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Potential, Current Status, and Applications of Renewable Energy in Energy Sector of Iran: A Review

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Abstract
During the last decade, serious issues such as the energy demand, depletion of fossil fuels, and their environmental impacts have drawn attention towards the renewable energy sources. In addition, the energy supply chain of Iran is deeply reliant upon fossil fuels. Further obstacles such as electricity blackouts in the hot season and future energy security require us to address these issues. For this reason, the growing consensus is to dominate a sustainable energy system on the grounds of energy, especially the renewable energies, with a low emission and pollution. The mean annual solar radiation in Iran is 2200 kWh/m2, which is greater than the worldwide average, due to locating on the world's Sun Belt. The total installed capacity of solar energy in Iran is not significant; however, it is growing annually. Moreover, the Persian Gulf coasts could provide the possibility of using the tidal energy of the ocean as well as the Caspian Sea coast that are suitable sites for thermal energy. Currently, 550 MW of renewable energy is being built in Iran, and the installed capacity of renewable energy has reached 575 MW. Renewable energy has also led to the employment of 47,321 people directly and indirectly in the country. The installed capacity of Iran's wind power is about 259 MW (45% of the total renewable energies installed capacity), which is mostly located in Manjil and Roodbar. The biogas energy in Iran is mainly produced from domestic and industrial sewage/waste, animal waste, and agricultural product waste.

Keywords: *Renewable energies, Iran, Current energy, Power plant.*

1. Introduction
Iran, as a developing country, is located in the Middle East on the southern side of the Caspian Sea and adjacent to the Persian Gulf in the south with various fossil and renewable resources. The population of Iran is more than 80 million, and the land has an area of 1,648,195 km2. Considering the diverse geographic coverage, Iran's climate is almost semi-arid with a 228 mm average yearly rains and an average temperature of 19-38 °C in the summer and 10-25 °C in the winter [1]. The population of Iran, especially the urban population, is growing rapidly. The term of urbanization in Iran is defined by the significant economic gap between the rural and urban areas, more access to facilities in cities and seasonal drought-related agricultural issues [2].

In general, with advances in the social and economic development, the energy demand is rising. rapidly. Consequently, in defining the energy supply, the sustainability and environmental policies should be considered as ensuring public health and security of energy. In fact, the development of strategy based on crude oil exports is exclusively the main issue of unsustainability. Today, the world's energy is mainly supplied by various types of fossil fuels such as coal, oil, and NG. About 66% of the world's electricity is based on the use of fossil fuels. Iran's economy is heavily dependent on the crude oil exports, and oil price volatility affects the country's development [3]. Iran has the fourth-largest oil reserves in the world after Venezuela, Saudi Arabia, and Canada. The statistics also show that Iran is the second-largest natural gas reservoir in the world [4]. More than 98% of the world's oil is produced by 42 countries, a smaller amount than 2% of the world's oil is supplied from 70 countries, and the rest 70 countries are not oil-rich countries [5, 6].

Iran has great non-renewable fossil energy reservoirs. According to the 2011 IEA assessments, Iran's fossil reservoir is about 33.1

trillion cubic meters of natural gas (NG) and 151,200 million figures 1 and 2 show the top 10 countries in the oil and NG reservoirs [7].

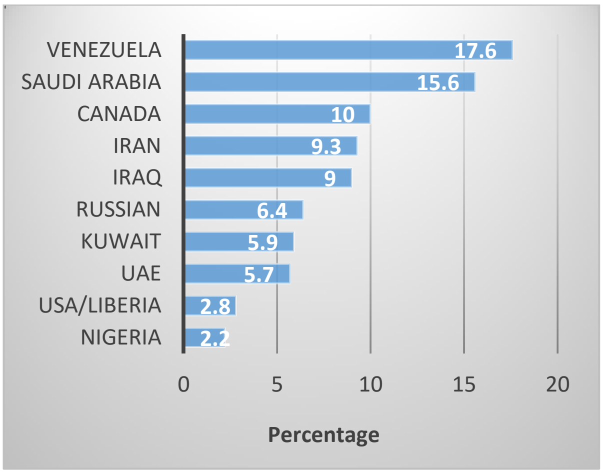

Figure 1. Top 10 oil reservoir countries in the world [7].

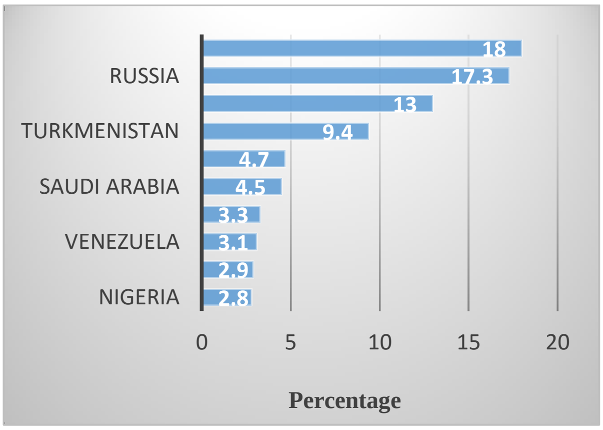

Figure 2. Top 10 natural gas reservoir countries in the world [7].

The reports have shown that Iran's oil and gas production will reach 789 ml/d and 240 bcm, respectively, in 2030 [8]. Like other countries, energy plays an important role in improving the quality of life, and social and economic progress in Iran. In the past decades, oil and coal have had an average of 33% and 27% share of the world energy spectrum. However, energy consumption in Iran almost consists of 54% NG and 44% oil. In some countries such as China and the United States, coal is a key element in energy policies. However, less than 0.5% of the total energy demand in Iran is provided by coal. According to the reports, coal is utilized very limited in Iran's industries. Also Iran does not have any coal power plant [9].

The share of non-renewable resources of energy in the world and Iran is 81% and 99%, respectively. Even though Iran has great renewable energy potentials, the share of renewable energy in Iran is less than 1% of the total energy production. Figure 3 depicts a comparison of the energy mix in Iran and the world [10].

The International Energy Agency (IEA) has predicted that NG and oil will end in 60 and 40 years, respectively, which indicates that RSE could be the primary future energy resource [11]. Concerning the environmental issues made by the use of fossil fuels, countries of the world should replace their fossil resources with the renewable and sustainable energy resources. The target share of RSE resources in the transportation and power generation sectors is 7% and 29%, respectively, by 2030 [12]. The 2016 Iran's primary energy demand was reported 270.7 Mtoe, which shows an enhancement of 20% from 2010. Figure 4 represents the primary energy demand in Iran over the past decade [7].

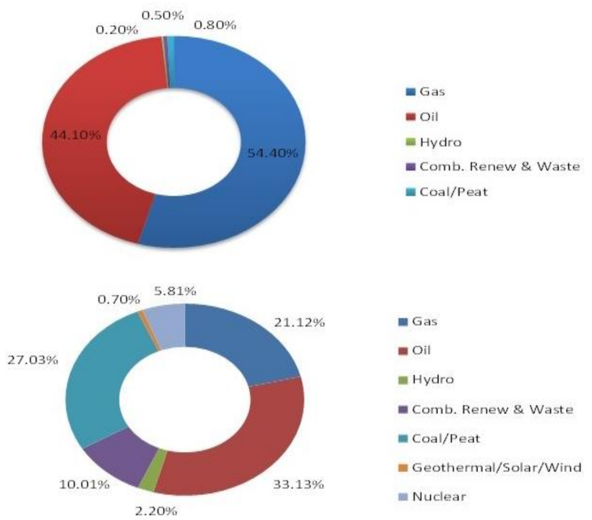

Figure 3. Scenario of energy mix in Iran (A) compared to the energy mix of the world (B) [10].

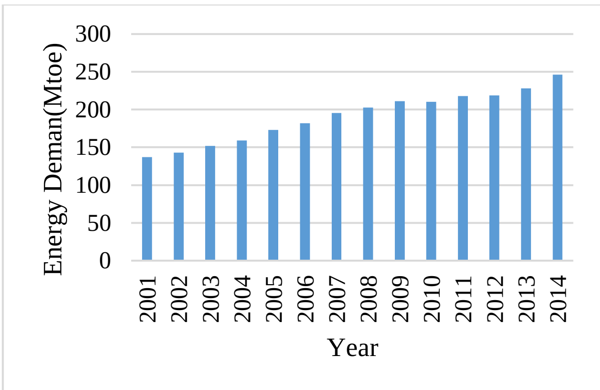

Figure 4. Primary energy demand in Iran [7].

It has been reported that the Iran's electricity demand is 50,000 MW. This is about 80% output of the fossil fuel use. By the year 2030, the Iran's electricity demand is expected to be 200,000 MW. Clearly, the fossil resources are not able to provide this amount in 2030 [13]. This increasing energy demand pattern is only be met in a case in which Iran becomes an energy importer or some new energy strategies should be adopted by the Iran energy policymakers. Lately, the Iranian government has focused on switching to the renewable energy resources as an essential element. Numerous plans for the expansion of sustainable energy have been appointed by the Iran's renewable energy organization (SATBA). Figure 5 compares the electricity production by various sources of energy in Iran in the last four decades (1972-2009) [14].

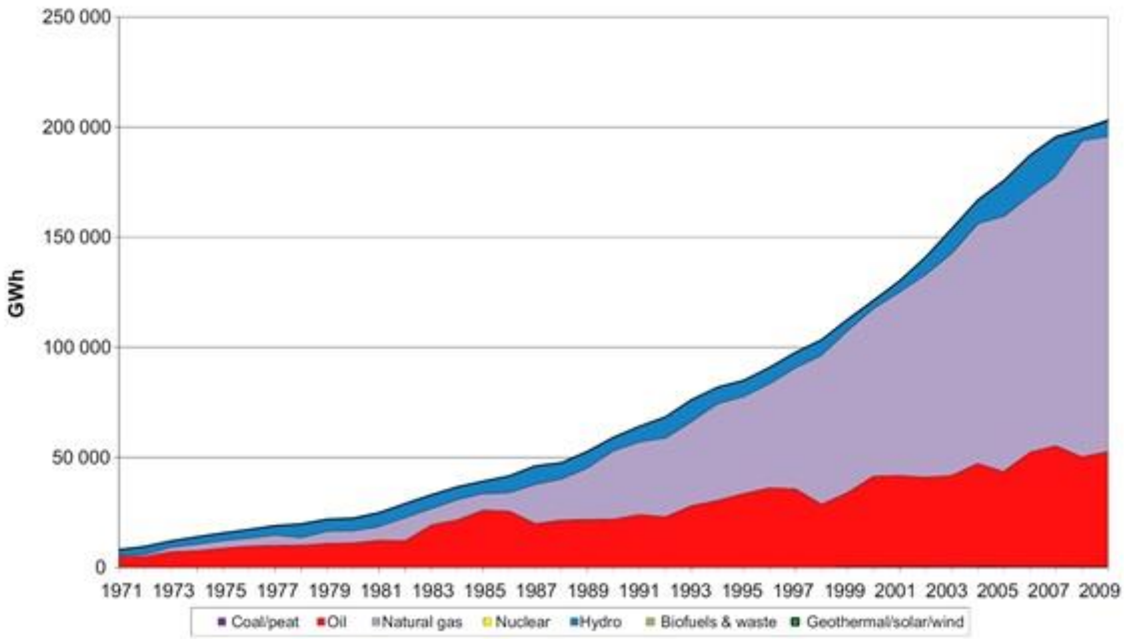

Figure 5. Electricity production by various sources of energy in Iran (1972-2009) [14].

