energy anywhere without restrictions, as well as the possibility of delivering it to remote areas to provide various services that contribute to raising their standard of living, as it is carbon-free and significantly and effectively contributes to preserving the environment and reducing the threat of global warming. In terms of cost, renewable energy initiatives are economical and have not experienced a significant price increase in comparison to conventional energy generation techniques. The environment, society, and economy will all benefit from the continued development of renewable energy generation techniques (Pillai & Naser, 2017).

The Sustainable Energy Authority has worked to develop a system of "renewable energy certificates". These certificates are granted to entities investing in solar energy systems by registering their production of renewable energy with the Sustainable Energy Authority through an electronic platform managed by the Authority, and then the Authority evaluates and monitors the amount of energy produced and approved in the form of a "renewable energy certificate" and then granted to investors for every (1 megawatt/hour), thus it is possible to verify energy production reports and their credibility, and investors can sell these certificates to parties that want to benefit from clean energy without producing it themselves (*Solar PV Commissioning Certificate*, n.d.).

The Renewable Energy Certification System's electronic platform enables investors and financing institutions to evaluate investment and financing opportunities in sustainable energy projects as well as verify the energy produced using dependable, approved programs and tools. A limited number of solar energy systems will be evaluated based on their adaptability in terms of application and management, as well as their conformance with best practices and international experiences. The first experimental phase will assess the viability of expanding and applying the system on a national scale to include all solar energy systems in the Kingdom. It will also provide an opportunity to investigate the viability of implementing BlockChain solutions to ensure transparency, traceability, and verification of each certificate. The "Renewable Energy Certificates" system will achieve additional benefits that enable users to overcome obstacles that may limit their ability to benefit from renewable energy, such as the limited space available for the installation of solar energy systems or technical or financial constraints, by allowing them to invest in energy

projects. Sustainable energy by purchasing "renewable energy certificates", as this will contribute to the Kingdom of Bahrain's commitment to achieving the seventh objective of the United Nations' sustainable development goals. Approximately 230 million Bahraini dinars will be saved annually as a result of implementing the National Energy Efficiency Plan's initiatives (*Solar PV Commissioning Certificate*, n.d.).

Adoption of the green building guide prepared by the Sustainable Energy Authority in collaboration with the Ministry of Works, Municipalities Affairs, and Urban Planning as one of the 22 initiatives included in the National Energy Efficiency Plan is among the other accomplishments in the sustainable energy sector during the past period. This initiative is a pioneering and significant step in the history of the Kingdom of Bahrain and the countries of the region, as it constitutes an essential reference for all sectors with regard to the special standards and requirements that must be adhered to when requesting new building permits. These standards and requirements encourage and contribute to the construction of more energy-efficient buildings that consume less energy and, as a result, save what is estimated to be tens of millions of dollars each year. 20% to 30% of electric energy and water, as the green building guide contains ten mandatory requirements and 64 optional requirements, noting that the property's fulfillment of the optional criteria increases the building's or facility's market value when compared to a comparable property with only mandatory criteria. Coordination with the Ministry of Works, Municipal Affairs, and Urban Planning is currently underway to prepare complementary policies for the Green Buildings Guide, through which buildings will be classified based on their availability of energy and water, as well as their compliance with the Green Buildings Guide's

mandatory and optional requirements. Green building classification policies will be one of the most important and essential tools for evaluating investments in various buildings, as well as determining the investment returns from integrating renewable energy solutions in buildings and applying technologies to improve energy efficiency in them ("Sustainable Green Buildings," 2019). In addition, the Authority, in collaboration with the Strategic Planning Office of the Ministry of Works, Municipalities Affairs, and Urban Planning, has developed policies to regulate the central cooling initiative, which is regarded as one of the most significant initiatives and a major contributor to achieving the national goal of improving energy efficiency, given that cooling accounts for approximately 60 percent of the total energy consumption of buildings and residences. The policies are presently being reviewed for imminent approval (Thomson Reuters Projects News, 2019).

4.5 The opportunity of Solar Energy in the Kingdom of Bahrain

The *National Renewable Energy - Action Plan (NREAP)* (2017) discussed the opportunity of Solar energy in terms of the following:

A. Resource Potential

Bahrain has a powerful solar resource potential. Figure 8 shows the Global horizontal irradiance which is (2,120 kWh/m²) whereas the estimated annual PV generation is (1,600-1,700 kWh/kWp/year). The average solar radiation is around 5.18 kWh/m²/day, with an average sunshine duration of 9.2 hours as per to the measurements which were taken at the PV plant installed at the campus of Bahrain.

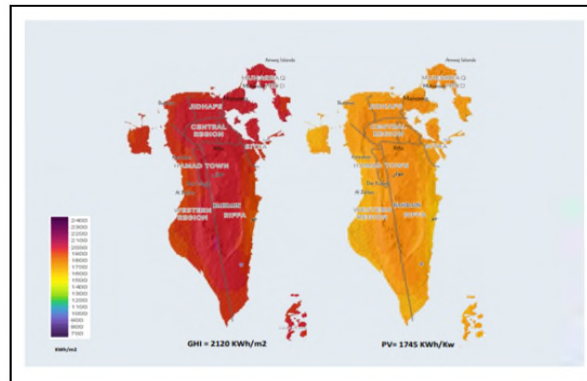


Fig. 8: Global horizontal irradiance and the estimated annual PV generation
(National Renewable Energy - Action Plan (NREAP), 2017)

B. Solar Technologies

Generally, technologies which transfers the solar energy to a useful energy are divided into three technologies as below:

1) Photovoltaic (PV): This technology directly transfers solar light into electricity.

Using photovoltaic (PV) cells, solar energy is transformed directly into electricity. Numerous PV cells composes a solar panel. There are a variety of PV cell technologies available on the market currently. PV cells made of crystalline silicon (c-Si) and thin films are the two most commonly used types of PV cells today. Multi-crystalline silicon accounted for 69% of global PV production in 2015, with mono-crystalline silicon coming in second (24%) and thin film third (6%), according to the Fraunhofer Institute for Solar Energy. Crystalline silicon cells are more expensive to produce but generally more efficient (13–19%) and more space-efficient; however, they are costly to produce and must be installed in a rigid frame due to their rigidity. Moreover, narrow films are less expensive to produce than thick films, but they are less effective (7–13%) and less space-efficient. Due to their adaptability, thin films can be used in a variety of contexts.

A solar PV system consists of solar panels, inverters, metering systems, and interface protection, among other components. There are two primary categories of photovoltaic (PV) systems: grid-connected and off-grid systems. In addition to powering on-site consumption, a grid-connected PV system's excess energy can be sent to the power grid. Off-grid PV systems are more expensive because they require batteries.

Generally, off-grid solutions are preferable for remote locations or situations that are not connected to the power grid.

