Future Energy
Open Access Journal
ISSN 2832-0328

November 2024| Volume 03 | Issue 04 | Pages 56-66

Journal homepage: https://fupubco.com/fuen

https://doi.org/10.55670/fpll.fuen.3.4.4

Future Publishing LLC

Review

Qatar's energy policy in the field of renewable energy

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ARTICLE INFO

Article history:
Received 18 July 2024
Received in revised form
20 August 2024
Accepted 30 August 2024

Keywords:
Renewable energy, Qatar, Energy policy, Energy security, Fossil fuels

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DOI: 10.55670/fpll.fuen.3.4.4

ABSTRACT

Qatar has abundant oil and gas reserves and has made extensive investments in renewable energy according to the zero-carbon policy in recent years. Renewable energy is vital for Qatar, and many investments and plans have been made in this country. Therefore, this article examines Qatar's energy policy in renewable energy using a mixed quantitative-qualitative methodology. In this article, an attempt has been made to answer the question, what is Qatar's energy policy in the field of renewable energy? As a hypothesis, Qatar's energy policy has changed from dependence on non-renewable energies to using and developing renewable energies to stabilize its energy security in the coming decades. Also, the theoretical framework of energy security has been used to test the hypothesis. The research findings indicate that Qatar has also adopted this policy due to the significant changes in the orientation of developed and developing countries towards new energies. Like many Persian Gulf countries, Qatar's policies have been aimed at reducing carbon. With extensive investments and long-term planning until 2030, Qatar can become a model country in the Middle East region in terms of renewable energy. This issue and fossil fuels give Qatar a special place that can turn Qatar into a fossil and renewable energy hub.

1. Introduction

Today, the importance of fossil energy is not hidden from anyone. The importance is not limited to the industry sector; it is also used in the home sector. However, pollution and carbon generation are some of the problems associated with these fuels. On the one hand, the increase in population and the limited resources of non-renewable (fossil) energy, and on the other hand, the increase in environmental pollution caused by the excessive consumption of fossil fuels has made countries and human societies face serious threats [1]. Finally, these factors show the necessity and importance of paying attention to renewable energy sources. The importance of using renewable energy compared to fossil energy due to factors such as strengthening energy security for the current generation as well as future generations has been reducing greenhouse gas emissions and solving environmental problems, but to achieve and expand renewable energy requires several plans and policies [2]. As one of the countries with rich oil and natural gas resources, Qatar has played an essential role in the energy security and economic development of the world, but in the last few years, due to the increase in the price of fossil fuels, environmental considerations, and the security of energy supply, this decision It has reduced dependence on fossil fuels and the use of renewable energy. Therefore, the main goal of this article is to review and analyze Qatar's energy policies in the field of renewable energy. In this regard, it is hypothesized that Qatar's energy policy has changed over the last few years from dependence on non-renewable energy to using renewable energy to stabilize its energy security in the coming decades. The main goal of this research is to explain Qatar's renewable energy policies in the field of renewable energy. Regarding the necessity of conducting research, considering the importance of energy, especially renewable energy, in the present and future, it was necessary to study and examine the role of renewable energy in the future due to the lack of a similar article. Analyze the country of Qatar. A necessity often ignored is the study of renewable energy in countries with no reserves or low reserves of fossil fuels and energy, and less attention is paid to countries with abundant reserves of fossil energy. This article deals with the expansion and development of renewable energy, as well as its perspective and position in fossil energy-producing countries like Qatar. This topic can be a good model for studying renewable energy in countries with fossil fuels. Also, this article provides a deeper understanding of the position of renewable energy in Qatar in line with the zero-carbon policy. Policy and strategy that is in line with the Paris Agreement. In

the following section, after examining the theoretical foundations, the infrastructure of renewable energy, its importance, and finally, the goals, opportunities, and challenges ahead, as well as the future of renewable energy development in Qatar, will be examined.

2. Materials and methods

2.1 Literature review

Among the most important research that can be mentioned as the background of the research is an article titled " A recent review of energy efficiency and renewable energy in the Gulf Cooperation Council, "examining the trend of using renewable energies in the region and states that despite the strategic location of the Persian Gulf and it is vast oil and natural resources, due to the high price of oil, the deterioration of the financial markets and also the incident of the Arab Spring, the use of renewable energy sources such as solar energy, wind They have turned to geothermal energy to meet their electrical needs [3]. An article entitled " The transition solar and wind energy use gulf cooperation council countries " examines the evolution and transition of the use of renewable energy in the region and states that extensive investment and practical and effective programs in This field can be a transitional stage in the use of renewable energy in the member countries of the Persian Gulf Cooperation Council [4]. An article entitled " Grid integration of renewable energy in Qatar: Potentials and limitations " examines the potential of integrating different renewable energy sources in Qatar's current electricity network. Finally, they conclude that large-scale facilities and advanced technologies in the field of renewable energy can significantly reduce the cost of emissions from electricity production [5]. The second chapter of the book "Sustainable Qatar: Social, Political, and Environmental Perspectives" deals with the vision of Qatar's renewable energy in 2030 and examines the policies and related institutions in the field of renewable energy and the future vision of this country [6]. The article "Made in Qatar' Energy Transition Strategy" examines Qatar's national climate change plan, which commits the country to rapid energy system decarbonization in line with the Paris Agreement. It also discusses the legal and financial frameworks, which can lead to the progress of carbon reduction goals [7]. The last source used in this regard is the article entitled "Status of renewable energy in the GCC Region and future opportunities" by Elrahmani et al. [8], which deals with the role of the government in the expansion of renewable energies in the Persian Gulf countries. Part of the article also deals with the role of technology and innovation and its role in the expansion of renewable energies.