Iran's ability to generate electricity by means of renewable energy resources, with the exception of 9,000 MW of hydroelectric power plants, is currently near 155 MW. This is about 3% of the Iran’s total power production capacity. The installed wind and geothermal energies are 98 and 55 MW, respectively. The share of solar energy is insignificant [15].

Considering the fact that the annual electricity consumption is rising by more than 10% in Iran, it is an irrefutable need to focus on the energy portfolio to enhance the energy security. The reports given in 2015 showed that the total consumption of electricity in Iran was 280633 GWh. Only 1.11% of this total electricity consumption was from the nuclear, solar, and wind resources. Also due to the low fossil fuel prices, the renewable energy power plants were not economically feasible. However, due to performing the targeted subsidy project, the fuel price is more real. Nowadays, the investment costs of the renewable energy plants are economically vindicated and defensible. The power generation capacity increased more than 220 MW by employing the green and renewable resources in 2015. The renewable energy growth and progress in the decrease of CO2 emissions have prevented the country from substantial international fines. Due to the great renewable energy resources in Iran, the development of green plants should be the aim of the energy policymakers. The main task in this regard is the determination of the proper price for renewable electricity. The renewable electricity price may not be cheaper than the electricity of subsidized fuel plants but considering the actual Persian Gulf, the FOB fuel prices show that it is cost-efficient to obtain electricity from renewable energy plants, particularly wind power plants [15].

The socio-economic effects of the renewable energy penetration due to interplay between energy and economy sector include GDP, employment, and welfare [16,17]. The energy efficiency, carbon dioxide taxes, and grid flexibility would result in GDP, whose cumulative gain between 2018 and 2050 could reach 52 trillion USD. Another impact of the renewable energy utilization is demonstrated as increasing employment, and it has been indicated that the annual employment growth rate would reach 0.42% per year in 2050. Moreover, the amount of energy-related jobs has been estimated to reach 85 million as well. The effect of renewable energy utilization is less prevailing on employment than GDP since the global salary would be boosted as well. On the other hand, by 2050, the fossil fuel-related jobs would inconsiderably be reduced, which is compensated by brand-new stablished jobs regarding the renewable energy employment [16,18,19]. The last but not least impact of the renewable energy application is related to human well-being including health, education, and environment, which is represented as welfare. The global welfare would be stepped up by 2050, and the welfare index would be enhanced by 15% in comparison to the 2018 reference case. Even though the renewable energy prospective is significant, the renewable energy technologies have a slow diffusion rate due to the lack of knowledge, skill, and market capacity [20,21]. In that regard, the authorities and policy makers can play a momentous role in the renewable energy utilization by assigning fossil fuel taxes, renewable energy incentives, and carbon emission penalties. Furthermore, the government should consider the public opinion to constrain a successful development of the renewable energy applications [22, 23].

2. Renewable Energy Potential in Iran

The renewable energy sector has a great potential in Iran's power industries due to its geographical location and rich renewable resources. Iran's renewable energy sources are investigated and reviewed in the following.

2.1 Solar

As shown in figure 6, the mean annual solar radiation of 2200 kWh/m2 (greater than the worldwide average) is due to the geographical region of Iran, which is located in the world's Sun Belt [24]. Figure 7 illustrates the average annual global irradiance for 21 sample cities of Iran in a period of 10 years [25].

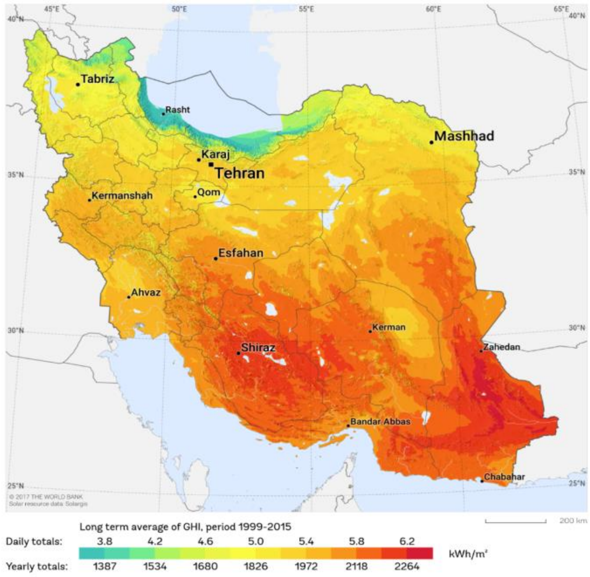

Figure 6. Iran Solar energy map 2015 [18].

It has been reported that more than 280 sunny days have been recorded over 90% of the lands of Iran, indicating that the potential source of solar radiation is very noteworthy and rich [27]. Along with the research works carried out for determining the proper geographical locations for the installation of solar power plants, it should be noticed that other numerous economic, environmental, social, and risk parameters (and their related sub-criteria) are determinant in the evaluation of the regions priority [28].

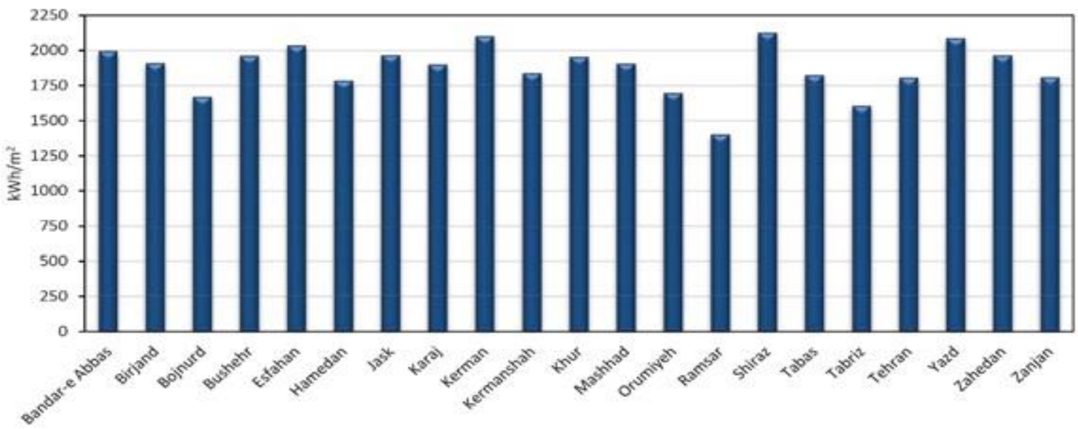

Figure 7. Average annual solar irradiance for 21 sample cities [25].

In addition, the total annual sunny hours are about 3080 h; in other words, an average sunny hour per season equal to 770 h. The diagram in figure 8 illustrates the daily sunshine hours at 63 stations as the annual average of the monthly sunshine hours by measurement of the Campbell–Stokes recorders [29]. While the solar potential of Iran is outstanding, there are not sufficient infrastructure and equipment to utilize it. One reason has been the fuel price for producing electricity, and the other is the oil export since 80% of Iran's income is based on oil and gas exports. It should be noticed that despite the historical use of the solar energy, the technological use of this source of energy in Iran has taken place only since the 1980s [30-36].

In addition to thousands of single photovoltaic units used on traffic lights, highways lighting, public places, and communications, an installed capacity of 650MW is available. The solar thermal collectors are usually employed to provide the required hot water for local and small industrial applications. There are frequent developments that have been carried out by some universities, research institutes, and the Energy Research Center of the Ministry of Energy [37-39]. Currently, solar-powered houses in Iran are mainly utilizing photovoltaic panels. Although the total installed capacity for solar houses is not significant (0.1% of the renewable capacity in Iran), it is growing annually. Many activities are underway in the subject of solar power generation systems. In this regard, opening the 250MW Shiraz solar thermal power plant is one of the main projects that have been done [38-41]. The final project of the Centralized Solar Power Plant (CSP) of Shiraz will provide a capacity of 500 MW (Figure 9). This project will be the first step for the development of the required integrated solar technologies in the future [39-50].

The Yazd Combined Solar-NG Power Plant is another main solar project in Iran with a capacity of 470 MW, which has been connected to the national power grid since 2009 [45-49]. This power plant is the first of its kind in the world. The Yazd power plant utilizes the solar energy to increase its steam production by focusing on the solar energy technology (Figure 10).

The Yazd Solar Power Plant was the world's eighth-biggest solar power plant at the beginning of 2010. Further, 18,000 solar water heaters and 77,000 m2 of solar collectors in the event of household, official and commercial solar energy usage, were installed [39-49]. General information on Shiraz and Yazd power plants is brought in table 1 [39-50]. The solar photovoltaic electricity stations with a capacity of 30 kW in Darbid and Sarkavir have been installed as well. Moreover, the Tabriz solar power station with a capacity of 50.4 kW has been launched in 2009 (Figure 11). Two wind turbines with a capacity of 5 kW have been installed on the solar station site as well.

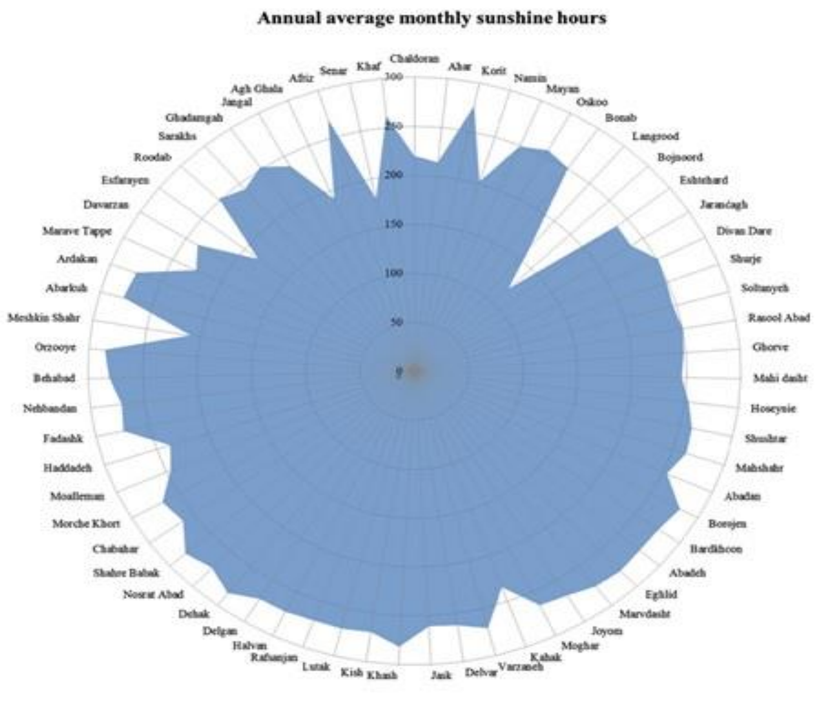

Figure 8. Annual average of monthly sunshine hours [29].