Two benefits of solar photovoltaic energy are significant for Bahrain. First, the modular nature of solar PV makes it optimal for small-scale decentralized applications. Solar panels installed on rooftops are an example of a decentralized renewable energy source that generates electricity close to the site of consumption. Solar PV has the distinct ability to be implemented inexpensively at nearly any scale, unlike any other energy technology. Depending on the efficiency of the solar panels, a residential solar PV system requires 5 to 10 m²/kW of space and can be installed on rooftops, parking lots, and other surfaces. Given Bahrain's lack of available land for large-scale renewable energy initiatives, distributed solar PV generation on the scale of homes, businesses, and government buildings can contribute significantly to Bahrain's energy mix. Second, compared to other renewable technologies currently in use, solar PV has experienced the most rapid technological and financial development. Since 2006, solar photovoltaic (PV) prices have decreased by 75–80 percent, making it an attractive and competitively priced energy source. From 2005 to 2014, the price of electricity generated by utility-scale PV facilities in Germany decreased from over 40 cents per kWh to 9 cents per kWh. At the start of 2015, the Dubai Electricity and Water Authority (DEWA) signed a contract for a 200 MW utility-scale PV facility at a cost of 5.84 US cents per kWh. One year later, for the construction of an 800 MW PV project, DEWA obtained an even lower bid of 2.99 US cents per kWh, garnering significant media attention as the lowest solar PV price in the globe.

Solar PV systems typically have a lifespan of 20 to 25 years and lose efficacy at a rate of 0.5 to 1% per year. Recent statistics indicate that the initial capital expenditure for PV projects larger than 1 MW is approximately USD 1,100/kWp, while the initial capital expenditure for small-scale PV is approximately USD 1,400/kWp. The cost of inverters has decreased by a remarkable amount. Inverter prices decreased from 1 EUR/Wp in 1990 to approximately 0.10 EUR/Wp in 2014, while efficiency and power density increased substantially. Figure 9 shows Bahrain's utility-scale PV projects' levelized cost of energy at present and in the future, using three different discount rates (for installations greater than 1 MW).

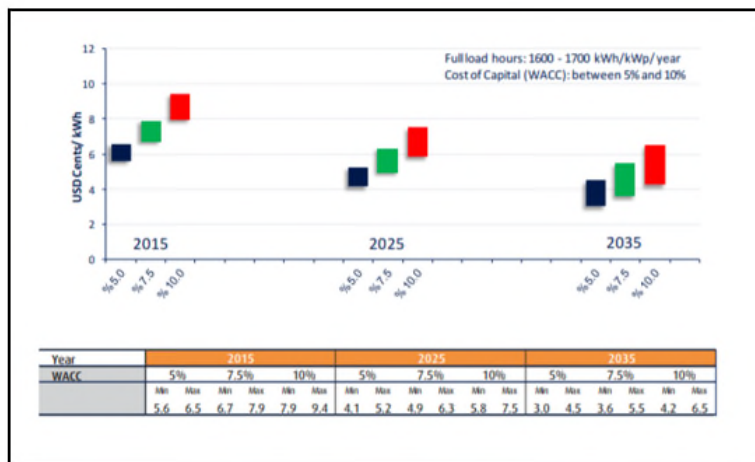


Fig. 9: Bahrain's utility-scale PV projects' levelized cost of energy at present and in the future
(National Renewable Energy - Action Plan (NREAP), 2017)

The estimations were derived using a model developed by the leading German think tank, Agora Energiewende. In 2015, the LCOE for utility-scale PV ranged from 6.7 to 7.9 cents/kWh (at a discount rate of 7.5%). This is comparable to PV tender prices in adjacent Arab countries. As the price of PV panels, inverters, installation, and financing falls, the

LCOE is anticipated to continue falling. Small-scale residential PV systems have also seen a trend of falling PV prices. In Germany, the cost to the end-user of 10 100 kWp PV systems decreased from 5,000 EUR/kWp in 2006 to 1,300 EUR/kWp in 2015. For small-scale PV plants in Bahrain, the LCOE estimations are shown in Figure 10.

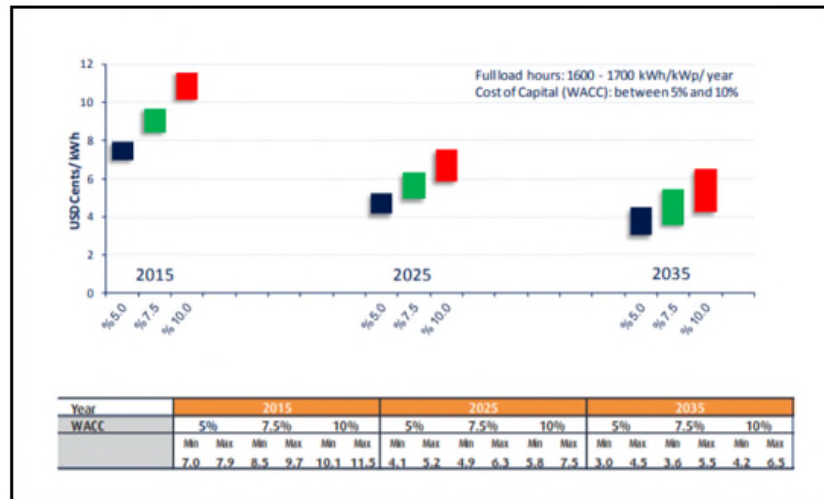


Fig. 10: LCOE estimations for small-scale PV plants in Bahrain
(National Renewable Energy - Action Plan (NREAP), 2017)

Utility-scale PV plants can be 25% more cost-competitive compared to decentralized small-scale PV plants. Nevertheless, utility-scale PV facilities necessitate expansive land areas, which is problematic in Bahrain due to the country's limited land area.

Based on the above, If no eligible land is identified for the construction of utility-scale PV facilities, Bahrain will focus on promoting decentralized small-scale PV applications.

2) Concentrating solar power (CSP): This technology depends on sunlight, as it concentrates on it and then transfer it to heat in order to drive conventional power generation turbines.

Because it requires little to no land area, building integrated photovoltaics (BIPV) could be an attractive option for Bahrain. BIPV is an acronym for building-integrated photovoltaics, which are solar photovoltaic materials implemented into building components such as roofs, skylights, windows, shading systems, and facades. In other terms, BIPV serves as both a structural component and a method of electricity generation. BIPV may also improve the architectural appeal of a structure. By substituting conventional materials for BIPV during the initial construction phase, building developers can reduce the additional costs of PV systems and eliminate expenses and design concerns for separate mounted systems.

The University of Applied Sciences and Arts of Southern Switzerland conducted a study of BIPV projects across Europe in which it was determined that the European market is supported by approximately 200 commercially available BIPV products and that the cost of the roof increases by EUR20,200/m² when PV are integrated into the roofs of buildings. Moreover, when integrating PV into a building's facade, the expenses tend to be comparable to those of conventional facade materials (such as glass or stone). As a result of the adoption of European Directive 2010/31/EU, which mandates that all new buildings be constructed as "nearly zero-energy" structures by the year 2020 and beyond, the BIPV market is anticipated to experience a substantial increase in the coming

years. BIPV products for zero-energy buildings will play a crucial role in meeting this requirement.

