Renewable Energy in Iran

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Despite Iran's diverse potentials in the field of renewable energy, wind energy has a higher priority than other cases in terms of economic justification and market competition, and domestic production rates. Other renewable energy sources for power generation and grid connection are less of a priority for short- or medium-term investment. However, for non-grid use in the country, they can also be very useful in the short term. In general, Iran can be a hub for renewable energy.

wind Iran renewable energy

1. Background, Potential, and Rationale for Renewable Energy Development

Iran, a developing country with a population of 80 million, is the second-largest oil producer in OPEC and the second-largest producer of natural gas in the world [1]. Iran is also the first holder of coal reserves in West Asia and North Africa. On the other hand, geographical diversity has enriched the country with significant renewable resources, including solar, wind, geothermal, and hydropower. Thus that the region with the most sunlight in Dina (Shahdad, Kerman province), the highest annual wind distribution in the world (Mirjaveh, Sistan, and Baluchestan province), the most powerful hydrothermal geothermal resources in the world (Meshkinshahr, Ardabil province) and the second-largest water resources, is a region of West Asia (Khuzestan province).

On the other hand, the demand for energy in this country has been growing rapidly. In recent years, environmental concerns and other energy issues have prompted the Iranian government to make efforts to increase energy efficiency and make more use of renewable energy sources.

In theory, it can be assumed that, given the abundance of oil and gas reserves, Iran is able to delay any effort to develop renewable energy [2]. However, environmental impacts play an important role in policymakers' decisions, and the continuous increase in the use of fossil fuels in Iran has had a detrimental effect on health and the environment. The total environmental damage caused by environmental pollution (mainly including PM_{10}, SO_x, NO_x, and CO) in 2006 was estimated at $4.7 billion or 5.7% of normal GDP [3].

According to forecasts made in the field of energy, with the continuation of the current trend, in 2029, this amount will reach twice the current level. Iran is one of the 20 greenhouse gas-producing countries that produce a total of 75% of the world's total greenhouse gases [3]. For other countries, another influential factor in the development of renewable energy is the rising costs and declining access to oil reserves. Currently, the renewable energy development plan is in accordance with **Table 1**, which is not as much as the projected global values of the country's potential, and this indicates that there are probably obstacles and challenges facing this industry in the country.

Table 1. Development in the field of renewable energy until 2027 [4].

Capacity (MW)	Technology
1600	Wind energy
130	Biomass energy
100	Geothermal energy
90	Fuel cell
40	Photovoltaic energy
40	Solar thermal energy
2000	Total

2. Renewable Energy in Iran: Status and Potentials

Basically, renewable energy technologies in Iran are related to grid-connected power generation technologies [5]. These technologies include offshore wind farms, medium and small hydropower plants, geothermal power, concentrated solar heat power, solar photovoltaics, and landfill gas (biomass energy). The following is a closer look at the potentials of various types of renewable energy in the country.

Briefly, more than three billion people live in rural areas of low- and middle-income countries. In most cases, rural households have high needs for energy, including cooking, lighting, heating, transportation, and telecommunications. The main purpose of Karami et al.'s research was to implement a conceptual model using renewable energy in rural areas of Iran [6]. After determining the calculated values based on meteorological station data, IDW interpolation method was used in GIS software for the entire geographical area of the province. After surveying several areas and identifying potential classes, a village with sufficient potential for solar and wind energy (Kahkesh village) was selected, and then a field survey was conducted based on biomass resources. The needs of rural residents and the potential of rural renewable energy were examined by studying conceptual frameworks over a year. By dividing the energy value of the frameworks, the amount of energy savings can be calculated. Iran's energy consumption basket is shown in **Figure 1**.

