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Article

The future of renewable energy in Iran's energy policy

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ABSTRACT

Renewable energy has become a very important issue in the world. Access problems, high prices, and environmental issues of fossil fuels have caused the world to turn to renewable energy. Using the quantitative-qualitative combined methodology and the theoretical framework of energy security, this research has tried to answer the question of what the future of renewable energy in Iran is. The hypothesis of this research is that despite the adoption of programs and policies for the productivity and development of renewable energy in Iran, sanctions and investment problems make the development of renewable energy in Iran a structural problem. The findings of the research indicate that in the long term, solving structural challenges such as sanctions and investment and encouraging investment in renewable energy can provide a transition path by diversifying energy sources. So, the article tries to analyze the situation of renewable energy in terms of opportunities and challenges and show a vision of the future of this energy in Iran.

1. Introduction

There is no doubt that fossil fuels have been one of the most important factors in the growth and development of countries in the years after their discovery. However, increasing exploitation and dependence on fossil fuels, especially oil and coal, has brought many environmental challenges, such as global warming, air pollution, climate change, and security and economic challenges for countries. In addition to these factors, it should be kept in mind that energy consumption is limited, and with the increase in energy consumption in the world, especially in Iran, it is no longer possible to rely only on fossil fuels. For this reason, investing in the development of renewable energies such as wind and solar energy should be the main priority in the energy sector of countries. The transition from fossil energy and lack of investment in renewable energy can lead to significant consequences. This issue is not only related to the economic sector but can also include wide political and social dimensions. One of the most important features of renewable energies is their inexhaustibility and cleanliness. It is one of the most basic characteristics and important differences between new energy and fossil energy. As a result of these issues and problems, developed and developing countries pay attention to the necessity of fossil energy and try to supply part of their energy needs from other sources, including renewable energy. Among these countries, we can mention the Islamic Republic of Iran, which has paid attention to the importance of developing renewable energy and adopting appropriate policies. The main goal of this research is to explain Iran'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 Iran. A necessity that is often ignored (and 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 can deal with the expansion, development, perspective, and position of renewable energy in fossil energy-producing countries like Iran. 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 Iran in line with the zero-carbon policy. Policy and strategy that is in line with the Paris Agreement. Using the quantitative-qualitative combined methodology and the theoretical framework of energy security, this research has tried to answer the question of what the future of renewable energy in Iran is. The hypothesis of this research is that despite the adoption of programs and policies for the productivity and development of renewable

energy in Iran, sanctions and investment problems make the development of renewable energy in Iran an issue of structural problem. The findings of the research indicate that in the long term, solving structural challenges such as sanctions and investment and encouraging investment in renewable energy can provide a transition path by diversifying energy sources. Therefore, in this article, we will evaluate and analyze the goals and policies, opportunities and challenges, as well as Iran's energy infrastructure in the field of renewable energy. On the other hand, by examining the capacities and current conditions of renewable energies, we pay attention to some existing capacities in Iran that provide the conditions for the expansion of renewable energies.

2. Materials and methods

2.1 Literature review

Several types of research have been done on the importance of renewable energies and their impact on the environment and sustainable economic development of countries. Also, the plans and goals of the Islamic Republic of Iran have been examined in line with the development of new energies, each of which overlaps with this article in some way. However, the present research tries to comprehensively and scientifically investigate and analyze Iran's policies in the field of renewable energy and the opportunities and challenges it has faced in the last few years.

- Yazdanipanah Daru et al. [1], in an article entitled "Comparative study of energy security promotion using renewable energy, in geopolitical comparison between Iran and Japan, with the strategic management pattern" compared and evaluated the impact of renewable and non-renewable energy factors on energy security mechanisms of these countries. Finally, they concluded that despite the limited sources, fossil energy also presents challenges globally, including pollution of the environment. Therefore, it is necessary for countries, especially Iran and Japan, to replace renewable energies that help improve national energy security in order to prevent the resulting crises that also affect energy security.
- In an article entitled " Strategic study for renewable energy policy, optimizations and sustainability in Iran by Zahedi et al. [2]. In this article, the authors have tried to review studies on the importance of addressing strategic issues in the field of general policies adopted and renewable energy development strategies in Iran. The results of these studies show that despite Iran's diverse potential in the field of renewable energy. Wind energy has a higher priority than other cases in terms of economic justification and competition in the market and domestic production rate.
- Quchani et al. [3], in an article entitled "Development of renewable energy in Iran," reviewed the future of Iran's renewable energy in three domains: long-term acquisition of renewable energy, the continuity of Iran's energy policy in the field of new energy and attracting foreign capital. Finally, it is concluded that success in implementing renewable energy policies in Iran depends on the choice of policies that are the most consonant with national goals, technical capabilities, and the country's economy. Finally, it is stated that to develop a comprehensive renewable energy plan and efficiently and successfully implement it, it is necessary to identify the limitations, obstacles, facilities, and existing agreements of international sanctions.

2.2 Theoretical framework

The theoretical framework for energy security has been considered more and more in the last few decades about the promotion and importance of more energy globally. Countries are well aware of the role of energy in local and international developments. Abbas Maleki [4] contributes to the energy security definition in his energy security book, which means providing energy to a sufficient amount of energy for the demand sector. On the other hand, there are other definitions of energy security. The most important of these definitions is the energy security of the International Energy Agency, which considers energy security uninterrupted access to energy sources at a fair price (https://www.iea.org/areas-of-work/ensuring-energy-security). The important issue in both types of definitions of access to energy is at the right price. It is permanently regarded as the most important principle of energy security. On the other hand, some believe that energy security consists of four principles: availability, cost, effectiveness, and acceptability [5]. As mentioned, the concept of energy security has wide dimensions. One of the most important aspects of energy security theory is the security of supply. This concept is used for countries that import or buy energy, which means that the buyer country is sure of the supply and access to a sufficient and long-term amount of energy. On the other side, there is also the concept of demand security for producing countries. The security of demand means that the producing countries are sure of regular and long-term customers for the sale of their energy carriers and know that they can be sure of their energy sales for the next few years [6]. To better understand the security of supply and demand, we give an example. As a producing country, Iran seeks to maintain the security of its demand and a suitable customer like China can be used to stabilize the security of supply. On the other hand, China considers Iran an energy exporting country to ensure the security of its demand. It forms the basis of its theories. In addition, energy security has taken on a broader dimension in recent years and includes environmental issues [7]. European countries, due to the problems of the environment and the pollution caused by using fossil fuels, have been used in the replacement of renewable energy and using them. Therefore, we can understand the security of the environment and sustainable development as a part of energy security. In fact, in addition to the importance of bioenvironmental issues, European countries have attempted to solve energy security, energy routes, energy dependence, and energy imports through renewable energy to satisfy their energy needs. On the other hand, the countries of the world, considering the importance of bio-environmental issues, try to reduce carbon and improve environmental conditions, which encourages the countries to use renewable energy to reduce carbon emissions. In this paper, we have attempted to explain and study the subject by considering the issue of the transition of fossil energy to renewable energy in Iran In fact, using the energy security framework, we can consider issues such as demand security as well as environmental issues and sustainable development in renewable energy development in Iran .on the other hand, the importance of the theoretical

framework of energy security in this paper is that with the development of renewable energy in the world, demand reduction in the fossil energy sector and fact endangering the security of demand for energy - producing countries such as Iran, can affect the wide economic, political and security aspects. Furthermore, the security of the environment and sustainable development can be considered an important topic in the report on renewable energy.