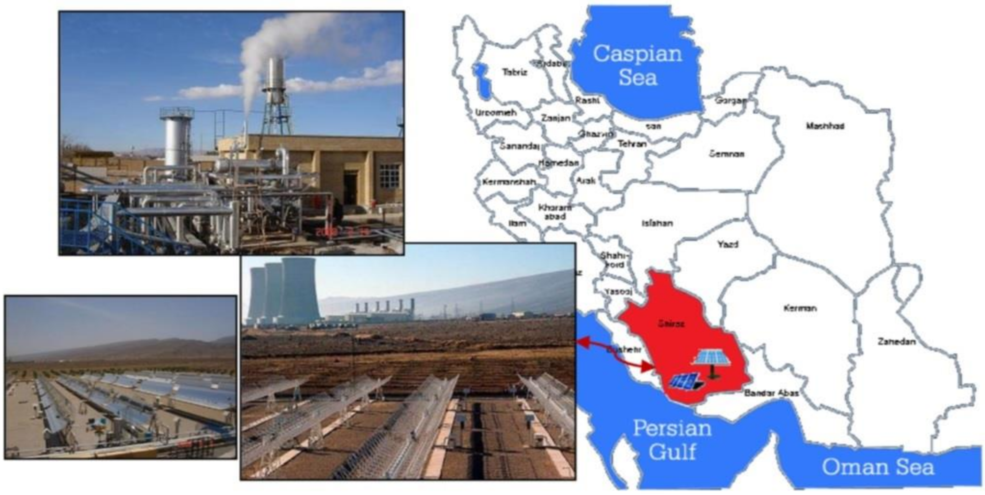

Figure 9. Shiraz power plant, 250 MW [34, 42].

Figure 10. Yazd solar thermal power plant, 470 MW [42, 43].

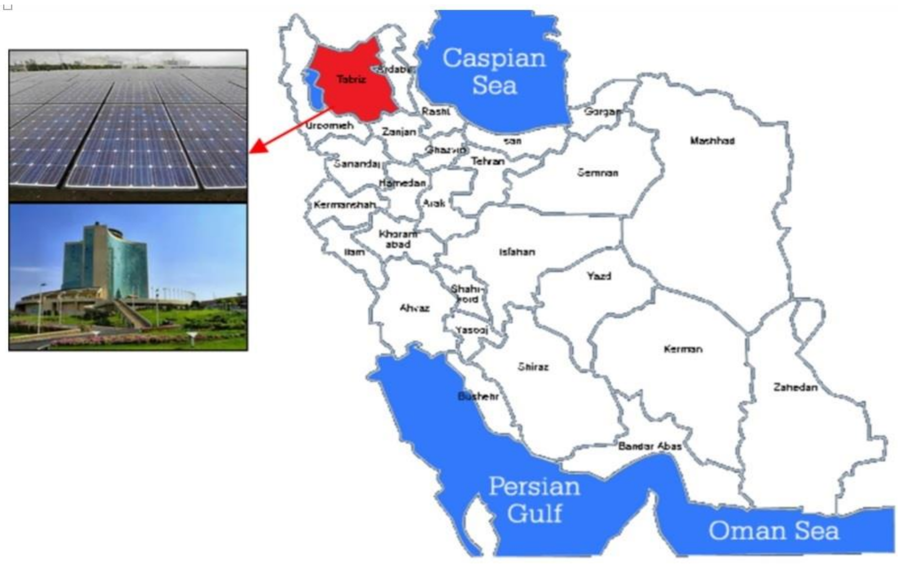

Figure 11. Electric solar power station of Tabriz with 80,000 kWh capacity [42, 44].

Table 1. Specifications of Shiraz and Yazd power stations [50].

Name	Location	Capacity	Type	Operational	Notes
Yazd solar thermal power plant	Yazd	467 MW	Integrated solar combined cycle	2009	Is the world's first integrated solar combined cycle power station using natural gas and solar energy and it is the largest solar power plant in the Middle East and the 8th largest in the world
Shiraz solar power plant	Shiraz	250 MW	Concentrating solar power	2009	Is Iran's 1st solar power station, currently being upgraded to 500 MW h

The Iranian government persuades the private sector to utilize solar systems with substantial subsidies. The results of these motivations are the solar water heaters that have been mounted all over the country in the last years. Here are the finalized solar energy plans in Iran:

- Dorbeed 10 kW Photovoltaic Power Plant.
- 97 kW Moalleman Photovoltaic Power Plant.
- Shiraz 250 kW Solar Power plant (Figure 12).
- 350 units (1400 m2) Solar Water Heaters.
- Photovoltaic electricity generation for water pumps in agricultural fields, border security posts, and faraway roads lighting.

Figure 12. Solar power plant in the southern Iranian city of Shiraz [89].

Some running solar projects in Iran are as follow:

- 1 MW Solar Power Thermal Plant under construction in Talegan-Karaj.
- 45 kW grid-connected P.V. under constructed in Taleqan.
- 650 units (2600 m2) Solar Water Heaters for domestic use under construction.
- Units (400 m2) Solar Water Heater for village public baths under construction [53].

Iran has electrical network connections with six neighboring countries: Afghanistan, Armenia, Azerbaijan, Iraq, Pakistan, and Turkmenistan; and has plans to expand this strategy owing to its significant benefits such as:

- Enhancing regional security.
- Optimizing the manageable electrical transmission capacities.
- Enhancing network reliability and stability.
- Exchanging reserved electrical capacities.
- Reducing the peak of electricity demand [54].

The remarkable development in the application of the solar energy production in Iran is reliant on the advances of proper policies and strategies owing to high electricity subsidies and low tariffs. The recent studies have revealed that only a 20% increase in the annual electricity rate will provide profitable investments in this valuable source of energy [55, 56]. It is noteworthy that not only the stationary solar heat and power generation could be utilized as an alternate source for fossil fuels, but also other solar energy technologies such as solar chimney and vented thermal storage wall for household consumption [57, 58], solar desalination for freshwater supply [59], solar thermal dryers [60], and local solar chimney power plants [61, 62] are decent options for solar energy harnessing with a great potential in Iran.
The solar power generation of Iran in comparison to the leading countries in solar technology can be given as follows [63, 64].

Table 2. Comparison of solar power generation between Iran and the leading countries in solar technology.

	Iran	USA	Spain	Germany	China
Solar power generation (Mwh)	4419.7	34997.6	23588.9	7806.2	247915.7

2.2. Marine Renewable Energy

2.2.1. Wave Energy

The wave potential power is the main factor that should be measured and analyzed in order to provide a site for a wave energy power plant. As it has been presented in equation 1, this energy is dependent on the wave height and the wave time period.

$$E = \frac{\rho g^2 T H_{m0}^2}{64\pi} \tag{1}$$

There are three major regions, the Caspian Sea, the Persian Gulf, and the Gulf of Oman, that could be evaluated for wave energy harvesting in Iran. The Caspian Sea with an average of 5-14 kW/m has a reasonable potential for wave energy extraction; however, the northern coasts of Iran are not suitable regions for installation of wave energy conversion systems due to the very little depth of south-east of the Caspian Sea. In other words, the wave energy that could be extracted from this area is not considerable [65]. There are various types of technologies for wave energy harvesting that could be classified into four main categories: Oscillating water column systems, Attenuator systems, Overtopping systems, and Point absorber systems [66]. On the other hand, the long-term hindcasted data of wave energy in the Persian Gulf based on wind data between 1984 and 2008 has shown an average of 1-5 kW/m [67, 68]. Due to the short height waves of the Persian Gulf, the point absorber converters would be the preferable systems for energy extraction [69, 70].

There are five high potential sites located in the South Coast bar of Iran in the vicinity of the Gulf of Oman. These sites are Sirik, Jask, Googsar, Chabahar, and Govatr. The data of wind characteristics over a decade has shown that the Chabahar coast has the highest wave energy potential. However, Chabahar, which is located in the northern part of the Gulf of Oman, is a free trade-industrial zone that eases the facility construction procedure [71].

Generally, for the determination of the wave specifications, the mean wave specification for a certain period of time is required. There is not enough available data in Iran about wave As the wind is the key factor for sea waves generation, the coastal wind data sets will be helpful to present the data obtained from SATBA [72, 73]. As shown in table 3, the Chabahar coast with a maximum total power of 1539 MW has the highest wave energy potential. It should be noted that the Gulf of Oman, where the Chabahar coast is located, has the regular wave power of 10-15 kW/m [74, 75].

Table 4 presents a comparison of the average and maximum wave energy in Iran [72, 73] and other areas of the world [74, 76, 77]. As described in table 3, the Persian Gulf islands have high potentials for wave energy extraction. These islands are not connected to the national power grid. Thus the power generated by waves could be cost-efficiently utilized by the island's consumers or even the extra power could be linked from the bottom of the sea to the national power grid.

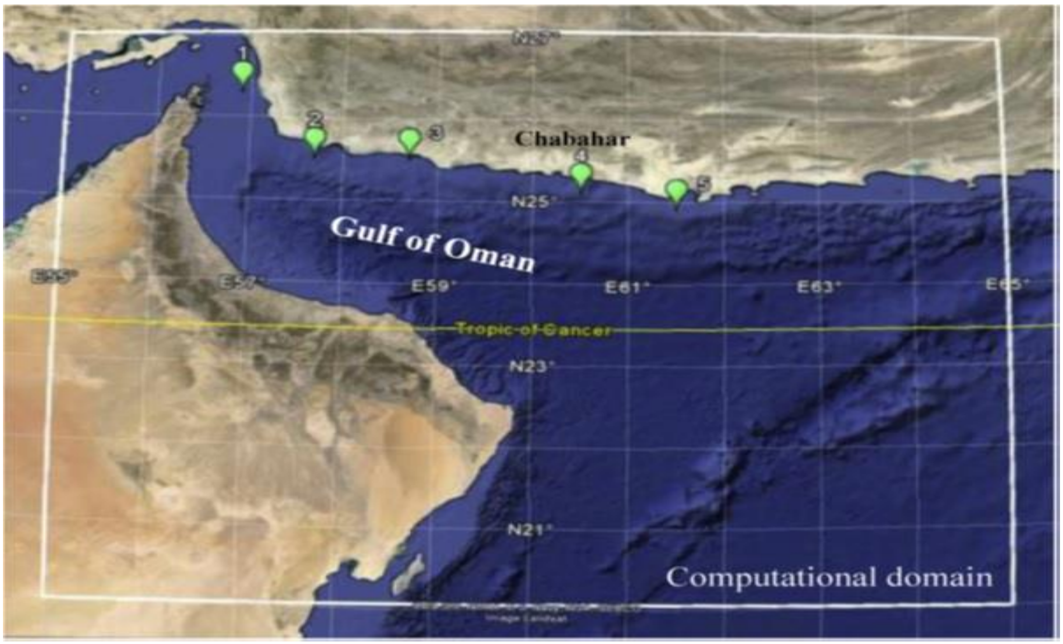

Figure 13. Five high potential locations for wave energy extraction in the Gulf of Oman [71].