In general, this research has been done on the importance of renewable energy, the progress and development of the Persian Gulf countries, and, in particular, the case of Qatar. An attempt has been made to comprehensively and scientifically examine Qatar's policies in the field of renewable energy, as well as its opportunities and challenges. The current articles and scientific activities rarely examine Qatar's infrastructure and potential for renewable energy. The innovation of this article is that it provides a unified vision of the current conditions of Qatar in the field of renewable energy. Then, with careful analysis and research based on the statistics and potential of this country, the future vision of Qatar in the field of energy has been analyzed. The end of this research provides plans and recommendations for developing this type of energy efficiency in Qatar. It can be beneficial and a practical resource for future research.

2.2 Theoretical and conceptual foundations

The concept of energy security has received more attention after energy has become more valuable and essential in the world and industrialized and energy-producing countries. We are witnessing internal and external conflicts and challenges in energy-producing countries that affect the energy market and other countries. The best definition regarding energy security is that energy security means the supply of sufficient and reliable energy for the demand sector. In this context, we can divide energy security into two short and long-term parts. In the short term, energy security means the ability of the energy system to deal with and react to sudden changes, such as changes in supply and demand [9]. In the long-term sector, investment in energy supply pursues different goals, such as economic or environmental growth. In the definition of energy security, we can refer to the International Energy Agency, which considers energy security as uninterrupted access to energy resources at an affordable price [10]. Customers, for example, from European countries, for an extended period, such as 20 years, will buy the resources of the energy-producing country. Term resources that are reasonably priced and economically justified for public and industrial use. May this also be defensible from a political perspective [11]. We are witnessing pollution during the production of oil and gas or the transfer of energy through sea and land, which causes environmental pollution and affects the ecosystem of that region. Governments have also considered that it is no longer like in the past when they could use fossil fuels excessively because environmental problems have become severe in human societies. Regarding transportation security, we are also looking for energy transportation to be done safely and cost-effectively. According to the research title, Qatar's energy policy in the field of renewable energy, Qatar has become inclined towards renewable energy based on energy security. Based on the security of demand, Qatar is trying to make the necessary investments in renewable energy, considering the transition period from fossil energy. On the other hand, based on the environmental security and the resulting pollution, Qatar is trying to use renewable energies so that it can follow the path of energy diversification according to the energy security framework and also be able to tap into endless resources such as the sun that the necessary weather conditions in Qatar are available to access and use.

2.3 Methodology

This article uses the mixed method, meaning quantitative and qualitative. Considering the use of statistics and figures in most parts of the article and for its analysis, it is natural to use a quantitative method. In fact, by using the quantitative method, it has been tried to provide conclusions about the state of renewable energy in Qatar. In other words, by using the quantitative method and comparing the statistics and figures of Qatar and other countries in various fields of energy, the position of Qatar has been well-defined and has resulted in clear results. Also, by using one of the parts of the quantitative method, the case study of Qatar, we have found accurate results by focusing on this country and examining it carefully. On the other hand, using a qualitative method, we could explain and analyze the statistics. In a way, according to the subject of the study, the combination of quantitative and qualitative methods is a very suitable method for study and investigation, which is used.

2.4 Data gathering

The method of data collection documents that have been used to collect the required resources using library resources such as articles and books.

2.5 Historical background

In 1939, oil was discovered in the Dukhan region of Qatar. Due to the outbreak of World War II, the development of the Dakhan oil field could have been faster. Although this discovery was great for the Qataris, it was insignificant compared to the gas field discovered 30 years later. In 1951, Qatar produced 46,500 barrels of oil per day, which earned 4.2 million dollars for the country. The discovery of oil in the sea and the investment of the Shell company for the development of the country's oil caused Qatar's oil production to increase to 233 thousand barrels per day. The increase in the income of the Qatari government due to oil led the rulers of Qatar to modernize this country. It was in the 1950s that the first school, hospital, power plant, water softener, and telephone booth were opened in Qatar. Qatar's oil revenues increased in 1960. The Al-Thani family appointed their relatives to government posts, and the family members were given unusual allowances and pensions. In 1971, The world's largest natural gas field, the South Pars/North Dome gas field, was discovered off the coast of Qatar. Due to the prosperity of oil production in that period, this field was ordered to be developed. In the 1980s, when the price of oil fell, Qatar's economy suffered a crisis [12]. Qatar increased the speed of development of the North Dome gas field, and with the increase in gas production, Qatar became an exporter of liquefied natural gas for the first time or became LNG. In the late 90s, Qatar signed production partnership agreements with many oil companies worldwide. Foreign companies started cooperating with Qatar through horizontal drilling, and Maersk drilled Qatar's longest horizontal well in one of these contracts. In 1997, Qatar signed contracts with Spain and Japan to meet the gas needs of these countries in the long term. Moreover, after the implementation of these contracts, he diversified his customers.

In 2006, the Qataris surpassed Indonesia in liquefied natural gas exports. However, this was not the end of the work because other competitors, such as Australia and the United States, were entering this market. Like other countries, Qatar has turned to investing in renewable energy to reduce carbon production based on the Paris Agreement. Although Qatar's investments could have been more impressive in the past years, the first large-scale power plant in the field of solar energy in Qatar was established in 2022, was named Al Kharsaah, and was in collaboration with France's Total [13]. This project is a big step towards expanding renewable energy in Qatar.

3. Discussion

3.1 Fossil fuel reserves, production, and consumption in Qatar

Oil and natural gas are three vital fossil energies. Coal has been crucial in energy consumption in recent years and is used in countries worldwide. In a way, we are witnessing that some European countries turned to coal after the war in Ukraine and problems related to the natural gas supply. Qatar is rich in fossil fuel reserves, especially oil and gas. According to BP statistics, Qatar has 25.2 thousand million barrels of proven oil. In addition to having oil resources, Qatar has a high position in the world in the natural gas field. With 24.7 trillion cubic meters of natural gas, Qatar has third place in the world after Russia and Iran. Now, according to the general explanations regarding the amount of oil and gas reserves, we will carefully examine the reserves, production, and consumption of oil and gas in Qatar and examine each part in detail.