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 Iran. In other words, by using the quantitative method and comparing the statistics and figures of Iran and other countries in various fields of energy, the position of Iran 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 Iran, 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 Novelty of article

In general, research has been done on the importance of renewable energy, progress, and development in Iran, each of which overlaps with parts of this region in some way. However, within the scope of the current research, independent, comprehensive, and transparent research has not yet been presented. Therefore, in this article, Iran's policies in the field of renewable energy, as well as its opportunities and challenges, are comprehensively and scientifically examined. In past articles and scientific activities, we rarely saw a detailed examination of Iran's infrastructure and potential for renewable energy. The innovation of this article is that it provides an integrated vision of Iran's current conditions in the field of renewable energy and then provides a future vision of this country with detailed analysis and research based on the country's statistics and potential. Thought to be. The innovation and distinction with future research of this paper make it more important than other research and the need to do it. Unlike other articles, this article examines the status of fossil fuels, policies, and renewable energy projects in Iran that have been built and are being built in Iran. At the end of this research, plans and recommendations for the development of this type of energy efficiency in Iran are provided, which could be useful for future research.

2.5 Data gathering

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

2.6 Historical Background

The first drilling operation in Iran started in the west of Iran near Qasr Shirin, and the first oil well, "Do Chah Sorekh" reached oil in 1902 at a depth of 507 meters. As a result of the help and courage of some managers and engineers of Darsi, after extensive efforts, finally, in 1908, the first well at a depth of 360 meters and the second well at a depth of 307 meters in the "Neftun" area of Suleiman Mosque reached a large reservoir of oil [8]. This well was dug with the simple and basic tools of that time and reached oil at a depth of 338 meters in the Asmari formation, and its exploitation began in 1290 with a daily production of 500 barrels. After the discovery of oil in Masjid Suleiman, the exploration operation continued to discover other reservoirs, and Haftgel oil fields were discovered in 1927, Aghajari (1936), Gachsaran and Pazanan (1937), nafte sefid (1938), followed by very rich and important reservoirs. Others, such as Lali (1948), Ahvaz (1958), Bink (1959), Bibi Hakimeh (1960), Maron and Koranj (1963), Parsi and Ragsefid (1344) oil fields were also discovered and exploited [9]. The first use of natural gas outside the oil-rich areas in Iran was to feed the newly established Shiraz Fertilizer Complex plant, which was built and operated in 1965, and natural gas was needed for its initial feed. A pipe with a diameter of 10 inches and an approximate length of 215 kilometers was built from Gachsaran to Shiraz.

About 30 to 35 years ago, the policies of the National Iranian Oil Company provided the technical and economical means to contain associated gases, prevent their waste and burning, collect and refine, transfer, export, and sell. In fact, compared to the oil industry, Iran's gas industry is less old, and global reasons and similar problems are influential factors in this field [10]. In the fifth development plan (2015-2016), the government of Iran announced its plans to install 5000 megawatts of renewable energy by providing incentives to the private sector, such as minimum tariff rates, to invest in this sector. This was an ambitious goal to achieve in a country where the renewable energy sector is in its infancy. International sanctions were also one of the factors that helped Iran achieve this goal. The government of Iran has now considered a new target in its sixth development plan (2016 to 2020), which was approved by the parliament in 2016, which will see installments of the renewable capacity of 5,000 megawatts, as well as planning for an additional 2,500 megawatts [11].

3. Results and discussion

3.1 Energy situation in Iran

Iran is considered a rich country in the world of fossil fuels. According to the latest BP statistics, Iran's reserves are 157 billion barrels of oil [12]. After Venezuela, Saudi Arabia, and Canada, Iran ranks fourth in the world in terms of oil reserves. On the other hand, Iran is considered a country with high natural gas reserves. Regarding natural gas, Iran ranks second in natural gas reserves in the world after Russia. In general, considering the oil and gas reserves in the world, Iran is considered the first in these fuels, which is of significant importance and position. Iran does not have significant reserves in the field of other fuels, such as coal, and there is little export in it. Most of Iran's attention in the field of fossil fuels is focused on oil and gas. Iran has been an influential country throughout history, with abundant oil and gas reserves. In fact, in the past, we witnessed events such as the Islamic Revolution of Iran or the imposed war between Iran and Iraq that caused an oil shock in the world, as you can see

in Figure 1, which caused severe shocks to the world economy.

On the other hand, in the recent energy crisis following the Russian-Ukrainian war, we are witnessing the world's attention to Iran's oil and gas and its role. These factors represent Iran's important role in the world's energy field.

3.2 Iran's crude oil

As mentioned, Iran is one of the world's most important oil producers. Iran is one of the founders of OPEC and has played a key role since the establishment of this organization until today. According to the latest BP statistics in 2022, Iran ranks fourth in the world in terms of oil reserves [12]. However, Iran's oil exports have faced wide fluctuations in recent years, especially after the withdrawal of the United States from the JCPOA. In recent years, Iran has faced the main problem in the field of the oil industry, which is the extensive sanctions against Iran. Oil sanctions have caused a decrease in production and also the non-expansion of oil fields in Iran. On the other hand, sanctions have caused a decrease and, in some ways, the lack of acceptance of foreign investors in the upstream, intermediate, and downstream industries of Iranian oil. Due to the high cost of oil industries and the need for extensive investments, an issue has affected Iran's position in the crude oil field and degraded Iran's role. On the other hand, since 2020 and the spread of the Corona pandemic, we have seen a wave of decline in oil demand worldwide, affecting Iran. The issue caused a decrease in demand and, as a result, a decrease in the production of oil-producing countries, and this caused a decrease in investments in the oil sector. Also, with the war between Russia and Ukraine outbreak, there has been a new wave of demand and attention for Iranian oil to replace it with Russian oil. Table 1 shows some statistics about some countries, like Iran and Saudi Arabia, with proven oil reserves. Also, in Table 2, we can see the oil production in five countries, including Iran.

3.3 Iran's natural gas

Iran is the second country in the world with gas reserves after Russia [12]. However, some experts believe that with the discovery of the Chalus gas field, which was discovered at the end of 2021, Iran has been promoted to the first rank of having gas reserves in the world. As mentioned in the oil sector, Iran's gas industry needs extensive investments. Javad Oji, the Minister of Petroleum, has also announced that Iran is the land of extensive domestic and foreign investments in the oil and gas industry. If the necessary investments in the field of gas are not made in Iran, Iran will face a serious problem with its gas supply in the coming years. In the winter of 2022, we also faced the problems of gas shortage in industries and household use in Iran. It can be said that sanctions have prevented the development and exploration of gas fields in Iran. In recent years, the Iranian Ministry of Petroleum has focused all its attention and investments on the South Pars field, and other fields discovered in Iran are unused, and development remains. The gas fields that are developed and exploited put Iran in the first place in gas reserves in the world by a margin. We can see in Table 3 the Proven reserves of gas in the world. After that, in Tables 4 and Table 5, we can see the production and consumption of gas in the world. Tables 4 and 5 show that the production and consumption of natural gas in the world is increasing every year, which shows countries' attention to natural gas.