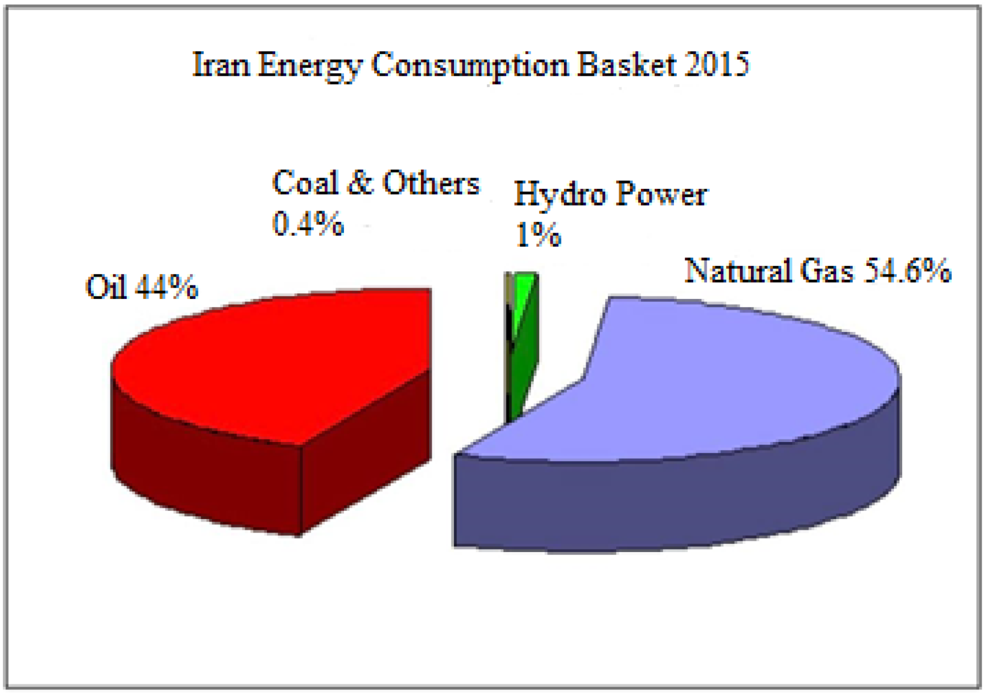

Figure 1. Iran Energy Consumption Basket 2015 [7].

2.1. Solar

Sunlight per day in more than two-thirds of the country is about 4.5 to 5.5 kWh/cubic meter. There are currently more than 2900 h, and, in some places, more than 3200 h of sunshine throughout the year in the country. The number of cloudy days behind the country throughout the country is less than five days a year, and the transparency of air in most parts of Iran is considered more than 60%. It is natural that using solar energy to supply hot water for consumption in Iran will be cost-effective [8].

Iran is one of the most talented regions for the construction of concentrated solar power plants in the Middle East, with an average direct radiation average of 5.5 kWh per square meter per day and about 300 bright sunny days per year [9].

The central and southern regions of Iran, such as the provinces of Yazd, Fars, Isfahan, and Kerman, with average daily direct radiation between 5.5 to 6.5 kWh per square meter per day, have high solar radiation.

In addition, Shiraz (the capital of Persia) is the best region in Iran to exploit the solar potential and establish centralized solar power plants [10]. The performance of centralized solar power plants, including parabolic systems and solar towers in the climatic conditions of southwestern Iran, has been technically and economically analyzed. The dry cooling place for concentrated solar power plants in the south-central regions of Iran has no justification due to its minor effects on technical and economic performance and due to the lack of water in such areas. The wet cooling system increases the annual water consumption by about 14 times but improves the technical and economic performance of the power plants by less than 4% and 5%, respectively.

Solar tower power plants have an annual power generation and a higher capacity factor and lower power level costs compared to parabolic power plants. Therefore, a 100-megawatt dry-cooling solar tower with 14 h of thermal energy storage and solar multiplier 3 is recommended as the most efficient option for exploiting the solar potential in the south-central regions of Iran [11].

With the aim of evaluating the technical, economic, and environmental dimensions of parabolic catchment plants and solar towers in the climatic conditions of southwestern Iran with an average of natural direct radiation of about 6 kWh per square meter per day. Based on the results, the optimal settings for the studied power plants are determined in relation to the economic-technical parameters. The 100-megawatt dry-cooled solar power plant, 14 h storage system, and 3.0 solar multiplier have been found to be among the most efficient settings in the weather conditions under investigation. For this concentrated solar power plant, the cost-balanced cost of electricity and solar-to-electricity efficiency was 11.3% per kilowatt-hour and 14.7%, respectively. In addition, the energy recovery time is about 15 months, reducing the annual carbon dioxide emissions by 399 kilotons and saving the annual fossil fuel 190 million cubic meters of natural gas [12].