3.2 Oil reserves

With 25 billion barrels of proven oil, Qatar ranks 12th in the world with oil reserves. At the beginning of this list are Venezuela, Arabia, and Iran. To better understand the number of oil reserves in different countries, we have examined some important countries and the growth of their reserves, as shown in Table 1.

Table 1. The number of oil reserves of different countries from 2000 to today [14]

Total proved reserves	One thousand million barrels at the end of 2000	thousand million barrels at the end of 2010	One thousand million barrels at the end of 2019	One thousand million barrels at the end of 2020	One thousand million tons	Total share	Ratio R/p
America	30.4	35.0	68.8	68.8	8.2	4.0%	11.4
Iran	99.5	151.2	157.8	157.8	21.7	9.1%	139.8
Saudi Arabia	262.8	264.5	297.6	297.5	40.9	17.2%	73.6
Qatar	16.9	24.7	145.0	25.2	2.6	1.5%	38.1
Iraq	112.5	115.0		145.0	19.6	8.4%	96.3

Based on Table 1, various countries have improved and upgraded their reserves in the field of oil by using the development of technology and the development of fields and drilling. Qatar had 16.9 billion barrels of proven oil at the end of 2000, which increased to 24 billion barrels at the end of 2010 and 25 billion barrels at the end of 2020. Qatar has 1.5% of the world's oil reserves, which is significant for a small country like Qatar.

3.3 Qatar's oil production and consumption

Due to the spread of Corona and the decrease in global oil demand, we saw a decline in oil production in Iran, which caused a reduction in Qatar's production [15]. Qatar's oil production also increased after the decrease in Corona and reopening due to quarantine and improved demand. As shown in Figure 1, in 2020, after a sharp drop in demand, Qatar's oil production reached one million three hundred thousand barrels per day on average in 2020. In Figure 2, we can see the daily oil consumption of Qatar from 2009 to 2020. Consumption that we have seen an increase since 2009, except for some periods, which is one of the reasons for the expansion and economic and industrial development of Qatar. The drop in early 2020 was also caused by the start of the Corona pandemic.

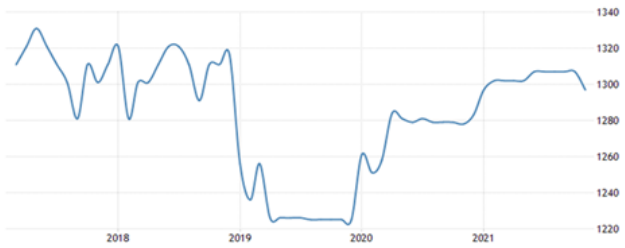

Figure 1. Qatar's oil production from 2018 to 2022 [16]

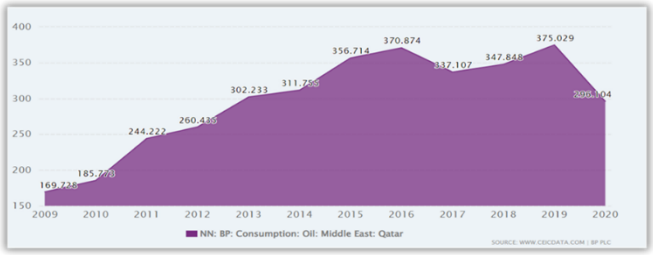

Figure 2. Qatar's oil consumption from 2009 to 2020 [17]

3.4 Qatar's natural gas reserves and amount of production and consumption

Qatar is considered the third holder of gas reserves in the world. After Russia and Iran, Qatar is in the world's third position in gas reserves. According to Table 2, Qatar had 14 trillion cubic meters of natural gas at the end of 2000. This figure increased significantly at the end of 2010 and reached 25.9. This figure reached 24.7 trillion cubic meters at the end of 2020. According to BP statistics, Qatar has 13% of the world's gas reserves. On the other hand, Qatar's natural gas production in 2020 was 171.3 billion cubic meters, which has grown compared to previous years. In the natural gas production based on Table 3, we see other countries in the natural gas production field, where Russia and Iran have much higher production than Qatar. According to Table 4, we can see that although Qatar has high production and reserves of natural gas in terms of consumption, due to the low amount of domestic consumption, Qatar has an excellent capacity to export natural gas. For example, a country like Iran needs to improve its ability to export more due to high domestic consumption. One of the reasons for less gas consumption in Qatar is its smaller population compared to Iran and Russia. According to the statistics, the lack of consumption and high production capacity of Qatar, if the development and expansion of the fields continue, can provide a new and good horizon for Qatar in the coming years in the field of natural gas production for this country. Qatar is the world's first LNG exporter, as shown in Table 5. With Qatar's recent investments in the past years and considering the lack of access to other countries through land borders, it has expanded and developed LNG. This issue has caused, for example, Qatar to be the first exporter of LNG to China, or due to the war between Russia and Ukraine and concerns about gas supply and a possible Russian gas famine, Germany signed a contract with Qatar to increase the amount of LNG exports to the country signed, which shows Qatar's plan to expand and centralize LNG exports for the country.

3.5 The importance of renewable energy

Renewable energies are among the energies with carbon neutrality and, therefore, do not enter carbon into the environment and cause environmental pollution. Although fossil fuels have significant advantages such as reasonable prices and easy transportation, factors such as environmental pollution and the lack of access to fossil fuels by all countries in the world have caused the attention of the world's countries towards renewable energies [19].