3.4 The importance of renewable energy

Today, the importance and position of renewable energy are not hidden from anyone. Many environmental problems and the increase in the price of fossil fuels have caused the world's countries to pay attention to renewable energies. Energies that carry the title of clean and pollution-free energy. An issue that has caused the special attention of environmental activists as well as the attention of supporters of the principle of sustainable development.

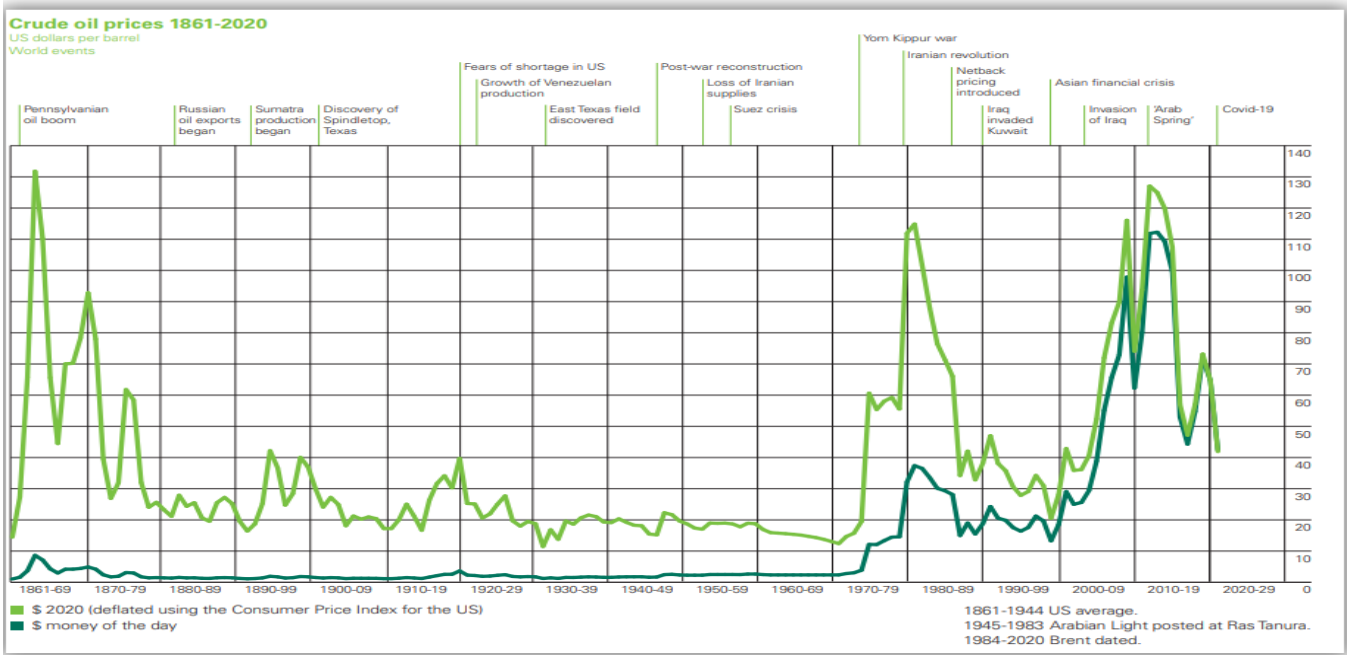

Figure 1. Diagram of oil prices from 1861 to 2020 [12]

Table 1. Total proven oil reserves [12]

Oil: Total proved reserves	At end 2000 Thousand million barrels	At end 2010 Thousand million barrels	At end 2019 Thousand million barrels	At end 2020 Thousand million barrels	Thousand million tones	Share of total	R/P ratio
Iran	99.5	151.2	157.8	**157.8**	**21.7**	9.1%	139.8
Iraq	112.5	115.0	145.0	**145.0**	**19.6**	8.4%	96.3
Saudi Arabia	262.8	264.5	297.6	**297.5**	**40.9**	17.2%	73.6
Canada	181.5	174.8	169.1	**168.1**	**27.1**	9.7%	89.4
Venezuela	76.8	296.5	303.8	**303.8**	**48.0**	17.5%	-

Table 2. Oil production rate per million tons [12]

Oil: Production of a million tons	2016	2017	2018	2019	2020	2021	Growth rate per annum 2021	2009- 2021	Share 2021
Iran	216.1	231.9	219.2	158.3	143.2	167.7	17.4%	-2.3%	4%
Iraq	217.6	222.4	227.0	234.2	202.0	200.8	-0.3	4.0%	4.8%
Saudi Arabia	586.7	559.3	576.8	556.6	519.6	515.0	-0.6%	-0.1%	12.2%
Canada	218.8	236.6	257.7	263.5	252.0	267.1	6.3%	4.6%	6.3%
Venezuela	132.6	114.1	83.8	52.1	32.7	33.4	2.4%	-13.4%	0.8%

Table 3. Proven reserves of gas in the world [12]

Natural gas Total proved reserves	At end 2000 Trillion cubic meters	At end 2010 Trillion cubic meters	At end 2019 Trillion cubic meters	At end 2020 Trillion cubic meters	Trillion cubic feet	Share of total	R/P ratio
Iran	25.4	32.3	32.1	**32.1**	**1133.6**	17.1%	128.0
US	4.8	8.3	12.6	**12.6**	**445.6**	6.7%	13.8
Russian Federation	33.2	34.1	37.6	**37.4**	**1320.5**	19.9%	58.6
Qatar	14.9	25.9	24.7	**24.7**	**871.1**	13.1%	144.0
Turkmenistan	1.8	13.6	13.6	**13.6**	**480.3**	7.2%	230.7

Table 4. The rate of gas production per billion cubic meters [12]

Natural gas: Production in billion cubic meters	2016	2017	2018	2019	2020	2021	Growth rate per annum 2021	2009- 21	Share 2021
Iran	199.3	213.9	224.9	232.9	249.5	256.7	3.6%	5.9%	6.5%
US	727.4	746.2	840.9	928.1	915.9	934.2	-1.9%	5.2%	23.7%
Russian Federation	589.3	635.6	669.1	679.0	637.3	701.1	-6.2%	2.4%	16.6%
Qatar	174.8	170.5	175.2	177.2	174.9	177.0	-0.7%	6.4%	4.4%
Turkmenistan	63.2	58.7	61.5	63.2	66.0	79.3	-6.9%	6.6%	1.5%

Table 5. Natural gas consumption per billion cubic meters [12]