Based on the aforementioned key findings, it is more cost-effective to encourage the implementation of BIPV in new real estate development projects and new buildings in the Kingdom, as it is evident that these PV can be integrated into the overall building design, thereby reducing the impact on the overall construction cost.

3) Solar heating and cooling systems: This technology works by collecting the solar thermal energy in order to provide hot water and air conditioning.

Concentrated solar power (CSP) devices generate energy through the use of mirrors or lenses to concentrate a large quantity of sunlight in a small area. When concentrated light is converted into heat that drives a heat engine—typically a steam turbine—connected to an electrical power generator, electricity is produced. CSP facilities can integrate inexpensive thermal energy storage, allowing them to meet power demands for many hours after sundown. This is one of the advantages of CSP over solar PV. However, CSP facilities have three significant disadvantages that make them less desirable for Bahrain.

The first disadvantage is that, compared to solar PV, CSP facilities demand more money up front. Contrary to PV, CSP has not seen a significant drop in technological costs. Investment costs for CSP plants (without storage) range from USD 4,600 to 8,000/kW in OECD nations and from USD 3,500 to 7,300/kW in non-OECD nations. As the predominant technology used in CSP plants today (85% of all CSP projects

deployed globally are parabolic trough collectors), these costs are for parabolic trough collectors. The anticipated cost of operation and maintenance per kWh ranges from USD 0.02 to USD 0.04. The second disadvantage is that CSP installations need a lot of land, just like utility-scale PV plants. The US Solar Energy Industries Association states that for every MW of installed capacity, a typical CSP facility needs 2 to 4 hectares of land. CSP plants may be built at smaller sizes, but they function most successfully and economically when they are built with a capacity of at least 100 MW. The third disadvantage is that water is necessary for cooling in CSP facilities. At the tail end of the thermal cycle, cooling water is frequently used in CSP facilities. The usual cooling requirement for a 50 MW parabolic trough plant is 0.4–0.5 million m³ of water annually. In order to preserve the mirrors' high reflectivity, water is also utilized for cleaning. Given that Bahrain's fresh water is mostly produced through the energy-intensive desalination process, meeting these water requirements might be difficult.

From the above disadvantages, it is likely that Bahrain will pursue of implementing and developing the CSP technology.

4.6 Overview of the Kingdom's economy, energy and electricity production and consumption in the Kingdom of Bahrain

Since its independence in 1971, Bahrain has experienced a comprehensive renaissance in all economic, educational, health, and other development fields and has been able to establish a modern and diversified economic structure that has strengthened its position as a major commercial, financial, and tourist hub in the region (Nakibullah & Islam, 2007).

The government of the Kingdom of Bahrain has adopted an ambitious business philosophy based on an integrated strategy for comprehensive development that aims to increase economic growth rates, develop economic and commercial activities, open the Bahraini market to a variety of local, Arab, and foreign investments, increase national income, provide more employment opportunities for citizens, and diversify the productive base of the national economy. Bahrain's policy is to attain a leading position in a variety of economic sectors (Pillai & Naser, 2018).

The Kingdom of Bahrain is one of the most diversified Gulf economies due to the high contribution of non-oil sectors to the gross domestic product, the National Oil and Gas Authority's interest in developing oil and natural gas resources in light of the importance of the oil sector as a major source of energy, and the establishment of modern and advanced institutions in the aluminum, petrochemical, and metal industries. As a result of the infrastructure and legislative facilities, as well as the presence of several industrial zones, there are engineering, food, and pharmaceutical facilities (Worldfolio, 2017). The Government of the

Kingdom of Bahrain approved the Economic Vision 2030 in October 2008, which is a comprehensive economic vision that establishes a clear direction for the economy's continued growth. In essence, it reflects a shared primary objective, represented by the improvement of the lives of Bahraini citizens. The vision was introduced after four years of in-depth discussions with a group of public and private sector decision-makers, including government institutions and specialized entities, as well as some houses of expertise and international organizations. The objective of Economic Vision 2030 is to crystallize an integrated government vision for society and the economy that is centered on achieving sustainable development. Three fundamental tenets are competitiveness, equity, and sustainability (Economic Development Board, n.d.).

Bahrain Economic Quarterly Reports (2022), published on the Ministry of Finance and National Economy database presented figures related to the country's economic sectors share in Gross Domestic Product. The report indicated that the Kingdom of Bahrain's Gross Domestic Product (GDP) increased by 6.95% in real prices and 22.87% in nominal prices from the second quarter of 2021 to the second quarter of 2022, according to a report published by the Information & eGovernment Authority (iGA) on the estimates of National Accounts for the second quarter (Q2) of 2022. The non-oil sector saw greater growth than the rest of the economy, growing by 9.05% in real terms and 17.83% in nominal terms. Due to decreasing production, the oil industry fell by an average of 2.20% at actual prices over the same time period. However, due to the favorable price effect, it climbed greatly by 51.66% at nominal prices compared to the same quarter in 2021. According to the report, the tourism industry has significantly recovered, with the recovery rate having reached 82% compared to the pre-pandemic period (specifically with the second

quarter of 2019), according to the most recent Ministry of Tourism statistics. The report revealed that hotels and restaurants have experienced the highest growth rates, with 18.13% and 25.55% in real and nominal prices, respectively. Manufacturing had increases of 7.63% and 49.78% at real and nominal prices, respectively, while Transportation and Telecommunications saw growth of 15.12% at real prices and 5.94% at nominal prices. Other Government Services saw growth of 7.57% at real prices and 4.33% at nominal prices. Commerce expanded by 7.51% in real terms and 2.66% in nominal terms, whilst Educational Services expanded by 6.81% in real terms and 7.79% in nominal terms. Also, the findings indicated a rise in agriculture and fishing prices of 5.78% in real terms and 1.02 percent in nominal terms. While financial services had a gain of 3.56% at real prices and 4.38% at nominal prices, real estate and business services saw growth of 4.49% at real prices and 3.27% at nominal prices. The growth rate for other social and personal services was 2.79% in real terms and 4.08% in nominal terms. At actual prices, it was estimated that the construction industry grew by 2.60%, and at nominal prices, by 5.09%. Comparing the second quarter of 2022 to the first quarter of the same year, the economy expanded by 8.31% nominally and by 5.03% in real terms. According to the report's findings, the oil sector's growth rate climbed by 10.69% and 26.64%, while the non-oil sector's growth rate increased by 3.93% and 4.88% at real and nominal prices, respectively. Mines and quarrying increased by 10.46% at real prices and 25.41% at nominal prices, followed by Electricity and Water by 10.45% at real prices and 3.21% at nominal prices, and trading activities by 7.66% and 1.28% at real and nominal prices, respectively. Overall educational services increased by 29.75% and 30.83% at real and nominal prices. Manufacturing saw an increase in real prices of 3.13% and nominal prices of 7.81%, respectively,

while health services saw real prices of 1.75% and nominal prices of 1.87% growth.