Table 3. Potential wave power in selected sites in Iran's northern and southern coasts based on the data provided by SATBA [72, 73].

Site name	Power per meter of the coast (kW/m)	Coast length (km)	Total power (MW)
Abadan	2.9	34	101
Abomosa	5.1	5	26
Anzali	3.4	124	423
Astara	0.6	83	50
Babolsar	2.2	155	341
Bandar Abbas	0.9	232	210
Lenge	3.4	359	1222
Boushehr	2.2	474	1045
Chabahar	5.8	265	1539
Jask	3.2	289	925
Mahshahr	1.7	223	380
Noushahr	1.1	99	110
Ramsar	1.4	100	141
Siri	5.3	5	27
Total			6540

Table 4. Comparison of wave energy in Iran and other parts of the world [72-77].

Site name	Average power (kW/m)	Max. power (kW/m)
Persian Gulf islands	16.6	19.0
Persian Gulf coasts	3.5	6.1
Gulf of Oman coasts	10.5	12.6
Caspian Sea coasts	3.2	6.7
Japan	7.0	12.5
New Zealand	23.6	100.0
Western Europe	46.9	70.0
World (average)	9.0	-

2.2.2. Tidal energy potentials in Iran

Tidal energy is one of the most obtainable and exciting forms of renewable energies. Contrasting almost all of the other types of renewable energy, which are resultant of the sun, this kind of energy is produced by regular tidal cycles affected by the phases of the moon. The most important specification of tidal energy is its intermittency. As the sun and wind are not always available due to climate changes, their intermittency is limited. Approximately, there is a potential of 100 GW of tidal energy in the earth's oceans and seas. It should be noticed that only a portion of this great amount of energy is utilizable due to the limited accessible tide locations [78]. The main countries in utilizing tidal energy are the United States, Canada, France, and the United Kingdom [79].

As there are no operational tidal power plants installed in Iran, the studies performed in this field focus on the potential analysis and technology design for harvesting tidal energy. Iran, by having more than 2000 km tidal coastline, has a great potential in the tidal energy production [80].

As the tidal energy analysis has a less random behavior study in comparison with the wave energy analysis, 2 and 3 dimension finite elements could be carried out in order to simulate tidal flows [80, 81].

Generally, the tidal energy could be utilized in the two forms of potential and kinetic energy, which are reviewed in the following.

The idea of employing tidal potential energy is alike hydro dams. The potential energy of water that causes the water static pressure is converted to electricity through the turbine. The flow direction to the turbine in hydro dams is invariant but in the tidal energy systems, there are various possibilities for flow direction to the turbine. As a result, various arrangements have been designed and presented for harnessing the energy of tides [82].

These arrangements are sorted as follow:

1- single-pool ebb system (Figure. 14);
2- single-pool flood system (Figure.15);
3- single-pool two-way operation system;
4- two-pool ebb and flood tide system;
5- two-pool one-way system (high and low pools) (Figure. 16).

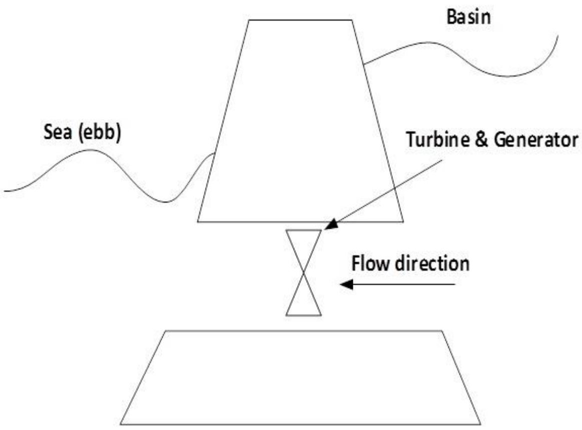

Figure 14. Design of a single-pool ebb system [73].

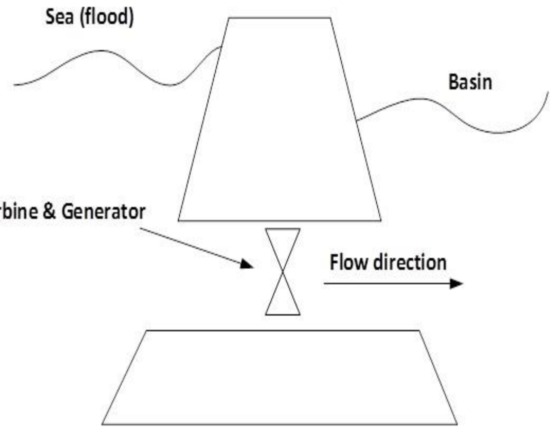

Figure 15. Design of a single-pool flood system [73].

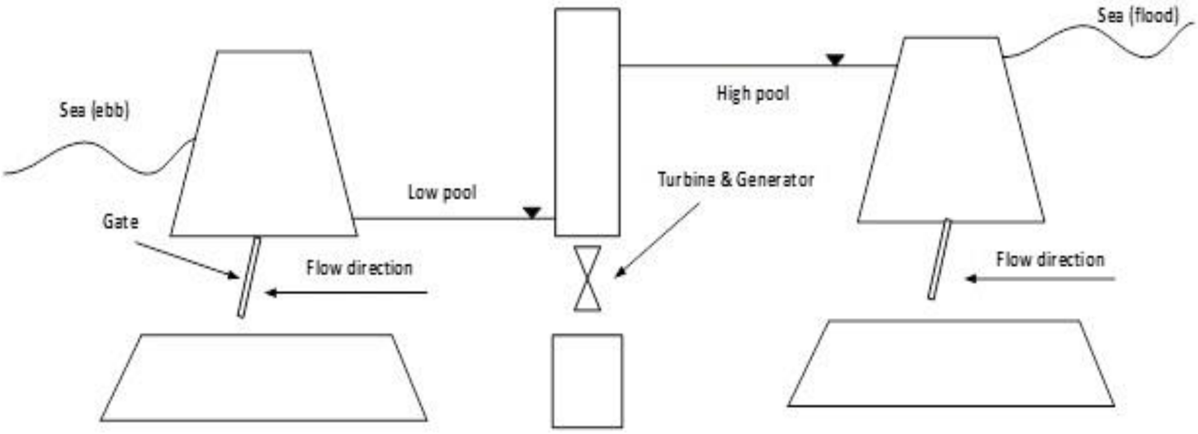

Figure 16. Design of a two-pool one-way system [73].

As the tide of the Caspian Sea is insignificant, the regions where the tide energy could be utilizable are limited to the south coast and high seas of Iran.

A minimum water flow velocity of 2-3 m/s is required that the tidal kinetic energy could be utilized [78, 82]. Flow velocity speeds less than 2 m/s are not proper and cost-efficient for energy utilization. Similarly, the speed of 3 m/s is an upper limit for the current speed in order to avoid turbine damages [78]. The Khowr-e Musa Bay, which is located in the north-western part of the Persian Gulf, has a peak tidal current speed of about 2 m/s [84]. A 3m/s tidal current contains an energy flux of about 14 kW/m2 [85]. In the Persian language, a branch of the sea that has entered the land is called Khowr.The average tidal current speed of the southern coasts of Iran may reach 1.5 m/s, which is less than the minimum required speed for tide energy utilization [86]. Hence, the potential energy of the water level difference between ebb and flood is discussed further in the following.

Several conditions should be taken into account for the tidal power production to remain cost-efficient. A high tidal range, a slender current entrance, and enough deep position of the turbine are the main essential conditions. In order to determine the best location, 36 preferable sites were investigated. These sites were analyzed based on the estimated annual tidal potential energy. The water level difference data between ebb and flood were gathered from SATBA [72, 73]. Table 5 presents the tidal data of 23 key locations in the Persian Gulf and the Gulf of Oman. Table 6 describes the tidal range, tidal potential energy, basin area, and length of the required barrage of the analyzed sites. As the pool size is an effective parameter on the tidal potential energy, only the sites with a basin greater than 1 km2 are presented in table 5.

Mahshahr, Bandare-e Imam, and Pohl sites are the best areas for tidal energy harnessing with tidal ranges of 3.14, 3.17, and 2.57 m, respectively. As it is presented in table 5, it is obvious that Mahshahr and Bandar-e Imam are the highest tides sites. These sites are located in the Khowr-e Musa region [87].

Equation 2 presents a simplified estimation of the tidal potential energy system for a single tidal cycle (one ebb and one flood) [78].

$$E = \eta \times \rho \times g \times h \times q \quad (2)$$

where E is the potential energy of the tidal system in each tidal cycle (J/cycle), η is the efficiency of the system, ρ is the density of seawater (kg/m3), g is the acceleration of gravity (m/s2), h is the mean level difference between the water in the basin and sea (m), and q is the flow rate of seawater flowing through the turbine at each cycle.

Equation 2 should be employed for each cycle for the turbine to generate power by filling or draining the basin. The turbine in the first structure generates power when the basin is drained. In the second structure, power generation occurs when the basin is filled and the third system is able to generate power in both directions. In this study, the first structure is investigated.

Table 5. Tidal data of 23 key locations in the Persian Gulf and the Gulf of Oman [72, 73].

Area		MSL (m)	Mean tidal levels (m)			
			MHHW	MLHW	MHLW	MLLW
1	Khorramshahr	0.66	1.04	0.77	0.54	0.27
2	Chouibdeh	1.67	2.52	1.97	1.21	0.55
3	Bandar-e Imam	3.17	5.04	4.24	2.11	1.29
4	Mahshahr	3.41	5.76	4.29	2.53	1.06
5	Deylam	1.82	2.84	2.07	1.57	0.8
6	Khark	1.29	1.8	1.46	1.12	0.78
7	Genaveh	1.43	2.29	1.52	1.35	0.65
8	Lengeh	1.52	2.3	1.6	1.3	0.5
9	Kish	1.25	1.86	1.36	1.14	0.64
10	Hengam	1.68	2.7	2.1	1.2	0.6
11	Tonb-e Bozorg	1.77	2.5	2.1	1.5	1
12	Qeshm (Gooran)	2.38	3.85	3.17	1.59	0.91
13	Qeshm (Gaz)	2.55	4.14	3.51	1.59	0.96
14	Qeshm (Basaeedou)	1.98	3.2	2.42	1.53	0.72
15	Qeshm (Doustkouh)	1.61	2.6	1.99	1.23	0.62
16	Qeshm (Kaveh)	2.47	4.14	3.12	1.83	0.81
17	Pohl	2.57	4.16	3.49	1.64	0.98
18	Bandarabbas (Haghani Port)	2.2	3.64	2.78	1.61	0.75
19	Shahid Rajaei Port	2.3	3.8	2.95	1.63	0.79
20	Hormuz	2.12	3.49	2.68	1.58	0.76
21	Minab	2.1	3.33	2.73	1.46	0.86
22	Chabahar	1.71	2.6	2.08	1.24	0.73
23	Konarak	1.76	2.81	2.11	1.41	0.71

Table 6. Specification of preferable locations for tidal power plants in the Iranian coasts of the Persian Gulf and the Gulf of Oman based on the data gathered from SATBA [72, 73].