Natural gas: Consumption in billion cubic meters	2016	2017	2018	2019	2020	2021	Growth rate per annum 2021	2009-21	Share 2021
Iran	196.3	205.0	212.6	218.4	234.3	241.1	3.2%	4.6%	6.0%
US	749.1	740.0	821.7	850.7	831.9	826.7	0.4%	2.3%	20.5%
Russian Federation	420.6	431.1	454.5	444.3	423.5	474.6	12.4%	0.9%	11.8%
Qatar	41.4	41.2	40.7	41.9	38.9	40.0	3.1%	3.3%	1.0%
Turkmenistan	25.1	24.8	28.4	31.5	29.6	36.7	24.2%	5.9%	0.9%

The IEA definition of renewable energy is carbon-neutral energy [13]. In addition to pollution and environmental damage, fossil fuels have other problems. One of these problems is the unavailability of fossil fuels in all countries. Fossil fuels are limited to a few countries, such as Iran or Saudi Arabia. This has limited and made it difficult for countries to access this vital substance, which is an economic driving fuel. On the other hand, according to the theoretical framework of energy security, countries are trying to reduce their dependence on fossil fuel-producing countries and meet their domestic needs through renewable energy. This issue is a key solution to reducing dependence on fossil fuels and the countries that produce these fuels. Renewable energies, in addition to being available and free, have no restrictions on use and can be reused, unlike fossil fuels [14]. Access to fossil fuels is one issue, and its transfer is another issue, which, in addition to environmental problems, also includes many costs. At the same time, renewable energies can be used and produced in most parts of the world, proving the advantage of this energy's availability. In a way, it can be said that renewable energy reduces the costs of transportation and buying energy from other countries and its transfer, which is both beneficial to the economy and in line with the theory of energy security. Now that we know the importance of renewable energy, we will examine some types of renewable energy worldwide.

3.5 Solar energy

Solar energy can be considered the most important and famous renewable energy in the world. In order to understand the importance and power of solar energy in terms of supplying the energy needed by humans on the planet, it is necessary to convert only one hour of the energy from the sun's radiation to the earth through solar panels into electricity, which is the energy of one year on the planet with a significant and very important number Global solar power generation capacity reached 7,800 MW in 2017, up from 3,400 MW in 2007. Germany, Spain, the United States, Japan, and Italy ranked first through fifth [15]. According to estimates regarding solar energy, if 0.1% of the amount of solar energy from solar radiation is converted into electricity by a factor of 10%, it will create something as much as three thousand gigawatts of electricity, which is four times the world's annual consumption [16]. On the other hand, 173,000 terawatts of solar energy continuously hit the earth, which is more than 10,000 times the world's energy consumption [17]. In addition to the power of solar energy in terms of providing the necessary amount of electricity, the biggest advantage of solar energy is radiation to all parts of the world and all countries have access to it. However, the amount of access and sunlight is different in different countries. It can be said that if humans can control a corner of the sun's radiation, the world's need in the field of electricity supply will be completely solved, which is considered a huge development in the energy sector [18].

Iran is a rich country in the field of solar energy. The country's priority for renewable energy is solar energy, which has an average of 300 sunny days per year. The average daily sunlight in Iran is about 5.5 to 8.5 kilowatt hours per square meter, especially in the central regions [19]. The technical potential for solar thermal energy is estimated at 91,000 TWh. July, August, and September are the months that have the most solar radiation with 1050 hours; January, February, and March have the least solar radiation with 500 hours. The cumulative installed capacity of renewable energy resources by 2030 is predicted to be 2.8 gigawatts. It represents an investment of more than 2.8 trillion dollars from 2010 to 2030. The central, southern, eastern, and southeastern parts of Iran, such as Yazd, Kerman, South Khorasan, Zahedan, and Kerman, have had high solar radiation throughout the country this year [20]. The cities in the country's north have the greatest investment potential in photovoltaic energy. In this regard, in Figure 2, we can see the world's photovoltaic energy potential. In this overview, it can be seen that the countries of the southern regions of the world have a very high capacity in the field of solar energy due to the more sunlight in these regions.

3.6 Wind energy

Wind energy is another type of renewable energy in the world. The energy produced by the wind has the title of the cleanest energy and the best in producing electricity [22]. Although wind energy is available in all parts of the world, like solar energy, it is impossible to produce and use it in all situations. A sufficient intensity and amount of wind and the installation of wind turbines are needed to produce electricity from wind energy. Some places like Manjil in Gilan province of Iran or Scandinavian countries like Denmark have suitable conditions for using wind turbines. According to statistics, gaming energy has experienced a growth of 26% since 1990, which is the highest among all renewable energies [23]. One of the major disadvantages of wind energy, as mentioned, is the lack of wind blowing in all parts of the world, which has caused all countries to be unable to use wind energy as opposed to solar energy. In Figure 3, we can see the Global cumulative wind power capacity from 2001 to 2020. It can be seen that the production of wind energy and its capacity have increased every year, which shows countries' attention to this

type of energy. Currently, there are 23 wind power plants in Iran. The largest wind power plant in Iran is in Manjil, Gilan province, with a capacity of 49.36 megawatts [22]. After this power plant, there is a Siahposh Qazvin power plant with a capacity of 43.26 MW. Provinces with strong potential for wind energy in the country include Gilan Province, South Khorasan (Khaf), Sistan and Baluchistan (North of Zabul), Semnan, and Qazvin, which have the highest capacity to build wind farms. Zabul is the most suitable area for setting up a large-scale wind turbine [23].

3.7 Hydropower energy

Other renewable energy sources are tidal and hydropower energy. hydropower energy, one of the types of renewable energy derived from water, is converted into electricity through turbines. One of the areas where the tides are suitable for using tidal energy to generate electricity is Burtpool Channel, England. This energy is created by the rotation of water turbines in the water, and in this way, electricity is produced. China is considered the largest producer of electric energy in the world. However, many countries are indifferent to hydraulic energy or have limited investments. Semi-arid countries of the world Based on this, the time and place are insufficient. Rainfall distribution is perhaps the most important reason for building dams in Iran. For this reason, hydropower plants cannot be considered a reliable and stable source of electricity production in the country - but hydroelectric power plants play an effective role in controlling the frequency of hydropower installations in Iran more than renewable energy production centers. Hydropower also plays an important role in socio-economic development, such as irrigating agricultural fields, providing sufficient water, especially during drought seasons, controlling the situation during monsoons, and improving main waterways. Currently, electricity is the only renewable energy that is commercial. It is available on a large scale in Iran. The sources and potential of hydropower have been estimated. Twenty-six thousand megawatts, most of which are supplied from the Karun, Karkheh, and Dez rivers [25].

3.8 Nuclear power

Nuclear energy is one of the most famous renewable energies in the world. The energy that comes from splitting the uranium nucleus and controlling it. Nuclear energy is very high and is used in various fields, including medicine. Of course, nuclear energy also has problems. One of the most important problems of nuclear energy is the environmental problems it causes. In the past, we witnessed the explosion of the Chornobyl nuclear power plant and environmental pollution, which affected various generations in that environment. On the other hand, another environmental device related to nuclear energy is the issue of nuclear waste disposal, which has become an important issue in countries with nuclear energy, and they are struggling with it. The energy that, with its high power and renewable nature, can play an irreplaceable role in the world's energy field and be a big step towards using renewable energies. In Iran, nuclear energy has been of interest from the past to the present. Perhaps one of the reasons why nuclear energy is more colorful compared to other renewable energies is its political dimension. In this regard, Iran has started a water desalination project with a capacity of 70 thousand cubic meters in a period of 2 to 2.5 years, which will be completed in 2 to 2.5 years [26]. This project has a daily capacity of 70 thousand cubic meters of water. About 2.5 to 3.5 cubic meters of seawater can be sweetened directly every second, and this project is designed to expand its capacity up to 105 thousand cubic meters per day [27]. Also, two more 1050 MW units are being built in the Bushehr nuclear power plant. In Figure 4, we can see nuclear generation by country in 2021, which is helpful information. In Figure 4, it can be seen that America, China, and France have the first ranks in the world in terms of electricity production through nuclear energy, which is a significant issue.