A. Consumption and usage of Natural Gas and Electricity in the economic sectors

This section seeks to quantify the economic sector's energy consumption in the Kingdom of Bahrain, given the sector's significance in terms of its contribution to Bahrain's economy. Data and consumption rates were gathered from various governments databases such as the Organization of Arab Petroleum Exporting Countries (OAPEC), Information & eGovernment Authority, Information & eGovernment Authority Open Data Portal, Energy Statistics Bulletin for the Cooperation Council for the Arab States of the Gulf, Electricity and Water Authority, Electricity and Water Authority (EWA Statistics) as represented in Table (7), Table (8) and Table (9).

Table (7): Energy Production and Consumption in the industrial, Commercial, Agriculture and other Economic Sectors

Year	Total Energy Production during the period 2010-2018 (Thousand Barrels of Oil Equivalent Per Day)				
	2010	2015	2016	2017	2018
	356	458	456	250 (Natural Gas Production only)	256 (Natural Gas Production only)
Year	Total Final Consumption of Energy during the period 2005-2016 (Thousand Barrels of Oil Equivalent Per Day)				
	2005	2010	2015	2016	
	81	103	126	128	
Year	Total Final Consumption of Energy in the Industrial Sector during the period 2005-2016 (Thousand Barrels of Oil Equivalent Per Day)				
	2005	2010	2015	2016	
	37.2	60.8	42.1	42.3	
Year	Total Final Consumption of Energy in the Transportation Sector during the period 2005-2016 (Thousand Barrels of Oil Equivalent Per Day)				
	2005	2010	2015	2016	
	29.7	21.2	24	24.6	
Year	Total Final Consumption of Energy in the other Economic Sectors during the period 2005-2016 (Thousand Barrels of Oil Equivalent Per Day)				
	2005	2010	2015	2016	
	13.7	21.4	60.2	60.8	

Table (8): Natural Gas Consumption for Electricity Generation

Year	Natural Gas Consumption for Electricity Generation during the period 2017-2021 (Thousand Barrels of Oil Equivalent Per Day)				
	2017	2018	2019	2020	2021
Sitra	255	276	256	254	27
Riffa	577	247	526	359	140
Al-Hidd	1,731	1,815	1,770	1,797	1,720
Al-Ezzel	1,167	1,108	1,263	1,335	1,395
Al-Dur	1,883	1,932	1,704	1,826	1,788
Al-Dur 2	0	0	0	0	499
Total	5,613	5,378	5,519	5,571	5,569

The gas quantity for IP(W)P are theoretically calculated.

Note: Measured gas quantity for Sitra & Riffa Stations are in Normal Cubic Meter.

Table (9): Electricity Production and Consumption in the industrial, Commercial and Agriculture Sectors

Year	Total Electricity Production (GW.H) during the period 2008-2020												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	11,657	1,223	13,757	13,826	14,104	14,760	16,257	17,183	17,085	17,978	17,861	17,854	17,933
Year	Electricity Consumption in the Industrial Sector (GW.H) during the period 2008-2020												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	1,258	1,237	1,408	1,821	1,739	2,017	2,632	2,728	2,587	2,710	2,766	2,769	2,175
Year	Electricity Consumption in Commercial and Public Services Sector (GW.H) during the period 2008-2020												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	3,165	3,493	4,720	4,523	4,551	4,855	5,521	6,141	5,979	5,412	6,083	6,515	5,632
Year	Electricity Consumption in the Agriculture Sector (GW.H) during the period 2008-2020												
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	43	44	49	48	45	52	48	57	61	59	61	60	75

The agricultural sector consumes the least amount of electrical energy compared to the industrial and commercial sectors. Moreover, in 2020, the Electricity Distribution Department reported that the commercial sector consumed 34.5% of electricity and water, while the industrial sector consumed 13.5%.

The Organization of Arab Petroleum Exporting Countries (OAPEC) report covered energy production and consumption in economic sectors from 2005 to 2016 and 2018. During the period between 2005 and 2016, total energy production in the Kingdom of Bahrain increased at a rate of

2.3% per year, from 324 thousand barrels of oil equivalent per day to 456 thousand barrels of oil equivalent per day. Natural gas and crude oil are Bahrain's two primary sources of energy production. Natural gas is the main source of energy production, as its production increased at a rate of 6.1% annually, doubling from 125.4 thousand barrels of oil equivalent per day in 2005 to 241.6 thousand barrels of oil equivalent per day in 2016, thus reaching 53% of the total energy in 2016 compared to 38.7% in 2005. Comparing 2016 to 2005, crude oil production increased by 0.7% to 214.6 thousand barrels of oil equivalent per day from 198.5 thousand barrels of oil equivalent per day. Regarding energy consumption, the report indicates that the final energy consumption in the Kingdom of Bahrain increased by 5.2% per year between 2005 and 2016, from 80,600 barrels of oil equivalent per day.

According to the report, electricity, natural gas, and petroleum products are the three primary sources that contribute to meeting Bahrain's energy requirements. During the period 2005–2016, the relative importance of electricity in the final consumption of energy increased significantly, as its consumption increased at a rate of 12.1% annually, from 13.6 thousand barrels of oil equivalent per day to 47.8 thousand barrels of oil equivalent per day. As a result, the share of electricity in the final consumption of energy doubled from 16.9% to 37.4%, and natural gas comes in second place, as its consumption increased at a rate of 2% annually. Petroleum products are ranked third, as their consumption increased by 0.9% annually from 32.2 thousand barrels of oil equivalent per day in 2005 to 35.6 thousand barrels of oil equivalent per day in 2016, thereby decreasing their share of total final consumption from 40% to 27.9%. Despite a decline in its proportion of total final consumption from 46.2% in 2005 to 33.1% in 2016, the industrial sector remains the largest consumer of energy in

Bahrain, as its consumption increased by 1.2% annually during the period 2005–2016, reaching 42.2%. One thousand equivalent barrels of oil per day in 2016 compared to 37,2 thousand equivalent barrels of oil per day in 2005. In 2016, the industrial sector consumed 24,2 thousand barrels of oil equivalent per day of electricity and 18,1 thousand barrels per day of natural gas. Chemical and petrochemical industries consumed the most energy in 2005, consuming 20,2 thousand barrels of oil equivalent per day, or 54.4% of the industrial sector's total energy consumption. In 2016, non-ferrous industries became the largest energy consumers in the industrial sector. In 2016, the volume of consumption in this industry amounted to 19,7 thousand barrels of oil equivalent per day, or 46.6% of the industrial sector's total consumption. These industries derive all of their energy requirements from natural gas. The iron and steel industry emerged as one of the most energy-consuming industries in 2016, as its natural gas consumption reached 8.3 thousand barrels of oil equivalent per day. As for other industries listed under the category of unspecified industries, their consumption decreased at an annual rate of 17.3%, reaching 14.3 thousand barrels of oil equivalent per day in 2016 compared to 17 thousand barrels of oil equivalent per day of natural gas and 2.5 thousand barrels of oil equivalent per day of electricity in 2005.