Site name	Nearest site with data available	Basin area (km^2)	Tidal range (m)	Potential (MW)	Barrage length (m)	Notes
Rig Port	Khark Island	10.5	1.4	3	500–700	Muddy pool
Shif Island	Khark Island	19.0	1.4	4	1000–2500	
Rig Port	Khark Island	17.5	1.4	4	700–1500	Muddy pool
Chark Port	Farour Island	2.5	1.4	1	100	Muddy pool
Asaloie Port	Kangan	50.0	1.4	12	7000	
Gatan	Jask Gulf	1.5	1.8	1	300	
Kerian	Rajaei	13.5	2.3	8	2500	
Kerian	Rajaei	2.5	2.3	2	750	Muddy pool
Banzarak	Rajaei	2.0	2.3	1	120	
Banzarak	Rajaei	1.2	2.3	1	100	
Tore	Arvandroud	35.0	2.6	28	800	
Choibadeh	Arvandroud	12.0	2.6	9	500	a
Darak	Galak	7.5	2.1	4	500	a
Gabrik	Jask Gulf	1.7	1.8	1	100	Muddy pool
Gabrik	Jask Gulf	1.7	1.8	1	120	
Yekdar	Jask Gulf	2.2	1.8	1	200	
Chabahar	Chabahar	4.2	1.8	2	500–800	
Gachin	Hengam	3.8	1.8	2	500	
Khormosa	Khormosa	13.0	2.5	9	600	
Mahshahr port	Mahshahr	170	3.9	301	1200	
Khorsalag	Khormosa	17.0	2.5	12	400–600	
Arzani	Sirik	2.5	2.3	2	500	

[a] The Bahman Shir river connection should be blocked.

Equation 3 calculates the seawater flow rate per each cycle of ebb and flood. It is assumed that the basin area is uniform and efficiency is 100%, which leads to a maximum accessible potential power estimation.

$$q = A \times H \quad (3)$$

where is the area of the basin (m^2) and is the maximum tidal range (m).

As power is being generated by the turbine, the difference level between see and basin water decreases. Consequently, the available hydraulic head will decrease continuously. Therefore, half of the maximum tidal height is defined as the average.

Tidal range: $h = \frac{H}{2}$

As it is presented in table 5, the Mahshahr port has the highest potential for tidal power production (equal to 301 MW). As mentioned earlier, the proposed approach provides a simple rough estimation with several assumptions, which is mainly suitable for the large basins sites.

The tidal power plants are able to operate in either grid-tied or off-grid types. As presented in table 5, the investigated sites in Iran are close enough to install connected to the grid power plants. Hence, the plant design and the operational conditions

definition, rely on grid necessities, either peak or base load. For the peak load production, the best structure is a two-pool one-way system (structure 5) which the power generation period can be variant. Moreover, during off-peak hours, Pumped-storage function can be utilized as well.
The single-pool ebb tide arrangement (first structure) could be a desirable choice in Iran, due to the simplicity and inherent cost-efficiency of the system. Iran’s dam construction industry has been developed widely since the 90s. Hence, domestic technology, experience and resources can be very helpful to develop tidal power plants as well.

2.2.3.3. Salinity gradient energy

Salinity gradient has worldwide great potential for power generation, particularly in regions with low salinity surface water discharge into hyper-saline lakes. Pressure-retarded osmosis (PRO) and Reverse electro-dialysis (RED) are the two main technologies that have reached the pilot phase. The PRO method is based on semipermeable membranes that permit only water molecules and the RED approach is based on the use of ion-exchange membranes that only allows ions to pass through [89]. Urmia lake is located at the southwest of the Caspian Sea between the provinces of East and West Azerbaijan, and its most significant river is ZarrinehRud River. Urmia Lake with a salinity higher than 260 g/L is the eighth saltiest body of water in the world. There are also several freshwater rivers linked to the lake that make the region an ideal site for the salinity gradient energy [83]. According to the recent studies, the Urmia Lake has a nominal potential of power generation equal to 0.4-1 GW. It has been reported that 20-30% of the aforementioned value could be utilized [90].

2.3. Wind energy

Due to the existence of wind regions in Iran, the design and manufacturing of windmills have been common since 200 BC. Today, there are also many good opportunities to develop the use of wind energy. Studies and estimations have shown that in only 26 regions of the country (including more than 45 appropriate sites), by taking into account the nominal capacity of sites and total efficiency of 33%, 6500 MW of wind potential energy is available (Figure. 17). It should be noted that the nominal capacity of the entire country's power plants was about 74,000 megawatts (by 2015) [95].
Figure 18 depicts the primary wind power production potentials and power grid connections for suitable sites (Factor Map 1). The top 15 provinces are Qazvin, Zanjan, West Azerbaijan, East Azerbaijan, Bushehr, Fars, Qom, Hormozgan, Semnan, Yazd, Zanjan, Esfahan, Khorasan, Sistan-Baluchistan, and Guilan [96].

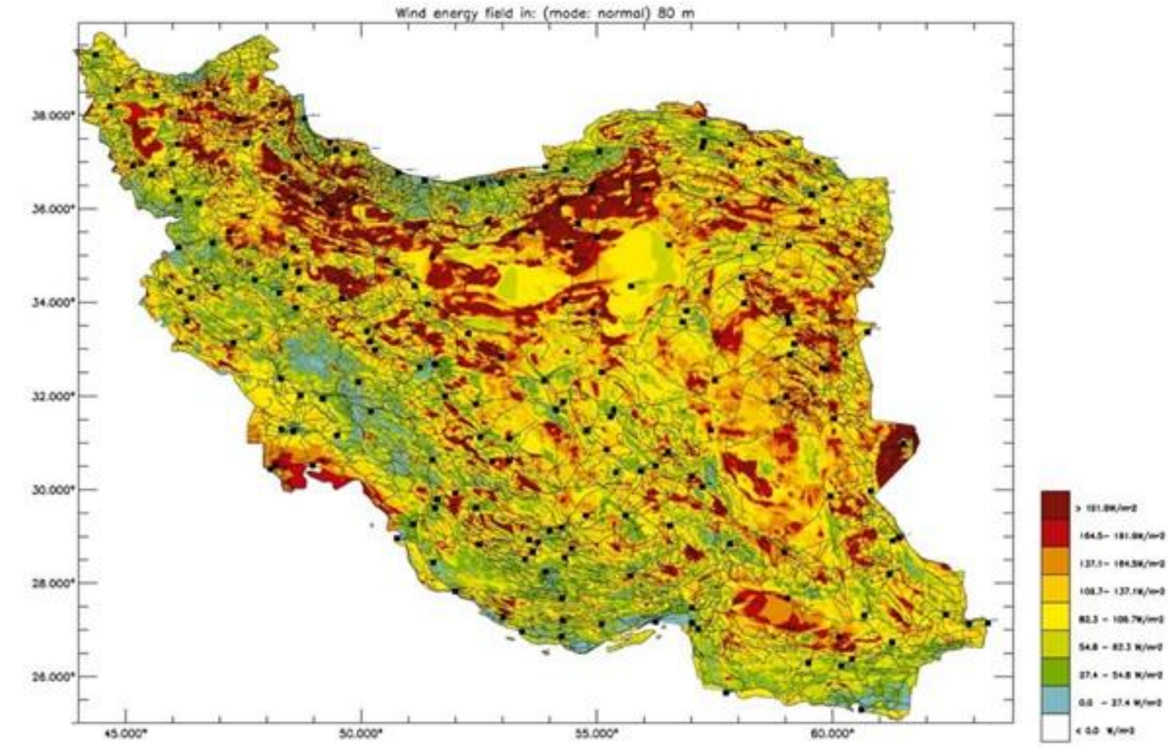

Figure 17. Iran's wind capacity distribution at an altitude of 80 m [85].

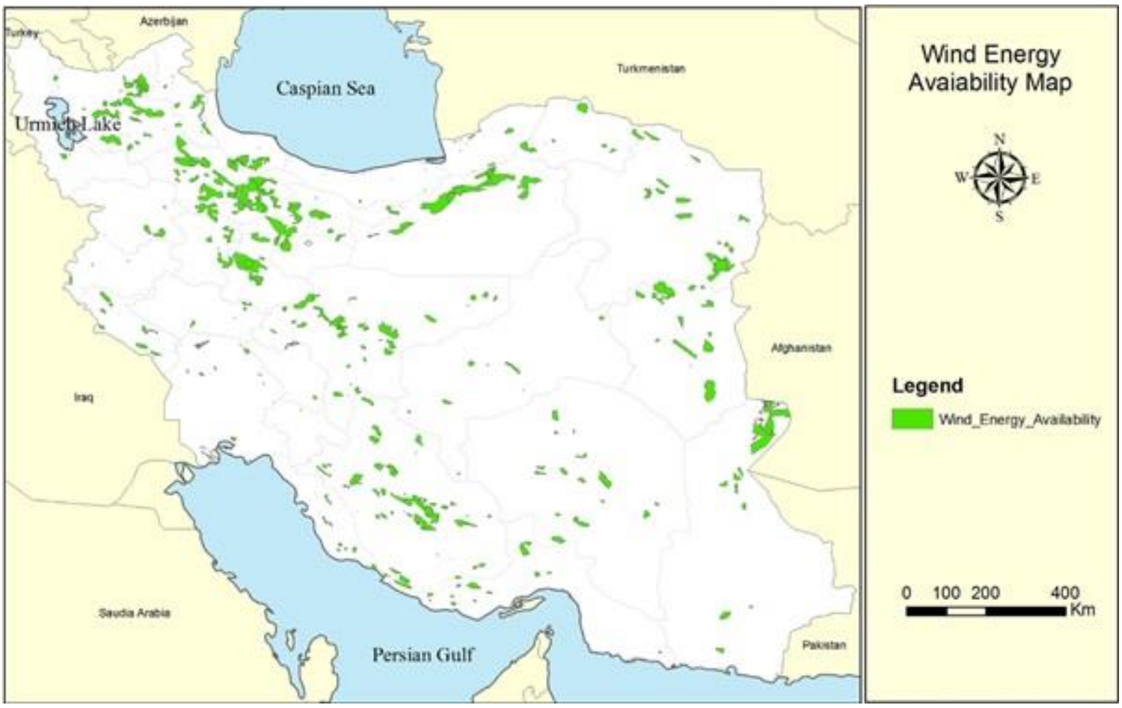

Figure 18. High potential areas of wind energy resource in Iran (availability map) [96].

Iran has invested heavily in the renewable energy sources of wind power. The allocation of subsidies in the fossil sector is about €3.6 billion, which is a major barrier to the development of renewable energies. In spite of the subsidies, the installed capacity of wind power in Iran was 91 MW by early 2008, which produced 307 GWh of electricity during the period of 1997-2009 [91]. Figure 19 shows the growth of installed wind energy capacity in Iran [93, 100].