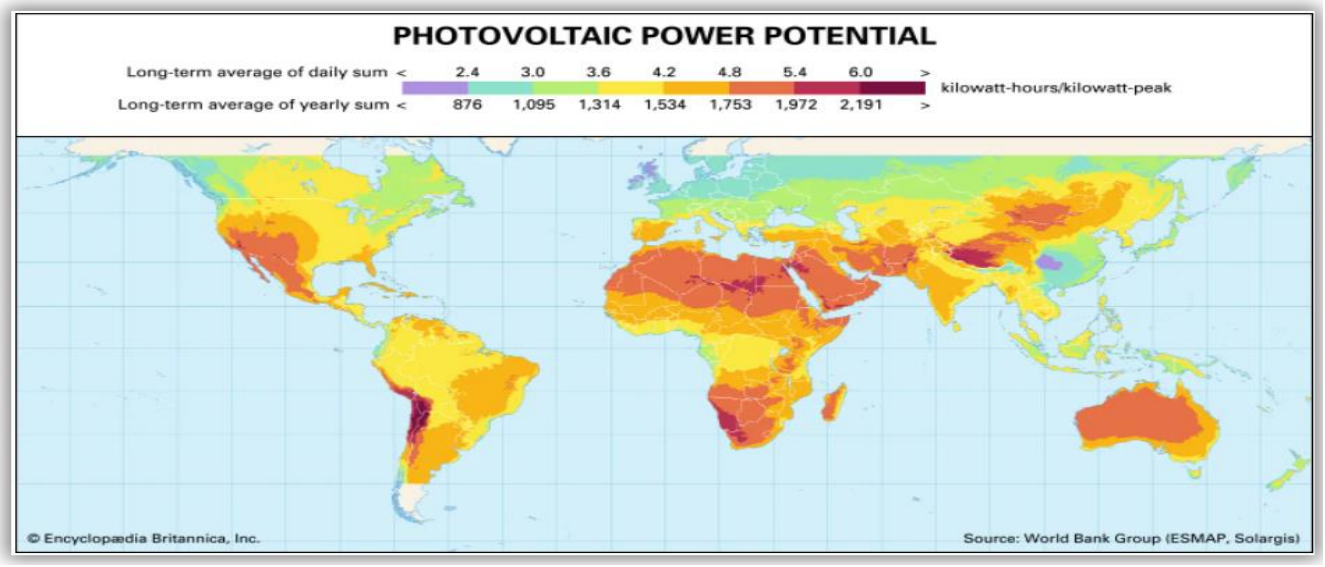

Figure 2. Photovoltaic energy potential [21]

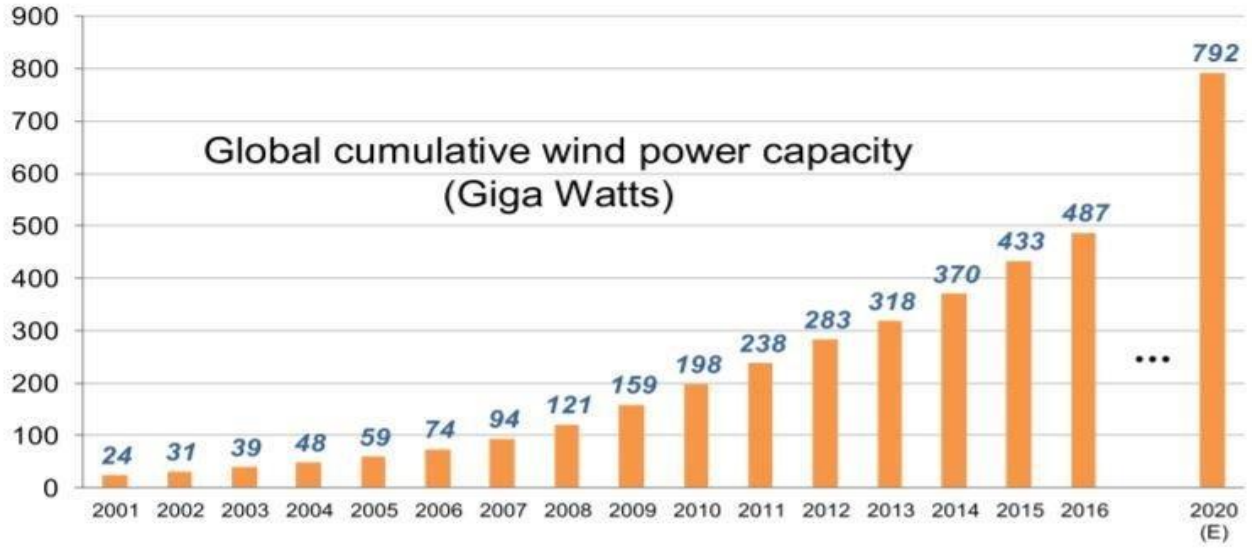

Figure 3. Global cumulative wind power capacity from 2001 to 2020 [24]