Aluminum Bahrain (Alba) can be considered an example, as it confirmed that its purchases of natural gas and diesel increased to 249 million dinars in 2022, compared to about 235 million dinars in 2021, about 230 million dinars in 2020, and about 238 million dinars in 2019. Alba purchases natural gas and diesel from the government, which is represented by the Ministry of Oil and the Oil and Gas Holding Company, in order to operate the aluminum smelter, which has an annual production capacity of more than 1.5 million tons (Aluminium Bahrain B.S.C. (Alba) | Kingdom

of Bahrain, n.d.). Alba is currently working on the solar farm project, which will involve the installation of approximately 11,300 solar cells on the roofs of its parking garages and a few other buildings, such as the Spent Pot Lining Treatment (SPL) Plant. The Solar Farm Project is anticipated to generate between 10,539 MWhr and 7,591,760 kilograms of carbon emissions annually, resulting in a reduction of 189,794,000 kilograms of carbon emissions over a 25-year period (Alba to Begin Installing Solar PV Panels over 37,000 M2, 2023). After increasing to 921 billion cubic feet in 2021, Bahrain's annual production of natural gas approached a trillion cubic feet. Natural gas is consumed for energy production by the industrial sector, with the largest consumers of gas being Aluminum Bahrain Company ("Alba"), Foulath Steel Company, and Iron Steel Company, as well as electricity production stations, such as the isolation station and the role station, that consume vast quantities of gas to generate electricity (*Bahrain Gas Production: Natural Gas | Economic Indicators | CEIC*, 2020).

From the above, it is evident that the energy sector in the Kingdom of Bahrain is experiencing rapid growth in various fields, including oil, gas, renewable energy, and electricity, all of which contribute to economic growth in the Kingdom; consequently, it is essential to consider shifting towards a more sustainable source of energy that can ensure efficient use of electricity and optimize the use of indigenous gas resources, reduce peak electricity demand, and encourage investment (Pillai & Naser, 2018).

Chapter Five

Discussion, Recommendations and Conclusion

Chapter Five

Discussion, recommendations and conclusion

This thesis attempts to evaluate the viability of adopting solar energy in the economic sector in order to achieve sustainable development. This chapter will provide a summary of the key findings and corresponding recommendations gleaned from the analysis of the key factors pertaining to the adoption of solar energy within the Kingdom of Bahrain.

5.1 Discussion and Recommendations

- A. Solar energy is a renewable energy source that cannot be depleted or exhausted. It is also pure energy that does not produce any waste that would have a negative impact on the ecosystem, human health, or the environment. Rather, the use of solar energy contributes to an improvement in the trade balance by reducing fossil imports and freeing up a greater quantity of fuel for export, as well as exporting solar products if their production is increased.
- B. Solar energy contributes significantly to the development of a promising industry, the solar energy industry, and the subsequent creation of new employment opportunities, which fosters economic growth and improves individuals' standard of living.
- C. As the Kingdom of Bahrain intends to expand the use of solar energy and increase its contribution to the overall energy balance, the analysis has uncovered obstacles to its optimal utilization. These obstacles include economic and financial obstacles as well as

technological and technical obstacles. These obstacles can be enumerated concisely as follows:

- 1) The government has worked on a number of initiatives to address the Kingdom's space constraints, including the initiative to benefit from the roofs of buildings and the use of unoccupied spaces in infrastructure projects, such as installing solar panels on water tanks and over service corridors for water distribution pipes and integrating an application for energy solutions.
- 2) In terms of economic and financial obstacles, the high investment costs of solar energy limit the expansion of its use on a national scale, as its prices remain uncompetitive compared to fossil energy, whose prices are decreasing due to government subsidies. Perhaps the government's plan to progressively raise electricity rates will have a significant impact on solar energy's competitiveness against fossil fuels. Technological advancement and global expenditures on research and development in the field of solar energy contribute to the progressive reduction of its production costs, thereby making its prices competitive and affordable. Due to the high investment costs of solar energy, its applications require sources of financing, but those sources are inadequate. Currently, solar energy applications rely on a combination of government funding and grants, and there is a general trend toward private sector involvement in renewable energy projects.
- 3) Concerning technological and technical obstacles, the problem of energy storage and utilization at night, on cloudy or smoky days, is one of the greatest technological obstacles.

Numerous studies have been conducted to determine the impact of dust on the productivity of solar panels in Arab countries. These studies have demonstrated a 50% decrease in the productivity of panels in the Kingdom of Saudi Arabia over a 6-month period and a 17–65% decrease in productivity, depending on the angle of inclination of the panels in Kuwait, over a period of 38 days (Kazem et al., 2020). In addition, the high humidity levels in the Gulf region cause water droplets to accumulate on the solar panels. This also decreases their productivity, and the humidity levels are high, especially in the summer when energy demand is at its zenith, necessitating regular cleaning of the panels, which requires large quantities of water (Ekinci et al., 2022). However, GCC countries are facing increasing water scarcity, which has made GCC one of the most used countries for desalination, which consumes a significant amount of energy. Modern technologies have been developed to address this issue, including techniques for cleaning these panels without water, but they are prohibitively expensive, thereby increasing the cost of using solar energy. Additionally, the region's high temperatures reduce the efficiency of solar panels and diminish their lifespan. To lower the temperature of the panels, they can be positioned so that air can circulate from both above and below them. Rather than using solar cells, it is possible to benefit from the sun's heat by concentrating solar energy; however, the technology used to concentrate solar energy is extremely expensive (Munawwar & Ghedira, 2014). Despite these obstacles, solar energy remains a promising energy source. Costs are decreasing, technology is advancing, and companies that

manufacture this technology are concentrating on increasing productivity and developing new products to surmount the aforementioned technical issues (Moossa et al., 2022).

- D. The nature and quantity of solar energy, the type and duration of use, and the total cost of energy storage all influence energy storage. It is preferable not to use storage devices to reduce the cost and to benefit instead from solar energy directly when it is present, such as solar pumps that do not use batteries and depend only on the sun throughout the day. Solar energy storage is one of the most difficult stages, requiring technological development in order to achieve the lowest potential cost for solar energy storage. In addition to the technological obstacles mentioned previously, such as clouds and poor weather, solar-powered devices require periodic maintenance and cleaning. If a solar-powered device that receives sunlight is not cleaned for a month, its solar energy efficiency may decrease by half. This issue can be resolved by continuously cleansing the devices every three days to maintain the solar receptors' efficiency (Ekinci et al., 2022).
- E. In addition to requiring employees with a high level of skill, solar energy technology also necessitates high levels of technical and scientific proficiency in manufacturing and technology, as well as installation and maintenance. This challenge can be overcome with the proper training of employees and technicians, which requires additional funding. With the proliferation of solar energy technology, training will become simpler and less expensive. Periodically, a number of employees must be assigned to clean the surfaces with solar energy. There is no doubt that the wages of these workers will be less than the losses that the Kingdom of Bahrain may incur as a result of the infeasibility of the solar system, as well as

less than the costs of maintaining the use of fossil energy, until a global technology that contributes to eliminating the dust accumulation problem is developed.