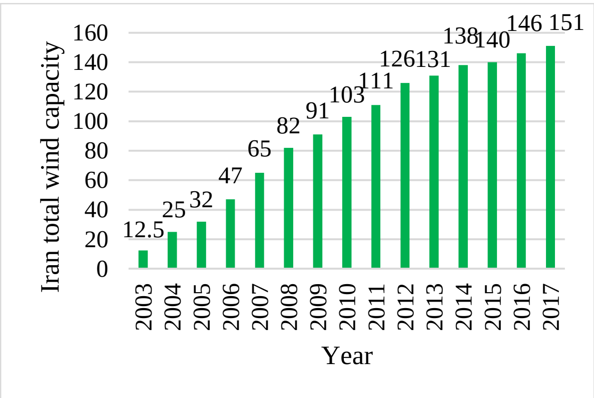

Figure 19. Growth of installed wind energy capacity in Iran [93].

This amount of electricity has saved 425,000 barrels of oil equivalent in the Iranian power plants, which, in turn, reduced one million tons of environmental pollutants. By the information of USDoE [92], the use of wind energy is growing continuously due to the following facts:

- Being more affordable in comparison with other sources of renewable energy.
- Providing a good opportunity for farmers and ranchers by providing wealth and local employment (ideal entrepreneurship [93]).
- Being zero-emission and not pollutant, which helps to reduce fossil fuels and energy imports.
- Being a local and domestic source of energy, which helps to provide national security and sustainable development.
- Minor effects on the environment and human life [94].
- Independency of any type of fuel reduces the risk related to a lack of fossil fuels.

The northern and eastern areas of the country are located in the pathway of strong wind streams, and are desirable locations for wind farms. Although the central and southern regions of the country do not have much wind potential, installing wind turbines is suitable to provide agriculture water supply system electricity [98]. Currently, the installed capacity of Iran's wind power is about 151 MW, which is most located in the Manjil and Roodbar. The generated power is linked to the local grid. The development plans for installed wind power plants and the installation of a new 60 MW wind farm is also in progress [99]. Table 7 presents the installed capacities until 2017 [100]. It should be noted that Feed-in tariff is one of the most effectual parameters for the cost-effective utilization of wind turbines. Also capital cost, wind features, and interest rate have been identified as the other important parameters that should be taken into account [101]. It should be noticed that the wind energy development in Iran is much less than the target of the 5th National Development Plan of the country. Despite considerable wind resources and available regions for wind farms, a higher exploitation of sustainable wind energy in Iran requires more effective macro-management [102].

Table 7. Installed windfarms capacity in Iran.

Item No.	Site Name	Capacity (KW)	Name of Project executor
1	Manjil Wind Farm Site	90220	Renewable Energy Organization of Iran(SUNA)
2	Binalood Wind Farm Site	28380	Renewable Energy Organization of Iran(SUNA)
3	Zabol - Sistan	660	Renewable Energy Organization of Iran(SUNA)
4	Babakoohi - Shiraz	660	Renewable Energy Organization of Iran(SUNA)
5	Oun ebn-e-Ali - Tabriz	1980	Renewable Energy Organization of Iran(SUNA)
6	Sar Ein (Ardebil)	660	Renewable Energy Organization of Iran(SUNA)
7	Seffeh - Isfahan	660	Renewable Energy Organization of Iran(SUNA)
8	Mahshahr	660	Renewable Energy Organization of Iran(SUNA)
9	Nir	660	Renewable Energy Organization of Iran(SUNA)
10	Sarab	660	Renewable Energy Organization of Iran(SUNA)
11	Khaaf – Khorasan Razavi	1500	Behin Ertebat Mehr Co.
12	Takestan	20000	MAPNA
13	Nishabour - Binalood	4300	Atrin Iranian - NIBA
Total		151000	

2.4. Geothermal energy

Extensive studies to identify the potential of geothermal energy sources have been initiated by the Ministry of Energy in cooperation with ENEL Consulting Engineers science 1975 in the north and northwest regions of Iran in an area of 260,000 km2. The result of this research has revealed that the Sabalan, Damavand, Khoy, Mako, and Sahand areas with an area of more than 31,000 km2 are suitable for further studies and geothermal energy utilization. In this regard, the exploration program including the geological, geophysical and geochemical studies was planned. In 1982, after completion of the preliminary exploratory studies in each one of the mentioned areas, the suitable areas were accurately identified, and as a result, in the Sabalan region, the Meshkinshahr, Sarein, and Busheli areas; in the Damavand region, Nunal; in the Maku-Khoy regions, Meshkinshahr; and in the Sahand region, five smaller areas were selected to focus on the activities of the exploration phase. After a relatively long gap and with the aim of reactivating the plan, the existing reports were revisited by the UNDP experts in 1900, and the Meshkinshahr geothermal region was introduced as the first priority for further exploratory studies. Following the studies mentioned above, the exploration, injection, and descriptive drilling project was designed to identify the potential in the Sarein Meshkinshahr region in the year 2002. The first phase of the project was completed in 2004. The second phase of the project began in 2005. Development of the geothermal field and the Meshkin-Shahr Power Plant, the drilling of wells, the operation of wells during the test period, the manufacture of test equipment in the country completely got indigenous and carried out by domestic experts [103]. Founded by the research works performed in well logging, 14 areas have been identified in the country, as depicted in figure 21.

As depicted in figure 21, Iran has considerable geothermal abilities in the northern part of the country. The hot underground water temperature of 85 ºC is accessible in a number of areas. Table 8 presents the different potentials of geothermal areas evaluated in Iran [105]. Currently, there are two geothermal power plants being installed in Meshkinshahr. Each one of the installations has 50% and 32% of development (Table 9).

The highest estimated thermal energy of geothermal reservoirs in Iran belongs to Maku-Khoy with 30.4*10^18 J, and the temperature of the reservoir reaches 170 ℃ [106, 107]. A comparison of the installed geothermal capacity has been presented to demonstrate the progress of renewable energy diffusion in the geothermal sector.

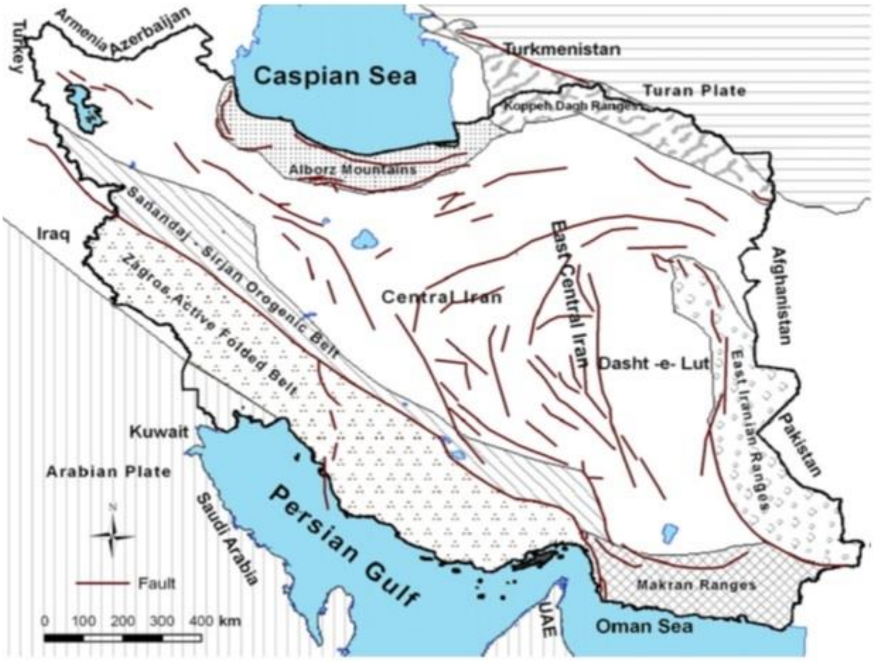

Figure 20. Main structural (tectonic) regions of Iran [94].

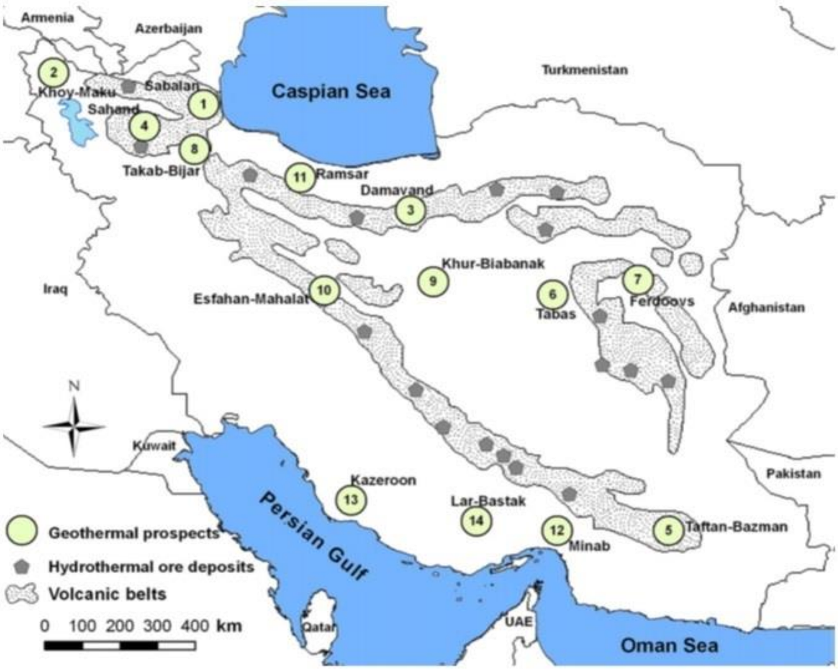

Figure 21. Geothermal energy distribution in Iran. Areas are ranked in the order of prominence [94].

Table 8. Different potentials of geothermal areas evaluated in the north-west of Iran [105].

S. no.	Region	Estimated thermal energy (J)	Estimated mean r eservoir temperature (C)	Reservoir depth (m)	Region area (Km^2)
1	Meshkinshahr	14.84×10^{18}	240	2000–3000	500
2	Sabalan (Booshli)	16.48×10^{18}	240	1500–2500	550
3	Sareyn	16.65×10^{18}	140	500–1000	550
4	Damavand	5.11×10^{18}	190	2000–3000	550
5	Sahand	7.6×10^{18}	160	1500–2500	11,000
6	Khoy-Maku	30.40×10^{18}	170	2000–3000	6200

Table 9. Details of geothermal energy projects being in progress [105].

Project name	Province	Start	Utilize	Percentage of progress until 2010	Capacity of project(MW)	Annual energy production capability(GWh)	Grid type
Meshkinshahr geothermal power plant(Conduct exploration drilling, production and injection)	Ardabil	2005	2014	51	50	370	On-grid
Construction 3–5 MW package	Ardabil	2005	2014	32	3–5	40	On-grid

2.5. Biomass and biogas

Biomass is a renewable energy source that comes from bio-materials. In general, the biological waste generated by cell proliferation is called biomass [108]. Samples of biomass resources are:

- Forest and forest waste
- Agricultural products and waste, horticulture, and food industries
- Livestock extinctions
- Urban and industrial wastewater
- Sewage, industrial organic waste
- Solid waste of municipal waste

Many studies have discussed the biomass classification such as classification based on the type of resource, on the characteristics of the biomass or on the disposal approaches that include forest residues, forest industry by-products, straw, maize residues, and energy crops. Municipal solid waste used wood and manure [109]. Biomass includes biofuels that can burn but excludes biofuels such as fossil fuels (oil, gas, etc.) that have changed through geological processes such as coal and oil.