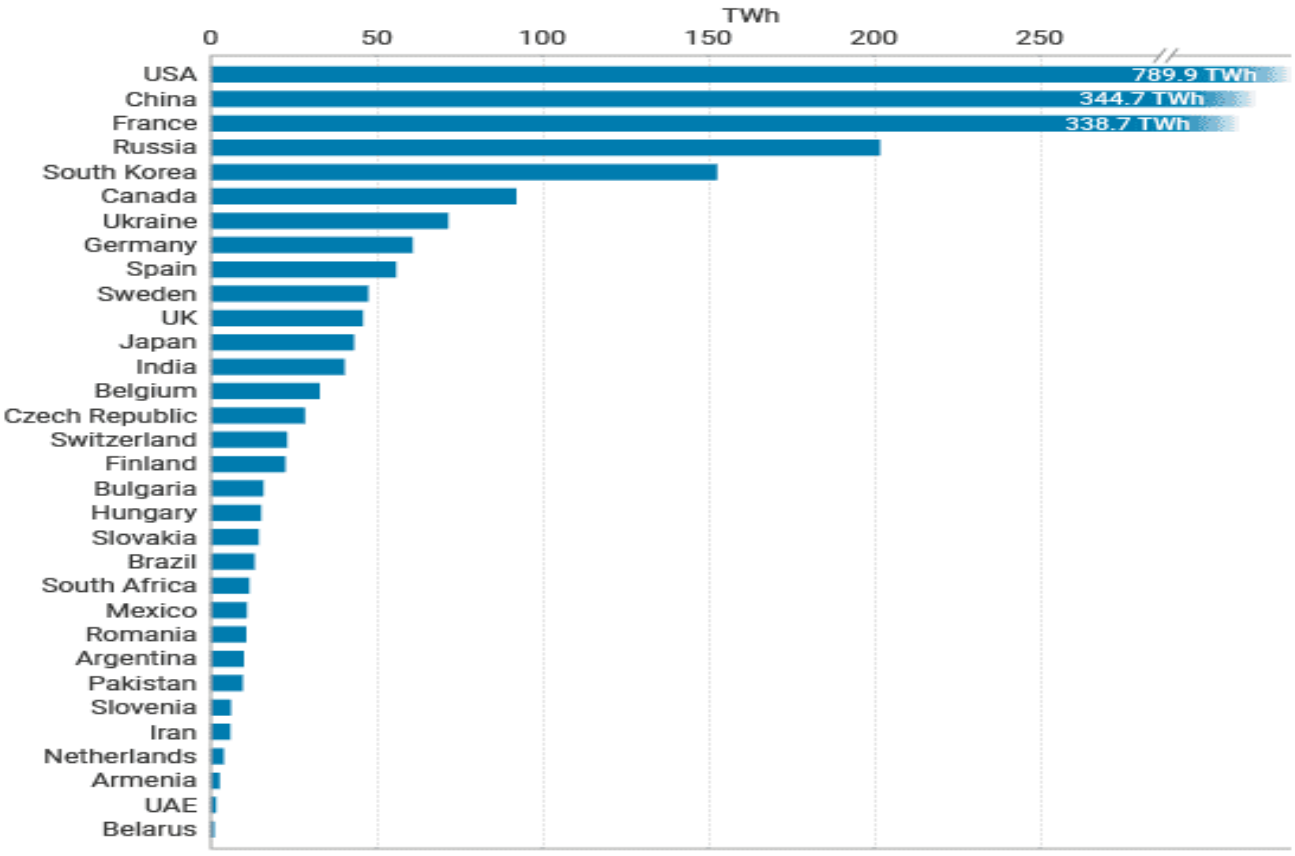

Figure 4. Nuclear generation by country 2021

3.9 Infrastructure of renewable energy in Iran

Considering the weather conditions, Iran is capable of using renewable energy such as solar, wind, and other renewable energy. In fact, the climatic conditions of climate change the ability and possibility of using and utilizing the field of renewable energy. One of these is the hour of solar radiation in Iran. According to estimations, the sunny days in Iran are 280 - 300 days. In some cases, in Iran, solar radiation is received ten months per year [28, 29]. On the other hand, the average solar radiation energy in Iran is 5.5 kWh/m^2 daily. In other words, the total amount of radiation daily in Iran is 9 billion kilowatt-hours [30]. Figure 5 shows the average solar radiation in the city of Tehran. As can be seen in this figure, the amount of radiation in the winter reaches its lowest rate, 134 hours, versus 346 hours in the hot months of the year. Also, in Figure 6, we can see Iran's photovoltaic power potential.

Regarding wind energy, Iran can produce 6.5, 15, and 100 MW of electricity due to its exposure to tropical wind [33]. Wind power in Iran is the least developed energy among other non-hydro-renewable energies, whose capacity was 303 MW in 2019. In Figure 7, we can see the wind speed map at 100m in Iran. It can also be seen in Figure 7 that the eastern parts of Iran have a good capacity and potential for using wind power to produce electricity. As mentioned, Iran has made investments in the field of renewable energies in recent years. On the other hand, due to the sanctions of the United States of America against Iran, the process of foreign investment in Iran has slowed down. The sanctions of the United States of America prevent the entry of foreign investors as well as the entry of equipment related to renewable energy and its power plants, which prevents the growth and development of renewable energy in Iran. The decrease in Iran's revenues in oil sales, which has played a key role in Iran's budget in recent years, has reduced the government's ability to invest in renewable energy sectors. Another issue is the growth of Iran's population and the high use of electricity, which has caused a shortage and the need to compensate for electrical energy. This issue caused widespread power outages in Iran in the summer of 2021. Figure 8 illustrates the price of electricity in different countries.

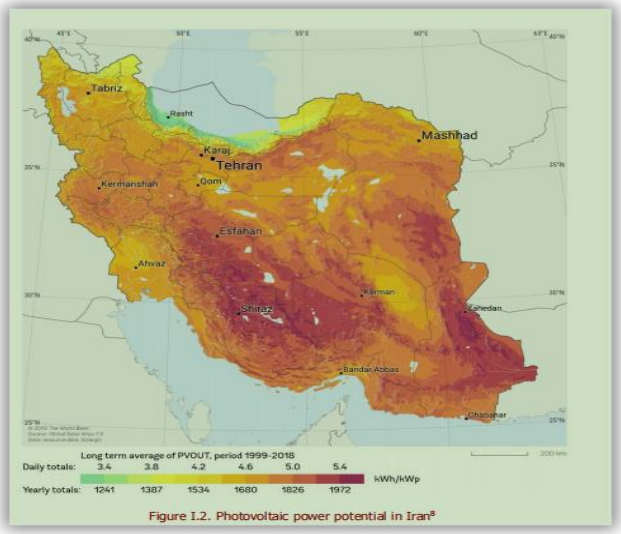

Figure 6. Photovoltaic power potential in Iran [32]

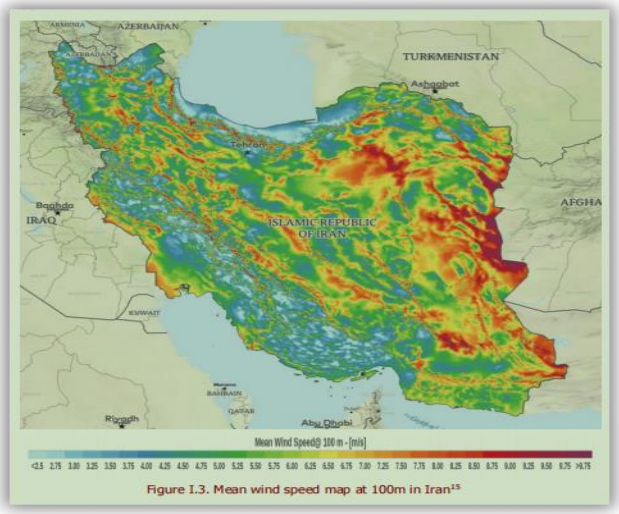

Figure 7. Mean wind speed map at 100m in Iran [32]