F. Regarding the implications of utilizing solar energy for achieving sustainable development in the Kingdom of Bahrain, it has been determined from the preceding analysis that energy is a crucial component for achieving sustainable development in the Kingdom of Bahrain, as its demand is rising to keep pace with economic, social, and environmental development. The government of Bahrain has developed a long-term strategy to attain sustainable development by 2030, based primarily on increasing the use of local energy sources, particularly renewable ones. Consequently, the following can be stated:

- 1) Economic dimensions: Increasing the growth rate, reducing the public budget deficit, attaining energy security, and enhancing the trade balance are objectives.
- 2) Social dimensions: Creating employment opportunities, reducing poverty, enhancing individuals' standard of living, and attaining social justice.
- 3) Environmental dimensions: Solar energy contributes considerably to the reduction of harmful particles and gases emitted by fossil fuel power plants, as it produces no solid, liquid, or gaseous byproducts during the production of electricity. Rather, it is a pollution-free technology that protects the environment. In addition to achieving environmental equilibrium and preserving the ecosystem, solar energy does not pollute the oceans or land, nor does it damage biodiversity or living organisms. Rather, it protects the environment, fisheries, and agricultural commodities, in

contrast to fossil fuels, whose intensive use causes degradation. Solar energy plays a significant role in the transition to a green economy, which integrates with the realization of the environmental aspect of sustainable development in the Kingdom of Bahrain. The implementation of solar power facilities has helped reduce carbon emissions from fossil fuels, thereby contributing to the transition to a green economy.

- G. Energy is essential to existence. It is a fundamental tenet of sustainable development and one of its most essential prerequisites. The view is no longer limited to the management of fossil energy in the present but has broadened to include energy security in the present and the future; consequently, the majority of countries in the world seek to exploit renewable energy sources, particularly in light of the global trend toward concern for environmental issues to reduce ecological deterioration and damage. In addition to corrosive precipitation and a significant increase in temperatures, climate change is caused by the increase in greenhouse gases, which also contribute to biological diversity. Consequently, renewable energy plays a prominent role in securing energy as a key input for sustainable development as well as contributing to the transition towards a green economy, as more than half of global carbon emissions are primarily caused by the excessive use of fossil energy, and if the use of energy is expanded, this will contribute to reducing the harmful effects of fossil fuels on the environment and thus contribute to the transition towards a green economy.
- H. As the sun shines on all countries in the world and can be exploited to produce energy, solar energy is regarded as the primary source of all energies and the most accessible source of renewable energy on

the surface of the earth. It is not monopolized by a specific country or certain political or economic forces but is available everywhere and at all times. Unlike fossil energy, which is threatened by depletion, solar energy accomplishes justice between generations and within a single generation, and it also promotes sustainable development in its many dimensions.

To analyze the role of solar energy in securing energy, transitioning to a green economy, and achieving sustainable development, the thesis sought to investigate the theoretical framework of the green economy and renewable energy, with a focus on the role of renewable energy in the transition to a green economy. In addition, international experiences in the field of solar energy and the transition to a green economy were highlighted in order to extract the most valuable lessons for the Kingdom of Bahrain.

In addition to analyzing the economic viability of its exploitation in a manner that contributes to the achievement of the intended goals, the purpose of the thesis was to track the most significant effects of solar energy use on achieving sustainable development in the Kingdom of Bahrain. The thesis was therefore divided into several chapters. The second chapter addressed the theoretical framework of the green economy and clean renewable energy, focusing on the fundamental concept of the green economy by identifying its concept, characteristics, and the most significant obstacles that stand in the way of its transformation, such as financing, economic, political, and technological obstacles, as well as reviewing the necessary mechanisms for the transition towards the green economy. Establishment of a sound legislative framework, support for green sectors, and strengthening the role of the private sector and civil society in the transition to a green economy were the most essential of these

mechanisms. Through the concerted efforts of the financial services sectors and investment institutions, as well as the role of public finance, development finance institutions, and capital markets, among others, the chapter also reviewed the most important sources of financing the transition towards a green economy on a global scale. Focus has also been placed on clean renewable energy as a pioneering sector for the transition to a green economy, where the concept of renewable energy and its significance in securing energy, reducing pollution, supporting the national economy, and promoting sustainable development have been emphasized. The concept of wind and water energy, as well as geothermal energy and biomass energy, as well as the advantages and challenges of expanding their exploitation, were examined. The chapter focused on the role of renewable energy in achieving sustainable development in its economic, social, and environmental dimensions, citing the most significant obstacles renewable energy faces in achieving this objective. The role of renewable energy in the transition to a green economy was finally analyzed. The third chapter focused on international experiences in the field of solar energy and the transition to a green economy, reviewing two examples of the experiences of developed nations in this regard, namely the United States and Germany. In addition to examining the most significant photovoltaic and thermal solar station initiatives in each country, reference was made to the solar capabilities available in each of the two countries. The United States is the world leader in concentrated solar thermal energy market investment and ranks second in the world after Spain in terms of installed capacity, while the Federal Republic of Germany ranks first in terms of total photovoltaic solar energy installed capacity. Two examples of the experiences of developing countries in the field of using solar energy and the transition towards a green economy were also reviewed, namely the People's Republic of China and the United Arab Emirates. The solar

capabilities of both nations have been discussed, and the most significant photovoltaic and solar energy stations in both nations have been analyzed. The fourth chapter discusses the most significant solar energy applications in the Kingdom of Bahrain and their implications for attaining sustainable development in that country. The focus was on Bahrain's tremendous solar potential, which contributes to the reduction of carbon emissions and the transition to a green economy.