Until today, close to 500 KW of photovoltaic systems have been installed in Iran. More network-independent applications for telecommunication reporting stations, park and tunnel lights, intermediate telephones, border police stations and foresters' stations, solar pumps for agricultural purposes, and rural homes in rural villages. The provinces are Yazd and Semnan. The only grid-connected application that has been installed thus far is a KW30 system in the Taleghan area, about 110 km from Tehran.

However, at present, there is no plan to install and operate a grid-connected photovoltaic system on a practical scale, either to power and amplify the grid, or for peak consumption times. Lack of familiarity of villagers with solar energy systems, costly creation of technical, scientific, and industrial potentials required for the implementation of these projects, instability in the process of current systems in the use of photovoltaic systems, and severe impact. One of the challenges of developing this type of energy is the reduction of allocated budgets.

The existence of 330 sunny days in Kerman is one of the main capacities of using local potentials for energy production in the country, which is being formed these days with government investments and domestic and foreign private sector. Iran is a good country to invest in solar energy, and due to the geographical location of Kerman and the number of sunny days, it has one of the most desirable places to develop solar energy projects. At present, it is possible to generate at least 2500 megawatts of electricity from the sun in Kerman, and with the investment of Afghans in Kerman, electricity can be generated in the province and transferred to the borders.

The 10 MW power plant in Kerman province in the Baft region was built on a 20-hectare land using specialized forces and fully localized equipment by the private sector, and today, 6 July 1998, it was connected to the country's national electricity network. By exploiting the mentioned power plant, the emission of 9598 tons of environmental pollutants will be prevented, and water consumption will be reduced by 3060 cubic meters per year. The 10-megawatt power plant also saves 3.95 million cubic meters of natural gas annually in the country's electricity generation process. Kerman province has the highest absorption of solar energy as one of the most potential provinces in the country, and thus far, 8 MW solar power plants with a total capacity of 48.7 MW have been built and put into operation in this province. In addition, thus far, 926 units of solar power plants with a capacity of 8228 kW have been installed in this province.

2.2. Wind

Iran has abundant wind resources. According to a wind map with the middle scale published in 2016, it is estimated that more than 10,000 MW of electricity generation from the wind farm in Iran. Average wind speed statistics in potential sites of wind farms in Iran the average wind speed situation in cities such as Khaf (Khorasan Razavi) is exceptional. Due to its special geographical location and being located in a low-pressure region compared to the high-pressure regions of the north and northwest, Iran in general in winter and summer in the direction of winds that blow in winter from the Atlantic Ocean and the Mediterranean Sea and Central Asia, which is located in the summer from the Indian Ocean and northwest to Iran. In Iran, 6500 MW wind energy potential has been identified, with such a capacity, 19,900 GWh of electricity can be generated [13]. At present, there is a capacity to produce 660 kW wind turbines in Iran, which has reached the commercial stage. In the perspective of Iran's electricity industry, at the end of the fifth five-year plan of the country's industrial development, the estimated capacity of renewable energy power plants is about 2000 MW, most of which belongs to wind power plants [14].

Some of the windy areas in Iran are difficult to cross, and there are special conditions for some meteorological stations installed, the distance between the towers is high, the challenge of buying parts and equipment from European countries due to the increase in the euro against the rial are the main challenges. They are in the wind power industry in Iran. In addition, other issues such as sanctions against Iran for importing some parts and raw materials are other problems in the development of this energy. Of course, recent cases are improving with the increasing rate of domestic production, which makes the future of this energy brighter.

2.3. Geothermal

Iran has favorable conditions for the formation of geothermal energy fields due to its location in the path of the earthquake belt and young volcanic activity. The existence of hot springs in the country proves this claim. Therefore, geothermal energy is one of the least expensive renewable energy options (in terms of production cost) for Iran. Unlike wind or solar, a geothermal power plant can provide baseload power and stability. Iran's total geothermal potential is estimated at about 500 MW for instantaneous or single-phase steam cycles and up to 10 times higher for dual-cycle systems that require lower reservoir temperatures. However, the share of geothermal energy in the country's energy composition for the next 10–20 years is less than 200 MW. This is almost the estimated potential of Sabalan region located in the northwestern region of Iran, where exploratory drilling studies and resource evaluation studies in this region were completed. Production wells are being drilled for a five-megawatt pilot plant. Exploratory drilling has started in the other three areas of Damavand, Khoy, Mako, and Sahand, and preliminary studies are underway in the other 10 areas.