The biomass energy consumption has grown recently, and it is estimated that it will take up to 50% of the world's primary energy until 2050 [108]. The biogas comes from the breakdown of microorganisms and bacteria in the lack of oxygen. Biogas is an environmentally friendly renewable energy source, which can be produced from biomass or biodegradable waste. The biogas is produced in an anaerobic digestion process by an anaerobic bacteria or in a fermentation process such as agricultural fertilizer, sewage, municipal waste, green waste (gardens and parks), plant materials, and agricultural products. Biomass generally consists of methane and carbon dioxide but it may also have small amounts of hydrogen sulfide, water vapor, and xyloxan (silicon oxide) [108].

The installed capacity of biomass energy in Iran consists of three biogas-fired power stations, one bio-ethanol plant and several undergoing programs for waste-to-energy and algal biofuels [110]. In Iran, domestic and industrial sewage/waste, animal waste, and 80% of the waste of the agricultural product are the main sources of biogas energy [13].

The produced energy of biomass in Iran was equal to 150 mboe in 2008 [111]. Based on the SATBA reports, the maximum power generation potential of a variety of biomass plants in 2014 for cities with a population above 250 thousand (30 towns) exceeded 800 MW including 311 MW waste incinerator, 217 MW Pyrolysis gasification plant, 159 MW power plant Anaerobic digestion, and 112 MW of the Landfill plant. It is worth noting that using the estimated potentials will not only help to extract energy but also address a large part of the pollution problems and environmental issues caused by waste management. Samadi et al. [112] has reported that industrial cattle manure can produce 760 million m3 of biogas (239.2 mboe) that could provide more than 97% of the agricultural sector energy consumption per year in Iran. Figure 22 shows the share of biomass sources in Iran. Bahrami and Abbaszadeh [99] have reported that the installed biogas power plant capacity of Iran is 1.860 MW. Recently, private sectors have begun to construct 600 MW of biomass systems in Iran.

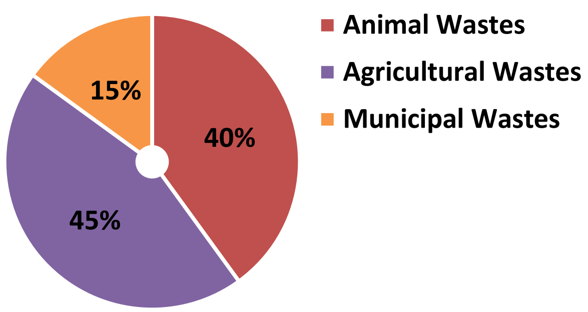

Figure 22. Share of biomass waste in Iran [101].

2.6. Hydropower

Hydropower is an affordable, reliable, cost-effective, and sustainable national energy source. Without any dependence on the fossil fuel prices, the expansion of hydroelectricity will create hundreds of thousands of new job opportunities.

The hydroelectric power industry is the capability of power production in each region of Iran, and it is the largest renewable clean electricity source as well. Hydropower composes 98.8% of renewable electricity and 13.8% of the total electricity production in Iran [13]. Most of the future developments of the hydroelectric power industry will focus on the existing infrastructure and facilities that will provide opportunities to increase renewable energy production without the installation of new large dams. Hydrogen power has been a reliable source of energy for more than 70 years in Iran. This proven reliability provides many benefits to the national electricity grid, from supporting other renewable energy sources to network stability and saving energy for future use. Hydroelectric power is a constant renewable energy source that has been used and produced for more than half a century in Iran and now provides cost-efficient electricity for more than 3 million houses. Hydroelectric power plants can quickly reach the highest output from zero. This feature has turned hydroelectric power into an excellent option against variant daily demands. This is due to an excellent advantage of hydroelectric power plants, which are the only large power generators, able to dispense power to the network in the absence of other sources of energy, quickly. Hydropower is not only a low-cost source of renewable energy but one of the most affordable renewable energy sources. Moreover, hydroelectricity is not dependent on unpredictable fossil fuel price fluctuations in stock exchanges. According to the latest studies of Electricity and Energy Dept (Office of Planning for Electricity and Energy-2016), Hydroelectric Electricity has the lowest Levelized Cost of Electricity (LCOE) between all renewable energy sources and major fossil fuels. LCOE includes the costs of operating, maintaining, and fossil fuel prices compared to other sources of electricity during the duration of a project (Figure 24). For hydroelectric projects, a longer lifespan (up to 50 years in studies) means that not only costs are spread over a long period of time, but the energy equipment used in these facilities can often be used for Longer periods with no need of major replacements or repairs.
Hydropower is an environmentally friendly source of energy that generates energy without producing air pollutants or toxic gases. With the use of hydroelectric power as the main source of Iran renewable energy, the annual emission of more than 174 million tons of CO2 (equivalent to more than 35 million passenger cars) is avoided, as reported in table 10.

It should be considered that the hydroelectricity industry should be committed to a better understanding of the effects of dams on local and aquatic ecosystems. Dams play an important role in preventing the financial and financial losses caused by floods. The flood control dams control the flow of floods to the lower river or that stored water can be used for other purposes. Iran currently has the tenth largest hydroelectric power plant installed in the world, with a capacity of 9.5 GW, including Pumped-storage hydroelectricity. However, there remains a huge untapped potential for these resources. It is estimated that Iran could add up to 65,000 MW by 2020 to the existing capacity [13, 114-116].

Table 10. Pollutant and Greenhouse gas emission in Iran by fuels, 2015, based on Energy Balance Sheet 2015-Deputy Director for Energy and Energy-Office of Electricity and Energy Major Programming [114, 115].

Power Plant Type	N_2O	CH_4	CO_2	SPM	CO	SO_3	SO_2	NO_X
10^3 Ton								
Government								
Gas Oil	30	149	3800018	1298	636	313	10815	17930
Natural Gas	66	664	47233443	4134	70620	-	-	175445
Fuel Oil	263	1319	23965807	10540	69056	2518	340961	53793
Total	359	2132	74999268	15972	140313	2831	351775	247168
Private Sector								
Gas Oil	109	544	13804891	4748	1489	1144	43930	100439
Natural Gas	134	1342	75344476	8352	17862	-	-	259092
Fuel Oil	19	94	2794921	752	147	180	41512	71490
Total	262	1980	91944288	13852	19499	1324	85442	366680
Large Industries								
Gas Oil	0.3	1	33036	13	17	3	163	88
Natural Gas	8	79	4565306	493	2795	-	-	13788
Coke Oven Gas	0.008	0.08	3716	●	●	●	●	●
Blast Furnace Gas	1	9	2464929	●	●	●	●	●
Total	9	89	7066987	506	2813	3	163	13876
Total	630	4201	174010543	30330	162624	4158	438381	627724

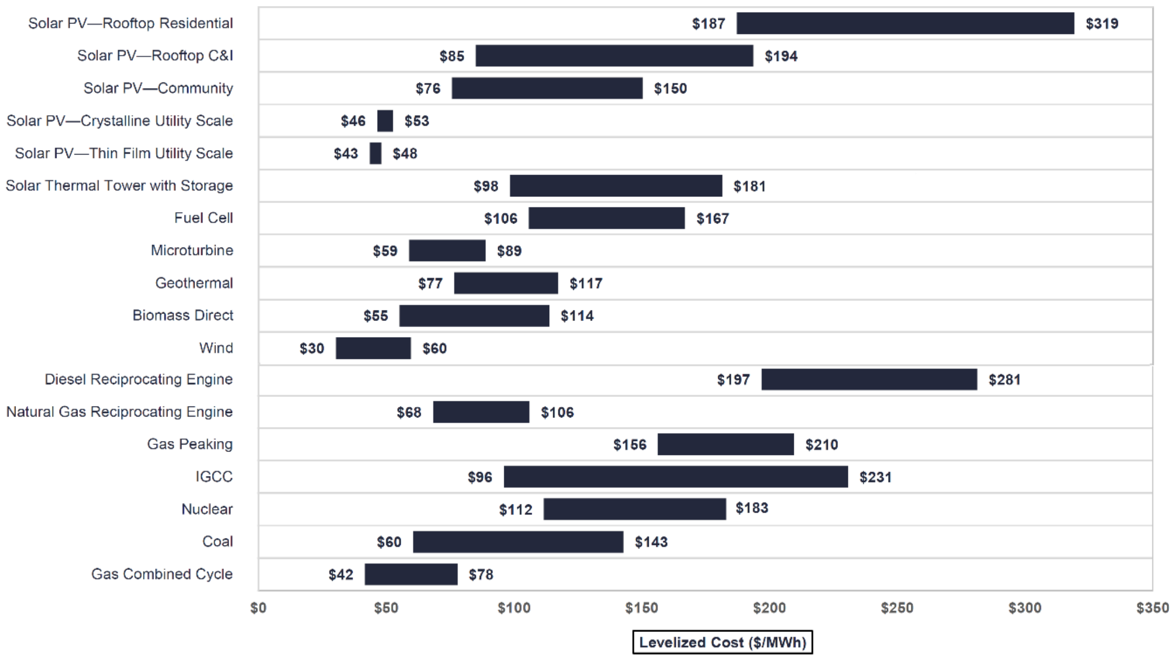

Figure 23. LCOE different costs for energy generation options ($/MWh) [105].

2.7. Fuel cell and hydrogen

Fuel cells are a novel technology for energy production; they generate high-efficiency electrical energy without causing environmental and acoustic pollution, combining direct fuel and oxidation. The purpose of direct electricity production without the thermodynamic limit of the Carnot cycle is the conversion of the chemical energy from the fuel to the thermal and mechanical energy, and ultimately, to the electricity, which minimizes energy loss and yields high theoretical efficiency.

A fuel cell is an energy converter that converts the chemical energy to the electricity power. This is a high-efficiency direct conversion. Currently, the most popular type of fuel cells is the hydrogen fuel cell. In the case of hydrogen fuel cells, electrolysis reaction happens in the transformation process. In other words, by the reaction between hydrogen and oxygen, the products of water, heat, and electricity are generated. Each cell in fuel cells consists of four main components: anode, cathode, electrolyte, and membrane.

Hydrogen, the most plentiful element on the surface of the Earth, could be produced by different approaches. It is assumed that 90% of the universe is composed of hydrogen [118]. Generally, hydrogen in hydrogen-based energy structures is provided by renewable electricity resources. Considering this approach, it is assumed that the definitive fuel will be the hydrogen.