Within the context of international experiences and an analysis of the capacity of the Kingdom of Bahrain to adopt solar energy, the following are the most significant findings of the thesis, which assumes that the use of solar energy as a source of clean renewable energy will contribute to the transformation of the Bahraini economy into a green economy and to the achievement of sustainable development:

- A. Greening the energy sector in the Kingdom of Bahrain necessitates replacing investments in fossil energy sources with investments in clean energy sources and progressively enhancing energy efficiency to reduce carbon emissions, thereby contributing to the transition to a green economy. Economically, expanding the establishment of new fossil energy stations is not a rational choice, as these sources are confronted with depletion, in contrast to solar energy, which is renewable and clean. Instead of launching stations that rely on fossil energy and fuels that pollute the environment, the Kingdom of Bahrain must expand the launch of photovoltaic and thermal solar stations and choose the most economically viable technology and engineering technology.
- B. It is possible to benefit from California's experience in the United States by requiring the owners of commercial and government

buildings to use solar roofs, as was done in the cities of Lancaster and Sebastopol, and by reducing the prices of solar roof-equipped buildings, as was done in the city of Richmond. To encourage the use of solar energy, financial incentives and support should be provided along the lines of the California Solar Energy Commission. It is also possible to benefit from the concept of renting solar energy equipment in the United States of America, which contributes to lowering the cost of obtaining electricity from solar energy and, consequently, the widespread adoption of solar roofs.

C. The Kingdom of Bahrain can learn from California's experience in utilizing renewable energy sources. As previously mentioned, renewable energy is initially expensive, but the results and benefits are long-lasting. Similarly, the equipment used to generate pure energy is expensive but has a very long lifespan. Moreover, every project has a negative side and a positive side, but when comparing the positives and negatives of this project, it becomes clear that the positive side has the largest share; therefore, the sacrifice is worthwhile. Additionally, solar energy has reduced annual carbon dioxide emissions by approximately 400,000 tons. As well as the fact that reliance on new energies increases employment opportunities, as 2100 construction employees and 86 operation and maintenance staff positions were created, this is a positive economic aspect.

D. From California's example, the Kingdom of Bahrain must work to bear the burden of financing sources for clean energy projects, whether through borrowing, self-efforts, or by encouraging the entry of the private sector, because the long-term returns are superior to those of traditional energy sources, making the sacrifice and perseverance worthwhile. The Kingdom must strive to implement

the use of environmentally friendly energies, as this will employ a significant number of young people in various project-related areas, thereby reducing the severity of the unemployment issue. Furthermore, the Kingdom will prioritize investments in solar energy, as reliance on clean energy will save hundreds of millions of dollars. The Kingdom of Bahrain will initially bear the costs of construction and operation, but maintenance and equipment replacement will be required after lengthy installation periods due to the durability of materials used in power generation.

- E. By relying on renewable energy sources in each region to the extent that each region seeks to exploit its renewable energy, those regions exchange all available renewable energies, and the surplus of other provinces covers the deficit of each province, the Kingdom of Bahrain can replicate the Feldheim experience in the Federal Republic of Germany. Finally, locally produced fossil energy sources are used to make up the difference between production and consumption, with imports of fossil fuels kept to a minimum. Solar energy should be supported temporarily, contributing to the spread of solar roofs and the use of solar air conditioners by the banking system, as German Development Tech is currently doing.
- F. Using the German example as a guide, the Kingdom of Bahrain must issue a special law for the use of renewable energy, activate it in a strict and mandatory manner, and include incentives. Start activating and encouraging scientific research centers and researchers in the field of energy in order to rely on the greatest quantity of non-polluting renewable energies rather than traditional energy. In addition, the Kingdom should educate investors and the general public about the significance of transitioning to a green economy in order to safeguard the environment and limit the climate changes

that the world is currently experiencing due to the increase in carbon emissions and the expansion of the ozone layer.

- G. It would be beneficial for the Kingdom of Bahrain to learn from the experience of Dogu in the People's Republic of China by mandating that all economic buildings be equipped with solar thermal energy facilities, so that buildings with fewer than 12 floors use solar thermal energy on their roofs and those with more than 12 floors use centralized systems.
- H. It is advantageous for the Kingdom of Bahrain to learn from the experience of Masdar City in the UAE in terms of sustainable and environmentally favorable urban development standards. To combat vehicle emissions, it is useful to examine the experience of solar-powered electric vehicles. Solar stations connected to the public grid can be launched, and the surplus will be transferred to the grid, identical to the "ten megawatt" station in Masdar City. It is also feasible to benefit from the Emirates' expertise in the use of photovoltaic panels for air conditioning on the roofs of commercial buildings.
- I. It has been emphasized that there is a need to establish an integrated solar energy industry in the Kingdom of Bahrain, along with the industries that feed it, in order to reap the benefits of the entire value chain, from research and development to manufacturing and marketing, and especially the availability of all factors that qualify the country to produce solar cells instead of importing them. In contrast to its enormous solar potential, the Kingdom of Bahrain possesses the necessary production inputs to manufacture solar cells from aluminum, glass, and others, in addition to the availability of a legislative and regulatory structure for renewable energy and

incentives that support and develop the use of solar energy in the Kingdom.

- J. The Kingdom of Bahrain must establish a fund for renewable energy to bridge the cost gap between fossil energy and renewable energy, particularly solar energy, and to contribute to the financing of pilot initiatives in the field of renewable energy.
- K. As many citizens are still unfamiliar with solar products and the legislation enacted by the Renewable Energy Authority to encourage the use of solar energy, the Kingdom of Bahrain shall begin promoting the culture of solar energy usage among its population. Consequently, awareness campaigns must be organized to promote the use of solar products.
- L. There is a need to expand the use of solar roofs, which contribute to reducing pressure on the public electricity grid and progressively securing energy, as well as to the transition to a green economy and the achievement of sustainable development. The Kingdom of Bahrain must learn from international experiences in this area, led by Germany, where solar roofs produce 90 percent of the country's total solar energy, as well as California's experience and its campaign for one million solar roofs.
- M. The Kingdom of Bahrain must institutionalize the use of solar energy across all sectors. For example, the current use of electricity generated from the network in buildings and institutions is characterized by the existence of an institutional framework that governs the producer-consumer relationship and regulates the rights and responsibilities of each party, whereas solar energy products lack this characteristic. The consumer uses these products without a mechanism, institution, or entity responsible for regulating his rights and responsibilities in relation to the product. Therefore, the

Ministry of Electricity or the Renewable Energy Authority in the Kingdom of Bahrain must provide this institutional personality to guarantee the use and expansion of the largest solar products company in the Kingdom of Bahrain.

- N. Attention should be paid by the Kingdom of Bahrain to the fields of scientific research related to energy and the environment, as the world is threatened by a collapse in the ecosystem and its diversity as a result of climate change caused by increased carbon emissions; therefore, it must be directed towards switching to new, renewable, clean, and environmentally friendly energy resources. Efforts should be redirected toward the generation of electricity from solar, wind, and biofuels.
- O. The Kingdom of Bahrain must guarantee that the new industrial strategy takes environmental considerations into account and contributes to the growth of the green economy and innovation.
- P. The Kingdom of Bahrain will implement a strategy that encourages the public and private sectors to invest in renewable energy initiatives. This can be accomplished by providing incentives and facilities, such as tax reductions, assistance, and streamlined establishment procedures.
- Q. The Kingdom of Bahrain must prioritize promoting international cooperation to aid developing nations, particularly in the areas of technology transfer, green financing, partial financing, trade and investment, and the dissemination of best practices adopted in mechanisms for adapting to climate change and mitigating its effects.
- R. The Kingdom of Bahrain should maximize local manufacturing while developing the efficacy of solar cells in order to reduce costs through appropriate tax policies, including the elimination of

customs duties and sales taxes on imports from these countries and the reduction of customs duties on their future needs.