Problems with opening letters of credit, sanctions on Iran for drilling goods and equipment, as well as weather conditions that in some cases cause delays in work are among the obstacles that face this type of energy.

It is predicted that there are over 200 geothermal regions in Iran, but they are not available in a codified and accurate form. Thus, Iran must move quickly in this area to make up for past delays thus that Iran do not lag behind the countries in the region in this area. Turkey is leading the way in the use of geothermal resources, as well as Saudi Arabia, which, such as Iran, has oil reserves but is considering using this energy and is preparing a geothermal atlas of their country. Recently, 12 geothermal zones were identified in west AzarBayjan.

2.4. Hydropower

Hydropower accounts for 13.8% of the national electricity generation and 4.98% of the total electricity generated in Iran. Hydroelectricity, on the other hand, accounts for about 19% of the total electricity generated in the world. Karun 3 hydropower plant with a capacity of 2280 MW of electricity and annual production of 4170 GWh is the largest hydropower plant in the country. At present, there is about 11.3 GW of hydropower generation capacity in the whole country. From 1387 to 1394, 5 to 13.5 GWh of hydropower energy has been produced in the country. Iran, with an average rainfall equal to one-third of the world average, is one of the arid and semi-arid countries in the world, and in addition, perhaps the most important reason for the establishment of dams in Iran is the inadequate temporal and spatial distribution of rainfall. This means, firstly, that a measure must be taken to store water for the time required for agriculture and drinking, and secondly, that it deviates significantly from the spatial standard of rainfall in the country.

2.5. Biomass

The vast country of Iran is relatively rich in biomass resources. The use of biomass in Iran has traditionally been high before the wide distribution of petroleum products in 1338, but after the mentioned date, its use has decreased. The first digester of methane production in Iran was built in the Niazabad village of Lorestan in 1975. According to the results of the 1996 census, five percent of rural households used biomass resources for heating and cooking, respectively. Recently, a power plant with a nominal capacity of 650 kW has been inaugurated at the site of the old landfill in Mashhad with an initial investment of 15 billion rials. Biogas can be produced from animal waste available in Iran 8668 million cubic meters. Biogas can be produced from the mass of agricultural and forest wastes in Iran is 8.8 million cubic meters. Biogas from anaerobic treatment is about 200 million cubic meters. The biogas that can be produced from large food industries in the country is estimated at 280–80 million cubic meters per year. By exploiting the anaerobic digestion process of perishable waste, a total of 2.7 million cubic meters of biogas can be produced in the country per year. It can be seen that only from the above sources, on average, 9 million cubic meters of biogas can be extracted annually [15].

Lack of encouragement of experts to localize resources and production of technical knowledge and the lack of a clear boundary between the activities of the public and private sectors are the main challenges for the development of biomass energy in Iran.

Hydrogen technology and fuel cell at present, hydrogen production projects are carried out by alkaline electrolysis and hydrogen storage methods, and by building fuel cell systems and connecting this complex to photovoltaic panels, the complete cycle of production, storage, and consumption of clean energy based on hydrogen is carried out. In any case, given that Iran is the second-largest source of gas, the development of this technology in the near future is predictable.

However, there are limited consultants, contractors, and competent supervisors in the field of hydrogen and fuel cell technologies, advanced technologies related to the production process, storage, and consumption of hydrogen, as well as problems arising from international sanctions from obstacles that have slowed the development of this technology.

Given the complex and evolutionary process of renewable energy development, it is essential to have a framework for its governance. Management of the transition to renewable energy can be conceptually divided into two stages, namely systemic analysis and policymaking. The article by Moalemi et al. focused on identifying the different methodological stages in the system analysis stage [16]. These steps provide the necessary input for the second stage of policymaking by gaining a clear understanding of the current situation. In the first step, the boundaries of the transfer process are determined by specifying the unit of analysis and identifying the components and relationships of the system. In the second stage, to have a big picture of the evolution of the system, the dynamics of technology development over time are drawn. In the third stage, by comparing different approaches and choosing the most appropriate method, an approach for analysis and sustainability transfer policy is selected. Finally, all these methodological steps in the Iranian Fuel Cell Technology Development Program are used to demonstrate the practicality of the proposed conceptual framework in a real problem and provide insights for employees.

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