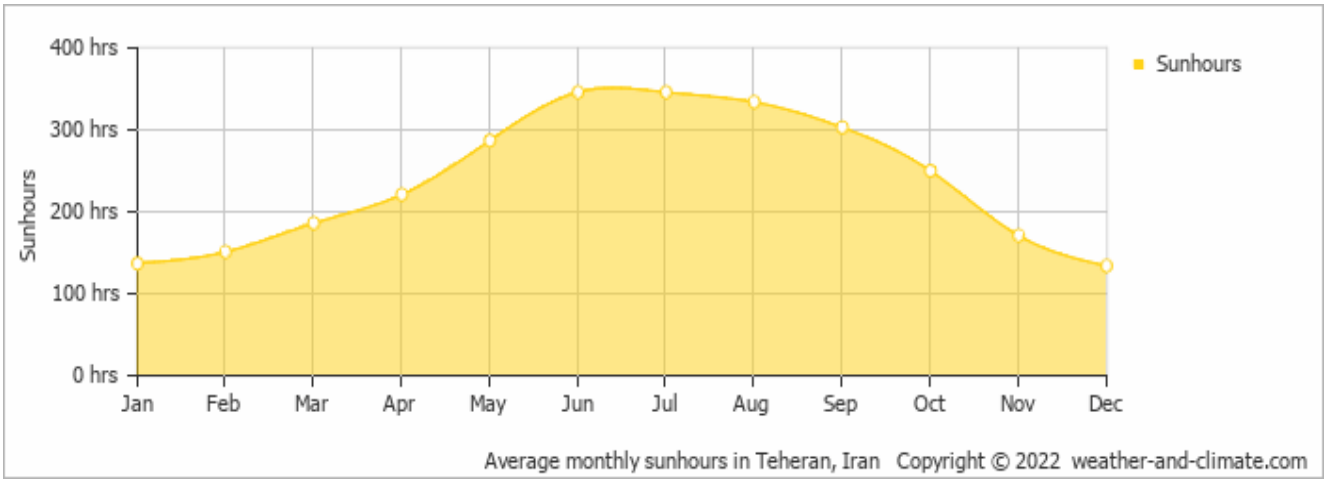

Figure 5. The average hours of sunlight in different months in Tehran [31]

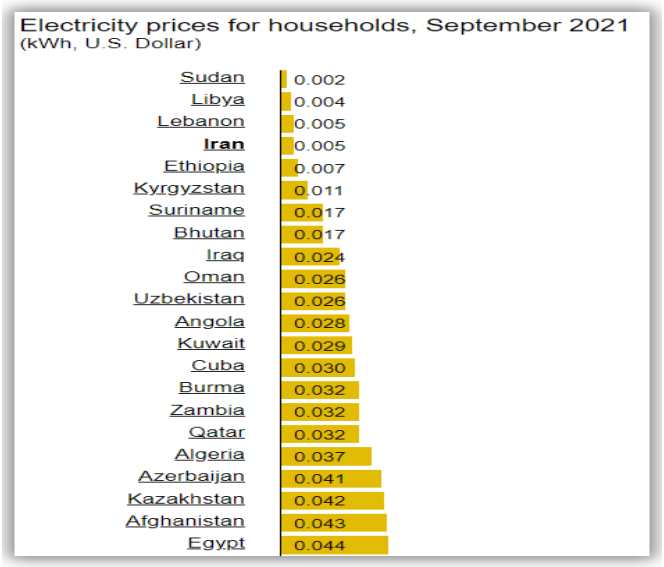

Figure 8. The price of electricity in different countries [34]

As illustrated in Figure 8, Iran's electricity is considered among the cheapest in the world, which is the reason for its excessive use and beyond the global consumption pattern, resulting in its shortage. A deficiency that can be compensated for through renewable energy. According to the plans in 2016, Iran planned to supply 5 thousand megawatts through renewable energy within five years, but only one-fifth of this figure was realized. On the other hand, Iran's Ministry of Energy announced in 2021 that there are only 900 megawatts of renewable power plants in the power grid. The ministry plans to add 10,000 megawatts to the power grid for four years [35].

3.10 The opportunities and challenges of renewable Energy in Iran

Considering its geographical location, Iran has a high potential for renewable energy, especially wind, solar, and biomass energy. In biomass, wood, human waste, sawdust, animal waste, food waste, and sewage are used for biomass. The process of converting biomass and other renewable resources into energy is called biotechnology. It also has a special opportunity in Iran; the Renewable Energy and Energy Efficiency Organization of Iran (SATBA) also believes that this area, by planning and focusing on the participation of small and medium-sized companies to develop innovation, knowledge, and business activities to create a Sustainable system product in the industry is of particular importance, so far no effective measures have been taken in this field [36]. Also, biofuels, renewable energy types, are made from organic materials living materials or biological materials). Their energy is from biomass, which is in the form of liquids (bioethanol and biodiesel), solids (dry plant materials), and gases [37]. Although the current sources of bioethanol, cane molasses, and sugar beet in Iran are easily available, the use of these biofuels in the country is relatively low, and South Khorasan province is the best place to establish biogas [38]. Discussion on formulating laws and policies in renewable energy has been common in political and professional circles for the past two decades. In order to stimulate the development of renewable energy technology and the market, it is necessary to develop national and local policies in the field of potential measurement and resource identification, construction, installation, and exploitation of renewable energy, which has not received special attention in the country [37]. Therefore, lack of accurate and efficient planning, a lack of necessary technologies, a lack of necessary capital to develop the use of renewable energy in the country, international sanctions, and a weakness of the country's Infrastructure in order to increase the production capacity of new energy, finally the collection of these cases, has become the main and determining factors for the non-progress of renewable energies in the country. However, during the last few years, the production and consumption of renewable energy in Iran have not been very suitable. By 2017, the total renewable energy production across the country was estimated to be 254.52 MW. It includes wind, solar, biomass, and hydroelectric power of 146,700, 37.92, 7.5, and 62.4 MW, respectively. This energy is supposed to increase to 300 megawatts, which is very low. However, due to its special geographical conditions, Iran has a large capacity to produce clean energy, including hydro, wind, solar, and geothermal power plants and biomass. Iran can benefit from these energies in case of investment [39].

3.11 Prospects of renewable energy in Iran

Despite the increase in the human need for energy, the use of fossil resources (except natural gas) has decreased. However, the development of renewable energy has been intensively done, especially since 2010, in such a way that this source of energy now supplies half of the world's electricity needs. At the end of the 20th century, most of the countries in the world, except for the Middle East, independent countries, and African countries, moved towards the development of renewable energy, and currently, European countries, the American continent, and East Asia are the leaders in this field, even African countries have had an acceptable growth trend, but the share of these resources in the Middle East countries and especially Iran compared to They have not grown much. Although the share of renewable energy has grown considerably in Iran in the past decades, most of which is provided by hydropower sources, the ratio of carbon dioxide gas production to energy consumption in Iran has increased in recent years, and in The coming years, can have consequences for the country's energy industries in the form of fines in the form of plans for environmental protection and reducing the earth's air temperature by two degrees, which the governments have signed. Iran can be implemented in the future [40]. Also, the main source of electricity production in Iran in the past few decades has been non-renewable energy; studies show that until the year 2021, only one percent of Iran's electricity will be produced from renewable energy. In line with the leap in modern energy, there are also plans to develop renewable energy capacity of up to 500 megawatts. The country's plan for the next four years is to increase the renewable energy capacity by 10 thousand megawatts, which is supported by foreign investments and private companies. According to the prepared plans, it is expected that shortly, we will see an increase in the infrastructure for the production of renewable electricity in Iran in such a way that