- S. The Kingdom of Bahrain will work to capitalize on European countries' desire to import energy from North Africa and the Middle East and will prepare to enter the solar energy export market as quickly as possible so that it can become a pioneer in this field.
- T. The Kingdom of Bahrain must prioritize the issuance of laws mandating the use of renewable energy in all new cities, tourist villages, factories, and industries with high electricity consumption, such as cement and ceramics production.
- U. The Kingdom of Bahrain shall commence to draw attention to the enactment of laws, as the initiation of any change necessitates strict and motivating legislation to adhere to and rely on renewable energy in order to achieve sustainable development.

5.2 Conclusion

The thesis examined the function of the green economy in achieving sustainable development. The thesis concludes that the green economy and sustainable development, economic growth, sustainable development, and environmental protection have complementary relationships. Additionally, the thesis discovered a positive effect of the green economy on economic expansion. In addition to establishing a strategy for low-carbon industrial development and expanding the use of renewable energy in the industrial sector, it is recommended that the Kingdom of Bahrain work on launching green projects by establishing new economic development projects with an emphasis on the environmental dimension, which contributes to encouraging semi-carbon-free activities, as well as establishing a strategy for low-carbon industrial development.

It is well known that the Kingdom of Bahrain will alter its production and consumption patterns by transforming its current activities into ecological ones. In addition, the Kingdom of Bahrain will review and redesign its tax, subsidy, and incentive policies to alter production patterns and consumer preferences. In addition, it is essential to consolidate the oversight and environmental authorities under a single body in order to, on the one hand, unify efforts and, on the other hand, expedite the decision-making and implementation of environmental tasks.

The relationship between energy and development is a close and indispensable one in which one is indispensable for the other, as energy is regarded as an essential pillar of development due to its reliance on the availability of sufficient energy services to achieve the economic and social objectives of the development process. The search for energy solutions

outside the circle of traditional sources, such as petroleum, which is still a vital and strategic source for the global economy, is not solely motivated by economic considerations. Rather, the large consumption of oil and its residues in the form of emissions caused significant pollution of the environment with all its elements, and the effects of this pollution began to manifest in the form of numerous environmental disasters that posed a clear threat to the continuation of life on Earth.

The beginning of the twenty-first century witnessed the consolidation of efforts to rely on renewable energies as clean sources that enable compatibility between energy security and environmental protection. Solar energy is regarded as one of the most important renewable energy sources, but despite its benefits, it is not without flaws, the most significant of which is the issue of storage for its use in times when production capacities decrease, as high storage costs lead to an increase in its price, which is what the world is attempting to overcome today.

Despite the certainty regarding the purity and permanence of renewable energies, particularly solar energy, their contribution to the total amount of energy consumed worldwide does not exceed 25 percent, which is a small percentage relative to the available resources. To overcome these obstacles, a set of means and methods have been implemented to encourage the use of solar energy and investment in this field, including the provision of financial loans from institutions and the enactment of national laws that provide the necessary incentives and facilities for investment in the field of solar energy.

As previously indicated, the economic sector in the Kingdom of Bahrain is enormous, making it difficult to apply the theory of solar energy

dependence to all economic sectors. Therefore, an overall summary was provided that detailed the quantity of energy produced by the kingdom and the precise locations where this energy is consumed.

In light of the preceding, it can be concluded that solar energy is an excellent investment on all fronts. The Kingdom of Bahrain is able to implement solar energy in its economic sector as it enjoys all of the characteristics necessary for accomplishing so;

- A. Location in terms of solar radiation: The Kingdom of Bahrain experiences high levels of solar radiation, making it an ideal location for solar energy production.
- B. Government Support: The government of the Kingdom of Bahrain demonstrates a high level of support for solar energy applications and investments. As discussed previously, the Kingdom intends to generate approximately 5% of its electricity exclusively from renewable sources by 2025. To reach this objective, the Kingdom has exerted significant effort in establishing policies and regulations.
- C. Implementation of solar energy cost: From the above analysis, it is clear that the cost of solar panels is decreasing, making it an affordable option for the government to select.
- D. Infrastructure: In terms of infrastructure (e.g., the distribution network), the Kingdom is able to rely on solar energy; however, it is necessary to undertake additional detailed research in order to maximize this potential.

This study is open for further investigation, considering the overall analysis which have been made in the above chapters

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المستخلص

يعتبر تنفيذ برامج الطاقة المتجددة من الامور الهامة حيث أنها تستهدف خفض انبعاثات الكربون وتقليل الاعتماد على مصادر الطاقة غير المتجددة على افتراض أنها ستسهم في التحول إلى الاقتصاد الأخضر وتحقيق التنمية المستدامة. وتسعى الدراسة الحالية إلى دراسة أهمية اعتماد الطاقة الشمسية وبيان ضرورة الاستثمار في تطوير أنظمة الطاقة الشمسية للقطاعات الاقتصادية. وقد اعتمدت الدراسة على المنهج الوصفي التحليلي، بالإضافة إلى الاعتماد على المنهج المقارن لدراسة تجارب الدول الرائدة في مجال الطاقة الشمسية والتحول إلى الاقتصاد الأخضر. بهدف تحديد أهم الدروس المستفادة، والتي يمكن لمملكة البحرين تطبيقها لتحقيق النمو المستدام والاقتصاد الأخضر. وقد خلصت الدراسة إلى أن مملكة البحرين قادرة على دمج أو تطبيق الطاقة الشمسية بشكل أوسع في قطاعها الاقتصادي، نظراً لما تتمتع به المملكة بالعديد من المزايا مثل الموقع ومصادر التمويل والتكنولوجيا. وتوصي الدراسة حكومة المملكة بتوحيد جهودها و زيادة الاستثمار في الطاقة الشمسية في أسرع وقت ممكن لتحقيق التنمية المستدامة وبالتالي التحول إلى الاقتصاد الأخضر في القطاعات الاقتصادية بحلول عام 2030.

الكلمات المفتاحية: التنمية المستدامة، الطاقة المتجددة، الطاقة الشمسية، الاقتصاد الأخضر، مملكة البحرين.

جامعة البحرين

قسم برامج الدراسات العليا



كلية العلوم

تقييم مدى إمكانية اعتماد الطاقة الشمسية في القطاع الاقتصادي البحريني لتحقيق التنمية المستدامة

تقديم أطروحة لاستيفاء جزئي لمتطلبات درجة الماجستير في التنمية المستدامة

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جامعة البحرين

مملكة البحرين

أكتوبر ٢٠٢٣