The activity and investment in industrial countries on the development of fuel cell industry, the establishment of strict environmental laws, the allocation of subsidies for new energies and accelerating the development of hydrogen and methanol fuel infrastructure, ending oil supplies, and increasing global warming and population growth are all signs of the replacement of fuel cell technology and a reduction in the trend towards internal combustion engines. Many power plant designers have planned fuel cell systems for installation in future plants. The fuel cells will be the source of power for sensitive places such as banks, stock exchanges, hospitals, and computer system centers in the near future, and will be used as a backbone for the local networks.

It can be said that the fuel cell technology in the near future will change three sectors of transport, power plants and portable generators (battery replacements) and, in line with that, push the oil companies to supply the required fuel for it.

Over the past few years, major investments have been made in developing fuel cell vehicles in various industrialized countries. So far, more than 2 billion dollars has been spent on the development and commercialization of fuel cell cars. Today, large industrial enterprises and small companies with high technologies are trying to optimize the system and reduce its costs. Realizing this requires time, and it is expected that this technology can achieve the economic goals necessary for commercial success. Fuel cell capabilities as a reliable source of hydrogen energy, as a fuel that can be obtained from renewable or non-renewable sources, have made the fuel cell a valuable strategic technology.

3. Status of fuel cell technology in Iran

Iran, on one hand, faces the depletion of fossil resources and high fuel consumption per capita, and on the other hand, is facing the backwardness of the automotive industry and power industry. Moreover, the lack of attention to air pollution issue has led a city like Tehran (the capital of Iran) to be the second-largest contaminated city in the world. Hence, the development of fuel cell technology is evaluated as the final solution to these problems.

Due to the importance of urban air pollution caused by transportation systems, the issue of electric transport consumption is highly regarded by the Iranian domestic automobile industry. Accordingly, research and scientific centers in Iran such as Organization of Novel Energies (designing a prototype fuel cell), Iran Khodro Research Center (electric vehicles), Ministry of Industry Vehicle Design (hybrid petrol-fuel cell cars), Office of Technology Cooperation (Applied Researches), Iran Development and Renovation Organization (Manufacturing of fuel cell sample), Green Institute of Iran University of Science and Technology, Isfahan University of Technology, Sharif University of Technology, Material and Renewable Energy Research Center and other private sectors are performing a numerous projects subjected to fuel cells.

Installation of several types of fuel cell systems was considered as the first fuel cell development plan in the country. In this regard, several small laboratory fuel cells have been established by the Iranian Novel Energies Agency and other research and academic centers of the country. Furthermore, the New Energy Organization of Iran has also been developing a 25 kW of polymer membrane fuel cell system. With the provision, installation, and commissioning of such system in Iran, important goals such as integrated combined heat and power generation, establishing comprehensive plans, providing access to educational objectives, promoting and informing and recording operating conditions data have been achieved [119]. The fuel cell technology in Iran is at the beginning of its technical maturity life cycle. Consequently, this technology has not been commercialized and introduced to the market. Figure 24 depicts the map of selected fuel cell technologies in Iran [120].

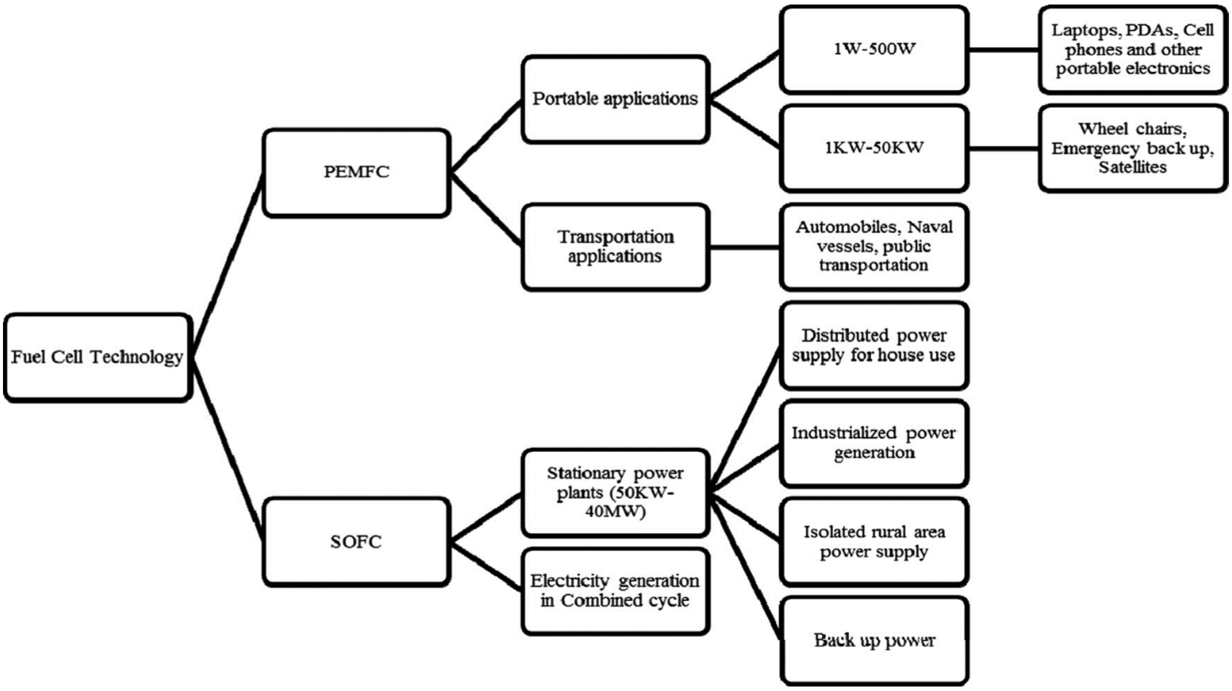

Figure 24. Map of selected fuel cell technologies in Iran [108].

4. Private sector renewable power plant projects

In spite of these challenges, Iran's renewable energy market is interesting due to a great demand for electricity and many encouragements from the government to motivate shifting from fossil fuels to renewable energy. The main challenge of Iran’s market is the bankability of renewable energy developments in Iran. It should be considered that the tariff rates obtained by the government are decreasing annually, and will soon reduce to be competitive with the rates offered elsewhere in the region. Beginner developers may take some risks today but they will meet their benefits for the next decade in the form of higher tariff rates than offered at the present.

As there are numerous needs of renewable energy applications in Iran, and in order to achieve Article 44 of Iran's Constitution, Iran's Renewable Energy Organization has determined participation and investment of the private sector as one of its main missions [121]. Private sectors have many projects in progress. Table 11 shows the private sector's renewable power plant projects in 2017. According to the reports by SATBA, the non-governmental sector has already contracted to install 3000 MW of electricity.

Table 11. Private sector renewable energy power plant projects in 2018 [122].

Company	*Capacity(MW)*	*Location*
Wind power plants		
MAPNA	5	Qazvin
MAPNA	20	Qazvin
MAPNA	30	Qazvin
MAPNA	2.5	Aghkand
Arin Mahbaad	23.8	Siahpoush
Binalood Green Elec	28.4	Neishabour
Dizabad Green Elec	4	Neishabour
Tavan Baad	0.66	Khaf
Fanavaran Energy Paak	1.5	Khaf
Total Wind power plants	115.86	
Solar power plants		
Atrin Parsian	0.514	Malard
Paak bana	0.228	Qom
Aftab maad rahe abrisham	35	Hamedan
Tara Moshaver	0.215	Karaj
Ghadir Energy & Elec	10	Jarghuye
Mehrad Energy Avand	1.2	Rafsanjam
Tose'e faragir Jask	10	Mahan
Arka solar energy	10	Mahan
Abovind	1.313	Damghan
Shahrekord Cement	1.5	Shahrekord
Atiye gostaresh	20	Yazd/Zahedan
Iran Tablo	0.63	Nazarabad
Behnad energy pars lian	4	Sarvestan
Pars Rey Energy	10	Shahrerey
Aftab kavir part	10	Khosf
Total solar power plants	114.6	
Biomass power plants		
Recycle organization of Mashhad Municipality	0.6	Mashhad
Niroo sabin aria	1.06	Shiraz
Bazyaft team kian	1.9	Abali
Tehran Water Company	4	Rey
Tadbir tose'e salamat	3	Hahrizak
Total Biomass power plants	10.56	
Small Hydro power plants		
Tose'e energy Mashhad	0.44	Mashhad
Parsian nano danesh	0.24	Arak
Azarmsa Co.	0.17	Broujerd
Farab Co.	10	Kordestan
Roshd sanat	2.7	Delijan
Sabz maah aab	6.3	Roudbar
Total Hydro power plant	19.85	
Total	260.87	

5. conclusion

It is described that more than 280 sunny days have been logged in 90% of Iran regions, representing that the high potential source of solar radiation is available. Along with thousands of single photovoltaic units utilized in traffic lights, highways lighting, public places, and communications, a capacity of 650MW is installed. In addition to the stationary solar heat and power generation, the solar energy technologies such as the solar chimney, vented thermal storage wall for household consumption, solar desalination, solar thermal dryers, and local solar power plants are proper options for solar energy extraction with great potential in Iran. The availability of energy in oceans and seas is divided into five general categories: tidal energy, wave energy, ocean current energy, ocean thermal energy, and salinity gradient energy. Eliminating the ocean current energy, other types of ocean energies are obtainable in Iran’s coasts and oceans by its several specifications of water. The marine energy in Iran could be extracted from the country’s body of water. Moreover, the Persian Gulf coasts have the potential to provide the tidal and thermal energy of the ocean. Also the Caspian Sea coast is capable of tidal energy extraction. The Gulf of Oman coasts and its remote islands are appropriate locations for wave energy harnessing. At last, salinity gradient energy could be produced in the Urmia Lake.

Studies and estimations have shown that 6500 MW of wind potential energy is available in 26 regions of the country with regards to the nominal capacity of sites and total efficiency of 33%. It should be noted that the nominal capacity of the entire country's power plants was about 74,000 MW (by 2015). Currently, the installed capacity of Iran’s wind power is 258 MW, which is most sited in the Manjil and Roodbar wind farms. The generated power is connected to the local grid. The development plans for installed wind power plants and the installation of a new 60 MW wind power plant is also in progress. Furthermore, there are two geothermal power plants being installed in Meshkinshahr. Each one of the installations has 50% and 32% of progress. The generated energy from biomass in Iran was equal to 150 mboe in 2008. SATBA has reported that the maximum power generation potential for several biomass plants for cities with a population higher than 250 thousand (30 towns) has exceeded 800 MW including 311 MW waste incinerator, 217 MW Pyrolysis gasification plant, 159 MW power plant Anaerobic digestion, and 112 MW of the Landfill plant. Eventually, the various research and

scientific centers in Iran are carrying out numerous projects to utilize and commercialize fuel cells.
Finally, the estimations have shown that the 915 MW nuclear power plant is available.
Potentially, the overall renewable energy projects have significant COE (Cost of Energy). For instance, the costs of a 10-kw biogas plant and 10-kw photovoltaic panel would be 8000$ and 12000$, respectively. On the other hand, considering the barriers of the grid expansion (for rural areas) and frequent black-out in summer peak load, the renewable energy sources can be a reliable solution in Iran.

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