Table 2. The amount of natural gas reserved by the top 5 natural gas countries from 2015 to 2020 [14]

Total proved reserves	trillion cubic meters at the end of 2000	trillion cubic meters at the end of 2010	trillion cubic meters at 2019the end of	trillion cubic meters at the 2020end of	trillion cubic meters	Share of the total
Qatar	14.9	25.9	24.7	24.7	871.1	**13.1%**
Iran	25.4	32.3	32.1	32.1	1133.6	**17.1%**
Russia	33.2	34.1	37.6	37.4	1320.5	**19.9%**
Turkmenistan	1.8	13.6	13.6	13.6	48.3	**7.2%**

Table 3. Natural gas production of the first four countries with natural gas reserves in the world from 2015 to 2020 [14]

Natural gas: production in cubic meters	2015	2016	2017	2018	2019	2020	Growth rate 2020	2009-19	Share 2020
Qatar	175.8	174.5	170.5	169.1	172.1	171.3	%0.7-	%6.4	**%4.4**
Iran	183.5	199.3	213.8	232.0	241.4	250.8	%4.6-	%4.8	**%0.3**
Russia	584.4	589.3	635.6	669.1	679.0	638.5	%6.2-	%2.4	**16.6%**
Turkmenistan	65.9	63.2	58.7	61.5	63.2	59.0	%6.9-	%6.6	**%1.5**
Saudi Arabia	99.2	105.3	109.3	112.1	111.2	112.1	%0.6	%4.1	**%2.9**

Table 4. The amount of natural gas consumption from 2015 to 2020 [14]

Natural gas: consumption in billion cubic meters	2016	2017	2018	2019	2020	Growth rate	2009-19	Share 2020
Qatar	41.2	41.2	34.1	36.7	**35.0**	**%4.9-**	**%5.6**	**%0.9**
Iran	193.3	205.0	219.6	223.4	**233.1**	**%.4-**	**%5.2**	**%6.1**
Russia	420.6	431.1	454.5	444.3	**411.4**	**%7.7-**	**%1.1**	**%10.8**
Turkmenistan	25.1	24.8	28.4	31.5	**31.3**	**%1.0-**	**%6.3**	**%0.8**
Saudi Arabia	105.3	109.3	112.1	111.2	**112.1**	**%0.6**	**%4.1**	**%2.9**

Table 5. The amount of LNG exports from Qatar and Russia from 2015 to 2020 [14]

Natural gas: the amount of LNG exports (billion cubic meters)	2016	2017	2018	2019	2020	Growth rate 2020	2009-19	Share 2020
Qatar	107.3	103.6	104.9	105.8	**106.1**	**0**	**%7.4**	**%21.7**
Russia	14.6	15.4	24.9	39.1	**40.4**	**%3.1**	**%19.0**	**%8.3**

Another reason countries desire renewable energy is that it provides easy access to this type of energy. All types of renewable energy are provided through the energy of the sun, water, and wind, which are available in all parts of the world. It is possible to access and use them, unlike fossil fuels that exist in some countries of the world. On the other hand, another critical reason for countries' preference for renewable energy is the finite nature of fossil fuels. The time-consuming nature of re-creating fossil fuels has led to these types of fuels being considered non-renewable, while renewable energies are not and are considered an inexhaustible resource. The reason for the importance of renewable energy is that it is free and God-given. For example, countries do not need to pay for sunlight, and this resource is provided for free.

The world's countries are based on energy security, which is easy access, low price, and, most importantly, supply within the country. No need to import has made the world's countries pay attention to renewable energy based on energy security. Reducing the need to import energy from other countries and supplying it with renewable energy can be considered a step towards energy security. On the other hand, environmental concerns that have increased recently are another reason for the importance of renewable energy. The increase in pollution caused by fossil fuels and climate change has caused the world's countries to turn to renewable energy. For example, the increase in pollutants and the entry of carbon into the atmosphere have caused international organizations to be concerned about climate change. On this basis, European countries have tried to reduce greenhouse gases by 20% of their total energy consumption with policies

in this regard. Supply by renewable energy. Now that we know the importance of renewable energy, we will introduce some types of renewable energy. The world's first and most important renewable energy source is solar energy. Solar energy can be considered the source of all the energy on earth, converted into direct and indirect forms of energy. According to estimates, if 0.1% of the amount of solar energy that reaches the earth is converted into electrical energy by a factor of 10%, 3000 gigawatts of energy will be produced, four times the world's annual consumption is a unique and significant figure. Another renewable energy is wind energy. According to the New Energy Organization report, wind energy has experienced the highest growth among renewable energies, with a growth of 26% since 1990. According to the Wind Energy Association estimates, if the side costs of wind energy are reduced, the final cost of wind energy will be cheaper than fossil fuels. It can be used. On the other hand, wind energy can be considered the easiest energy to produce electricity in the world, and its pollution level is very low compared to other energies. Of course, wind energy can be used in some parts of the world. For example, wind energy in Iran is used in windy places such as Manjil. Renewable energy includes water energy, waves, and tides. These types of energies are the result of water energy. This type of energy is supplied by water in rivers or seas. For example, Ukraine has the highest level of hydroelectric energy production in the world, and it has been able to produce electric energy through the construction of dams on rivers. This type of energy, like wind energy, has limitations. For example, the countries of the Middle East are facing water and river restrictions, and for this reason, this type of energy is used less. Although some countries like Qatar have access to the ocean and the Persian Gulf, it is possible to use beaches and wave energy. Nuclear energy is another type of renewable energy that produces electricity through the energy from uranium. However, the environmental problems of nuclear waste have reduced the attention of countries to this type of fuel in the world or problems such as atomic explosions. Chornobyl's destructive effects continue after many years.