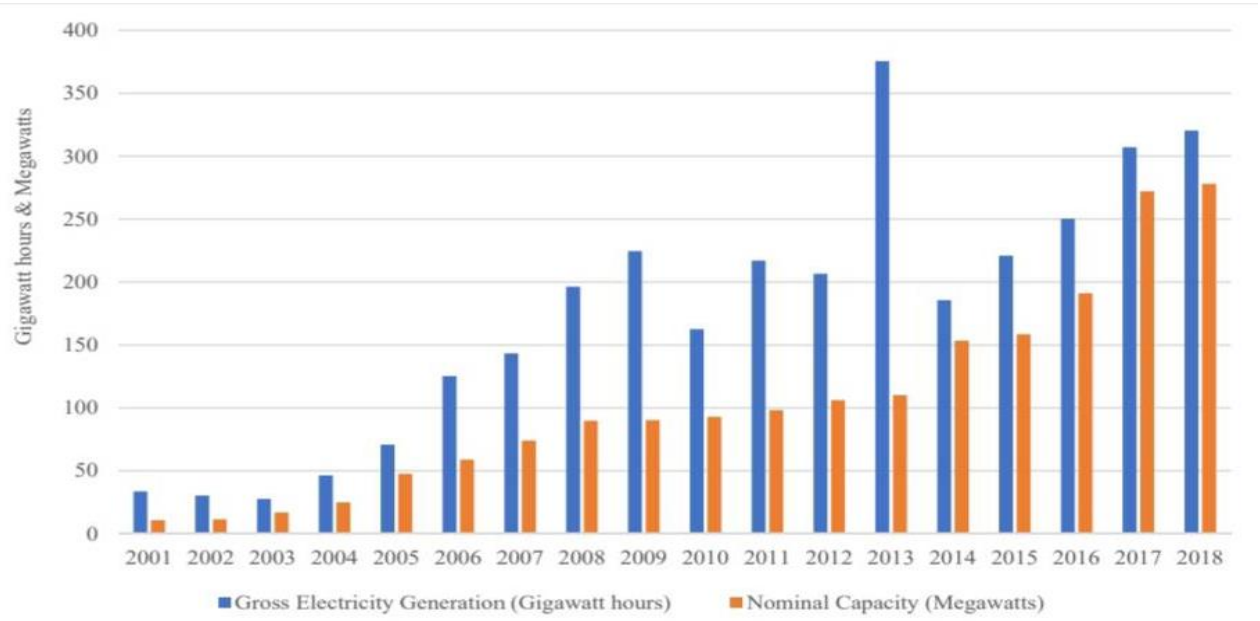

Figure 9. Electricity generation and capacity of wind power plants from 2009 to 2010 in Iran [19]

Iran will also be in line with many developed countries in providing a significant part of its electricity through clean energies [41]. Preservation of the environment and achieving sustainable development have been considered not only at the level of countries but also at the global level. The growth of non-renewable energy consumption started at the beginning of the 20th century and has continued with an increase in the future; the result of this growth was the increase in carbon emissions in the atmosphere of the earth and, finally, the increase in the concentration of carbon dioxide, which is one of the main reasons for countries to pay attention to the field of new energies.

In Iran, where most of the required energy is obtained from non-renewable sources, in the vision document of the Islamic Republic of Iran, to reduce environmental pollution and provide sufficient energy with a suitable reliability factor, the section on the development of renewable energy and achieving the goals of the vision It has an important and decisive position. As stated in the previous sections, due to its special geographical location, Iran is located in an area that has about 300 sunny days in terms of receiving solar energy from different parts of the world in the highest ranks. Also, in wind energy, it is possible to produce 40 thousand megawatts of energy by installing wind power plants. Therefore, in order to optimally use these new energies, Iran has approved new opportunities and regulations in the field of reforming the energy consumption pattern since 2014. the Ministry of Energy and the Ministry of Petroleum to provide the necessary support in order to promote the economical use of renewable energy sources in separate systems from the grid, such as solar water heaters, solar baths, wind pumps, wind turbines, and photovoltaic systems and provide and pay from their annual approved budgets. The New Energy Organization has also taken extensive measures to develop the country's new energies, one of which is providing sustainable and accessible energy for deprived and remote areas [42].

Despite these measures taken in the past few years, Iran is one of the countries that have a strong dependence on oil and gas in the field of energy, and there has not been much desire in various sectors to develop the exploitation of new energies. In wind energy, Iran intends to increase the share of non-hydro renewable sources in its total electricity production capacity to 5% by 2021. According to this plan, Iran must increase its share of non-hydro renewable energy to 32% by 2050 [43]. In recent years, local and foreign investors have installed approximately 350MW of renewable energy in Iran through the electricity purchase agreement mechanism, while several other energy farms with a total capacity of about 700 MW are in various stages of development. Also, in recent years, domestic and foreign investors have installed approximately 350 MW of renewable energy in Iran through the power purchase agreement mechanism, while several other energy farms with a total capacity of about 700 MW are under construction [44]. The figure below shows the process of wind energy production and wind capacity in Iran's power plants. Also, in Figure 9, we can see the electricity generation and capacity of wind power plants in Iran from 2009 to 2010. As a whole, the Ministry of Energy, as a governing body in Iran, as well as the Renewable Energy Organization, which was established in 2015, is responsible for all issues related to the development, planning, organization, legislation, and implementation of policies and initiatives related to renewable energy.

4. Conclusion

The recent energy crisis, which is the result of the war between Ukraine and Russia, caused an unbridled increase in the price of energy carriers, which turned the world's desire and attention towards the use of renewable energy more than in the past. On the other hand, based on the theory of energy security, the world's countries will work towards renewable energies not as a suggestion but as a kind of compulsion. This issue is considered essential to the zero-carbon strategy. The

strong impulses of fossil fuels, such as the past oil networks, and the bad environmental effects have caused a wave of demand and desire for renewable energies. The energy that is not paid for, fluctuations, and external events affect its price. Fluctuations affect every economy and cause severe inflation. Even though Iran has adequate reserves of fossil fuels, environmental issues, and sustainable development have caused Iran to look toward renewable energies. Iran is a country that, due to suitable weather conditions, has the possibility of using and producing energy through various types of renewable energy, such as solar, wind, and water energy, which, as mentioned, is one of the suitable conditions for Iran to transition from fossil energy to Renewable energies and especially solar energies have a suitable amount of radiation and the hours of radiation are higher than the global average. On the other hand, the issue that Iran has been struggling with in recent years is the reduction of electricity production, or in other words, the deficit of electricity produced compared to electricity consumption, which causes widespread power outages in the country like in the summer of 1400. For this reason, Iran has tried to enter into planned investments and goals regarding the use of renewable energies, according to the context and suitable conditions, which will reduce dependence on fossil fuels and increase Iran's ability to export these types of fuels because considering the closing of investments in the future, it is possible to supply most of Iran's energy consumption through renewable energies. Of course, we can consider this issue in line with energy security, diversity of energy, and reducing reliance on fossil fuels. On the other hand, if the production capacity of renewable energy increases, there is a possibility of exporting electric energy to neighboring countries, which requires extensive investments and large-scale plans regarding the exploitation of renewable energy.

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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