3.6 Renewable energy infrastructure

Qatar has suitable conditions for using renewable energies, especially solar energy, due to the suitable weather conditions (days and hours of high radiation). Long hours of sunshine have provided conditions for the use of solar energy. According to statistics and images in Figure 3, Qatar has an average of more than 200 hours of sunlight per month, which provides the conditions for using solar energy. Figure three shows well that Qatar has great potential in the field of solar energy due to the very high average radiation 200 average hours means 200 solar hours per month, not ordinary hours. Qatar's abundant solar hours have provided an advantage and suitable conditions for Qatar in renewable energy development.

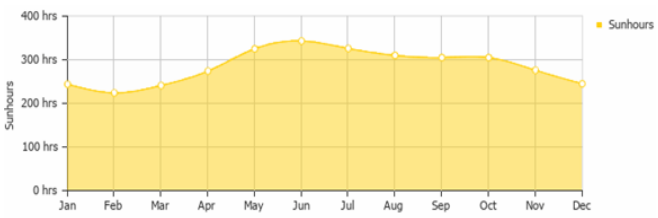

Figure 3. Average monthly solar radiation in Doha, Qatar

On the other hand, the creation of greenhouse gases in the Arab countries of the Persian Gulf has increased due to factors such as population growth and industrialization. According to the air quality index statistics 2019, Arab countries are among the most polluted countries in the world [19]. Qatar's average per capita electricity use is 16.6 MWh, much higher than the global rate. According to the statistics of Global Petrol Price, the price of electricity in Qatar is 0.0032 (kWh, U.S. Dollar), which is considered one of the countries with the lowest price of electricity in the world. The world average price is 0.172 U.S. Dollars per kWh for household users and 0.193 U.S. Dollars per kWh for business users. An issue that we saw increase with the increase in demand due to the increase in population or the expansion of industry. On the other hand, as it was said, the increase in greenhouse gas creation beyond the global average has caused the Arab countries of the Persian Gulf to worry. The increase in greenhouse gases can eventually lead to a decrease in the gross national product of these countries. This issue has caused Qatar's attention to renewable energy and its desire to reduce the amount of pollution. As mentioned, favorable weather conditions have led to broader investment in solar energy. With the spread of the Corona pandemic, changes were made regarding policies and attention to renewable energies, especially solar energies. The decrease in demand for oil and gas caused excess demand in Qatar and domestic use, and, in a way, renewable energy was ignored in the early days of Corona. Despite the favorable geographical conditions of Qatar, its electricity production from solar energy is tiny, around 5 megawatts. The insignificance of this figure is determined when Qatar's electricity production by fossil fuels was 13,099 MWh. Also, the total energy produced by renewable energies in Qatar was 43 MWh, according to the World Renewable Energy Organization statistics. 17% of the share of electricity production was in Qatar [20]. Qatar has tried to reduce electricity costs by using solar photovoltaic (PV) systems. In this regard, various projects in Qatar have been tried using this technology. In this regard, in January 2020, Qatar Water and Electricity Company tried to increase the power of solar energy by integrating the Lakher Solar Project. In 2021, the smart solar project continued in Qatar through the Qatar Foundation. Accordingly, the Qatar Foundation campus established a smart solar grid, which can produce 1.68 MWh [21]. Table 6 (renewable energy consumption) and Table 7 (renewable energy production) show that, as mentioned, Qatar has yet to make much progress in renewable energy compared to other countries in the world. The percentage of production and use of renewable energy in Qatar is low and insignificant. While we witness that the world's renewable energy consumption and production are increasing yearly, this does not apply to Qatar. However, Qatar's investments and programs of this country can increase the percentage and amount of renewable energy production in this country. In Table 8 (Renewable energies by energy type), we see a comparative comparison between Qatar and the world. Qatar did not increase its capacity in 2019 and 2020, and the capacity to produce renewable energy, separated by different sectors, remained the same. While according to the statistics of the countries of the world, there has been significant growth, especially in the solar energy sector. This growth in wind energy and other renewable energies has continued, which indicates the serious attention and investment of countries in the world in renewable energy sectors.

Table 6. The amount of renewable energy consumption in the world and Qatar [14]

Renewable energy consumption	2016	2017	2018	2019	2020	2020 growth rate	2009-19	Share 2020
Qatar	†	†	†	†	†	%0.6-	-	0
the whole world	20.11	23.06	25.88	28.82	31.71	%9.7	%13.4	%100.0

Table 7. The amount of renewable energy production [14]

Renewable energy production	2016	2017	2018	2019	2020	Growth rate 2020	19 2009-	Share 2020
Qatar	0.1	0.1	0.1	0.1	0.1	%0.3-	-	0
the whole world	1851.3	2180.2	2478.6	2789.2	3147.0	%12.5	%15.9	%100.0

Table 8. The amount of renewable energy production in Qatar by energy type [14]

Renewable energies by energy type	solar	Other renewable resources	2019 Total	the wind	solar	Other renewable energy sources	2020 Total	2020 growth rate (inflated)	solar	Other sources are welcome	Total
Qatar	†	0.1	0.1	-	†	0.1	0.1	-	-%3.0	-%0.3	%0.3-
the whole world	707.9	663.1	2789.2	1591.2	855.7	700.1	1347.1	%11.9	20.5 %	%5.3	%12.5

3.7 Opportunities and challenges facing Qatar in the field of renewable energy

As stated, in the last two decades, different countries have set specific goals and plans for the use and exploitation of renewable energies; in fact, they have realized that the increase in power generation from renewable energy sources is one of the most basic ways to protect the environment. However, to achieve these plans and goals, despite the opportunities available in its development, some limitations make these plans challenging. For example, although solar energy has provided its use and exploitation in a country like Qatar due to its high radiation, factors such as climate change may challenge the use of this energy. Also, solar photovoltaic (PV) systems that produce electrical energy directly from the sun's radiation could be more reliable in terms of fixed production [22]. Qatar, as stated in the previous section, has a certain amount of wind potential, which is shown from the data obtained from Doha, the capital of Qatar, between 1976 and 1989, that the average wind speed is 10 meters above the ground. This wind potential has helped the country to use wind energy and also in the development and progress of renewable energy. We can see the average wind speed in Doha in Figure 4. Paying attention to the natural conditions of Qatar with the ratio of wind turbines allows the production of energy from the wind on a large scale. Nevertheless, these conditions are different in different seasons of the year. For example, wind energy is very low in the summer due to the high ambient temperature.

In the summer, we face increasing electricity demand and decreasing wind energy [22]. Therefore, by using solar energy in the hot months of the year, if the capacity of CSP technology is increased, it can take a significant share of electricity production. Also, Qatar has one of the highest per capita urban waste productions, which can convert waste into energy. However, the waste management process must be formed wholly and comprehensively to achieve this goal. The biggest challenge in the field of renewable energies in the field of 100% exploitation of these new energies is their storage. Therefore, Qatar can obtain these resources to a large extent only if it develops the necessary infrastructure and technologies using private sector investment.

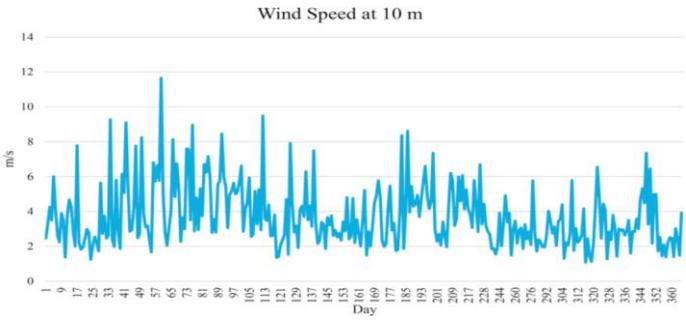

Figure 4. Annual average wind speed in Doha, Qatar

Therefore, in Figure 5, the amount of investment in the last few years in Qatar has the lowest amount of investment in renewable energy compared to other countries [23].

3.8 Objectives and future of renewable energy in Qatar

Due to the significant contribution of renewable energy in reducing the emission of harmful greenhouse gases, the global acceptance of renewable energy and the use of new technologies for its development has increased significantly. The countries of the Middle East, especially Qatar, have historically relied on fossil fuels in their economy and have been trying to increase their share of total renewable energy production in the last few years [24]. Therefore, the member states of the Persian Gulf Cooperation Council, of which Qatar is one of the critical members, have each set different strategic goals to produce a particular share of their total energy from renewable sources in the next two decades. Renewable energies such as solar and wind sectors, due to their abundance and favorable environment in these countries, have had a suitable place in the energy development programs in the field of renewable energies. In Table 9, an estimate of the capacity of renewable energy until the end of 2030 in the countries of the Persian Gulf has been made, based on the goals of the countries in the field of new energy. While the oil and gas sectors have a significant contribution to the regional GDP, the economic policy in the Persian Gulf Cooperation Council member states emphasizes diversity in their economy. Figure 6 shows the goals and plans of the Persian Gulf Cooperation Council member states in the direction of renewable energy development.

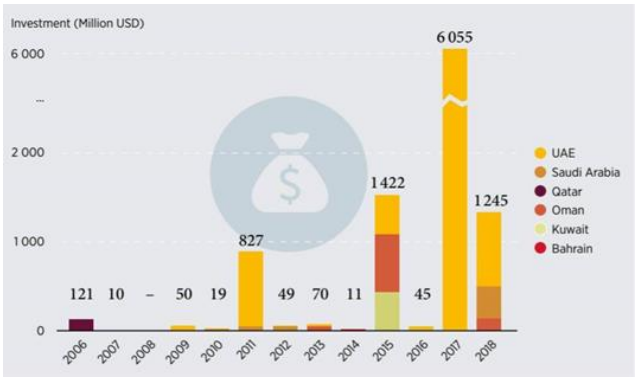

Figure 5. Amount of investment in renewable energy projects in the countries of the Persian Gulf Cooperation Council (2018-2006)

Table 9. Estimation of renewable energy capacity in 2030 [23]

	CSP	PV (utility scale)	PV (roof-top)	Wind	Waste-to-energy	Total	Source
	Capacity in 2030 (MW)						
Bahrain	70	520	70	20	20	700	IRENA assumption
Kuwait	1 000	5 800	1 000	200	-	8 000	Based on inputs from country expert
Oman	770	2 420	990	1 210	110	5 500	Target of 2.6 GW by 2025, followed by 600 MW added every year to 2030
Qatar	600	2 250	150	-	100	3 100	IRENA assumption
Saudi Arabia	9 500	10 500	750	3 500	750	25 000	Target of 9.5 GW by 2023, followed by 2 GW added every year to 2030
United Arab Emirates	6 000	18 900	4 200	300	600	30 000	Based on Masdar Institute/IRENA (2015)
GCC Total	17 940	40 390	7 160	5 230	1 580	72 300	

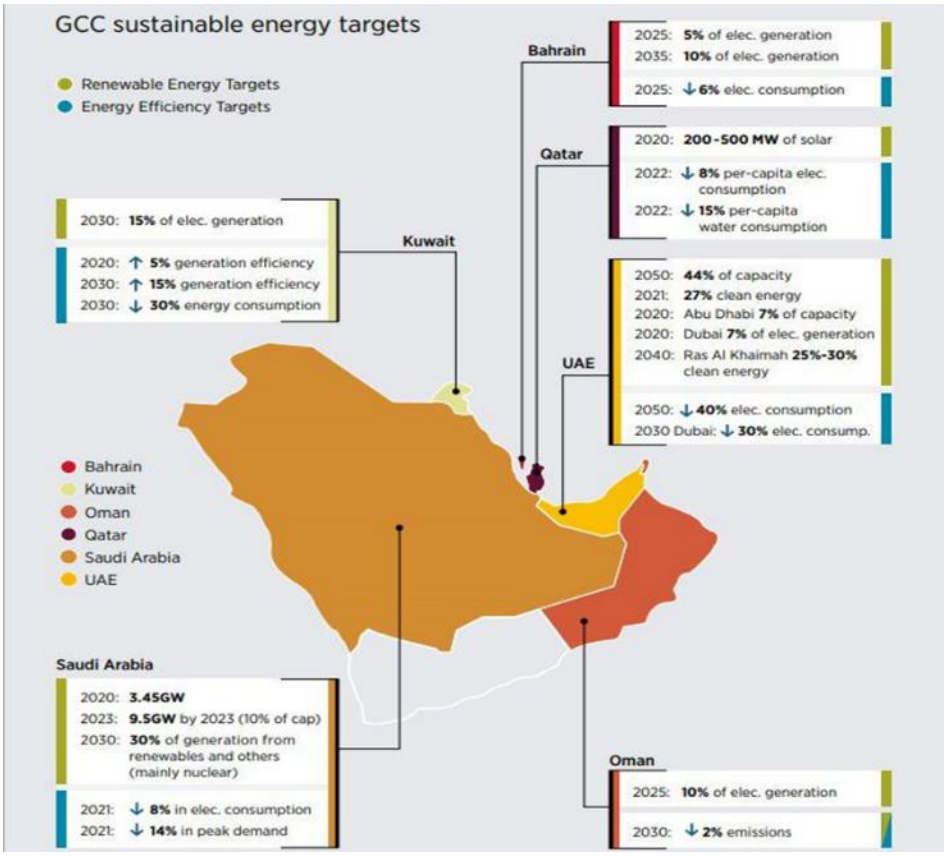

Figure 6. Sustainable energy goals in the member states of the Persian Gulf Cooperation Council Source [23]

Since 2000, Qatar has started extensive programs regarding the use and development of renewable energy. For example, a dedicated seawater desalination plant with solar energy can produce water for irrigation at 50 cubic meters per second [23]. In its national development strategy from 2011 to 2022, Qatar presented a plan for managing natural resources, which includes a request to increase the use of renewable energy [25]. Also, in the plans adopted in its national vision document in 2030, Qatar seeks to reduce climate change and balance development needs and environmental protection. Therefore, this country is committed to improving energy utilization, clean and renewable energy, and education and research in line with the development of this energy. Also, as part of its strategy, Qatar seeks to strengthen water and waste management and develop its transportation infrastructure by adapting to the development of renewable energy. As a result, Qatar's 2030 vision seeks to create a balance between the oil-based economy and the knowledge economy to diversify the country's economy. Qatar's second national strategy between 2018-2022 has adopted a plan for natural resources that calls for using renewable energy. Specifically, Qatar's strategy targets 200 to 500 MWh of solar energy production capacity by 2020. In a report, Qatar also announced its goal to use solar energy to cool stadiums during the 2020 World Cup. This project, announced by the Qatar Water and Electricity Company, was estimated to have a capacity of about 3,500MWh [26]. According to Qatar's plans and policies in the development of this field, during the last few years, Qatar has made slow progress in the development of renewable energy, except for municipal waste. Qatar has the largest waste-to-energy facility in the region. For example, the Moseed power plant produces 30 MWh based on biogas and municipal waste [27]. Qatar has presented a vision for the future of the country and its energy based on renewable energy. According to its strategy and plans, Qatar is trying to turn this country into an advanced and developed country in terms of renewable energy. The important thing about this country's plans is to pay more attention to environmental issues and reduce pollution caused by the use of fossil fuels. Figure 7 shows the perspective of renewable energies and environmental changes.

According to the above figure, Qatar seeks to increase its renewable energy capacity from 1.6 GW by 2025 to 2 to 4 GW by 2030, which will experience a growth of about 100 percent. On the other hand, Qatar seeks to reduce environmental pollution, especially carbon emissions. Also, in the LNG and upstream industries, 25 and 15 percent carbon reduction is considered by Qatar by 2030, which shows the importance of Qatar in the future vision of this country. Problems that are still plaguing Qatar today and have created environmental problems for this country. For example, according to estimates, the problems of global warming, especially in Qatar, will cause us to see an annual decrease of 26 mm of water in Qatar between 2071 and 2100. In recent years, Qatar has tried to create awareness among the people about expanding renewable energy and creating a culture of using it. Qatari society, according to the research and statistics that have been presented, more than 70% of the people have the necessary knowledge about the use of solar panels [28]. Based on this, it has predicted plans for the future of renewable energy in this country. The first goal of this country for 2030 in the field of transportation is to provide 100% of the fuel for buses in this country through renewable energy. Also, this country plans to build 400 electric charging stations for electric cars all over Qatar by the end of 2022. On the other hand, Qatar's final goal in transportation is to provide 10% of the fuel for vehicles that Qatar uses with electric and renewable energy. It will be built globally in this country by 2030. Also, due to the holding of the World Cup in this country, efforts have been made to make this World Cup the first World Cup without carbon production in the world. One of Qatar's most important renewable energy projects is the Siraj solar project, which can produce 700 MWh in 4 months. Through a contract with Japan's Total and Marubeni, Qatar is pursuing constructing an 800 MWh project called Al-Kharasa. The Al-Khorasa project, which is for the development of solar power plants in Qatar, this solar power plant is located 80 km west of Doha. The entire company owns 49% and Marobani 51% of this project. Al Khoraseh power plant has two phases. The first phase will be completed in the first half of 2022, and the second phase, which has a capacity of 400 MWh, will be connected to Qatar's electricity grid by the end of the year. On the other hand, in addition to trying to develop solar energy, Qatar is also looking to develop wind energy in this country.

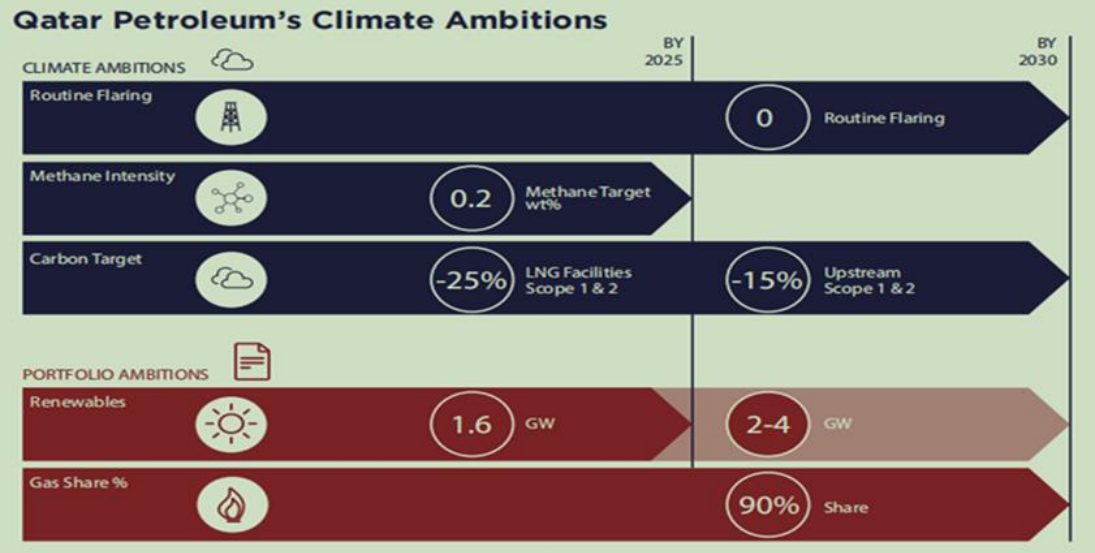

Figure 7. Qatar's oil outlook in the climate context

Qatar has the highest average wind power inland areas in the Arab countries of the Persian Gulf. According to the investigations carried out in Qatar, in some areas of Qatar, the possibility of generating electricity by wind energy in December and June is up to 282 volts per month, which is a power worthy of attention, and this is the reason why Qatar seeks to increase the creation of turbines. This country will have wind turbines by 2030 [29]. According to estimates and studies regarding the installation of wind turbines in Qatar, Abu Sera, Doha International Airport, and Doha, it is possible to install wind turbines. In some places, such as Abu Sera, it is possible to produce 0.9 gigawatts of electricity annually.

4. Conclusion

The environmental crises and limitations of fossil resources have been among the main reasons for changing the current energy system and replacing fossil fuels. A good energy system that replaces non-renewable energies, energy based on renewable sources such as the sun, wind, waves, sea tides, etc., can replace fossil energies. Therefore, in the past few years, countries have been paying attention to renewable energy. Despite having huge fossil energy resources, the Persian Gulf and Qatar countries have tried to reduce their dependence on these sources and switch to renewable energy sources. For several decades, in addition to the environmental factors and the limitations of fossil resources that have been stated, Qatar has tended towards renewable energy based on energy security. Considering the transition period from fossil energy, Qatar is trying to invest in renewable energy based on demand security. As a result, due to its good weather conditions, especially in solar energy, Qatar has tried to increase its utilization by adopting plans and policies and spending significant investments in the last few years. In recent years, Qatar has tried to be considered an excellent example in the transition from fossil energy to renewable energy among countries with fossil fuels. However, Qatar has the lowest rate of progress in renewable energy compared to other countries in the Persian Gulf. Based on the future perspective of energy development in renewable energy, Qatar is trying to achieve progress in the field of new energy according to its plans and goals. One of the most important goals of Qatar is to increase the use of renewable energy in the field of transportation by 2030. Also, Qatar plans to build 400 electric charging stations for electric vehicles throughout Qatar by the end of 2022. It is another program in this country. The effort is to create the world's first smart city by 2030. Therefore, despite the slow progress of Qatar in developing new energy compared to other countries, considering the pencils and opportunities that this country has for the development of renewable energy. Moreover, the plans and solutions it has presented for the future of its development. It can take steps toward sustainable development of this energy and achieve significant progress. Of course, one problem that exists, especially in countries with fossil fuels, such as Qatar, is less investment in renewable energy. In general, the country of Qatar can be considered a successful model in this field if it expands investment in the field of renewable energy. Solutions such as allocating a part of the revenues from the sale of fossil fuels to equipping and building renewable energy power plants, tax exemptions in the field of investment and other measures can play an accelerating role in the transition from fossil to renewable energy in countries such as Qatar. Also, due to Qatar's political support and legislation, it has a suitable perspective beyond the Persian Gulf countries. Finally, this research can be a helpful source for other future research, considering that there aren't many scientific articles in this field, and it can create openings regarding renewable energy in fossil countries despite limitations in accessing more sources and accurate statistics regarding Qatar's future energy policy.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically concerning authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Data availability statement

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no potential conflict of interest.

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