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Review

A Review on Energy and Renewable Energy Policies in Iran

Saeed Solaymani

Department of Economics, Faculty of Administration and Economics, Arak University, Arak 38156879, Iran; s-solaymani@araku.ac.ir or saeedsolaymani@gmail.com; Tel.: +98-8632621000

Abstract: Iran, endowed with abundant renewable and non-renewable energy resources, particularly non-renewable resources, faces challenges such as air pollution, climate change and energy security. As a leading exporter and consumer of fossil fuels, it is also attempting to use renewable energy as part of its energy mix toward energy security and sustainability. Due to its favorable geographic characteristics, Iran has diverse and accessible renewable sources, which provide appropriate substitutes to reduce dependence on fossil fuels. Therefore, this study aims to examine trends in energy demand, policies and development of renewable energies and the causal relationship between renewable and non-renewable energies and economic growth using two methodologies. This study first reviews the current state of energy and energy policies and then employs Granger causality analysis to test the relationships between the variables considered. Results showed that renewable energy technologies currently do not have a significant and adequate role in the energy supply of Iran. To encourage the use of renewable energy, especially in electricity production, fuel diversification policies and development program goals were introduced in the late 2000s and early 2010s. Diversifying energy resources is a key pillar of Iran's new plan. In addition to solar and hydropower, biomass from the municipal waste from large cities and other agricultural products, including fruits, can be used to generate energy and renewable sources. While present policies indicate the incorporation of sustainable energy sources, further efforts are needed to offset the use of fossil fuels. Moreover, the study predicts that with the production capacity of agricultural products in 2018, approximately 4.8 billion liters of bioethanol can be obtained from crop residues and about 526 thousand tons of biodiesel from oilseeds annually. Granger's causality analysis also shows that there is a unidirectional causal relationship between economic growth to renewable and non-renewable energy use. Labor force and gross fixed capital formation cause renewable energy consumption, and nonrenewable energy consumption causes renewable energy consumption.

Keywords: energy demand; renewable energy; biomass; energy policies

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1. Introduction

The close and high relationship between production growth and energy consumption growth in the economy refers to the dependence of the economy on energy [1]. Thus, the economy is not only sensitive to energy supply and price shocks, but any initiative to conserve energy can have an impact on the performance of the economy.

Iran was recognized as a country with significant oil reservoirs in the world when it discovered the first oil well in the Middle East in 1908 at Masjid Solaiman. With the subsequent exploration and extraction of oil reserves, the Iranian economy, like the world economy, has increasingly become dependent on crude oil consumption and export revenue for industrial growth. However, the dependency on oil has declined with time in Iran as well as other countries due to the use of other energy sources, such as natural gas and renewable energies. For example, the share of oil consumption in total final energy demand has declined significantly from 91% in 1980 to 43% in 2018 (Figure 1). This led to increased use of natural gas in the country, from 7% in 1980 to 56% in 2018. While oil consumption has declined and been substituted by natural gas, the share of oil in total consumption is still high and the use of renewable energy resources is low due to low production. The share of renewable energy consumption in total final energy demand declined from 1.5% in 1980 to 0.58% in 2018 (Figure 1). This shows that the country has not paid more attention to the generation of renewable energy sources through investment and providing some stimulations for private investors. One reason is the abundance of oil and gas resources and their low prices compared to their international prices. However, the country needs to achieve the diversity of energy resources and energy security, which are essential steps toward sustainable economic growth and social development. While Iran is endowed with abundant natural resources, it faces insecurity about the challenges of reducing energy resources, protecting the environment and sustainable development. Considering the diversity of climates in different regions and the cultivation of a variety of crops and food products, the country has a substantial potential for diversification of the energy mix, particularly the renewable energy base. In addition to the forests of the north and west of the country, which represent about 7% of the country's area, Iran also has many other products and agricultural wastes that can use to produce biofuel. Within the existing framework of government organizations and institutions, which supervises planting, farming, harvesting and, in some cases, distribution and research and development, efforts to strengthen cooperation and coordination among them will facilitate the transmission and implementation of sustainable development plans.

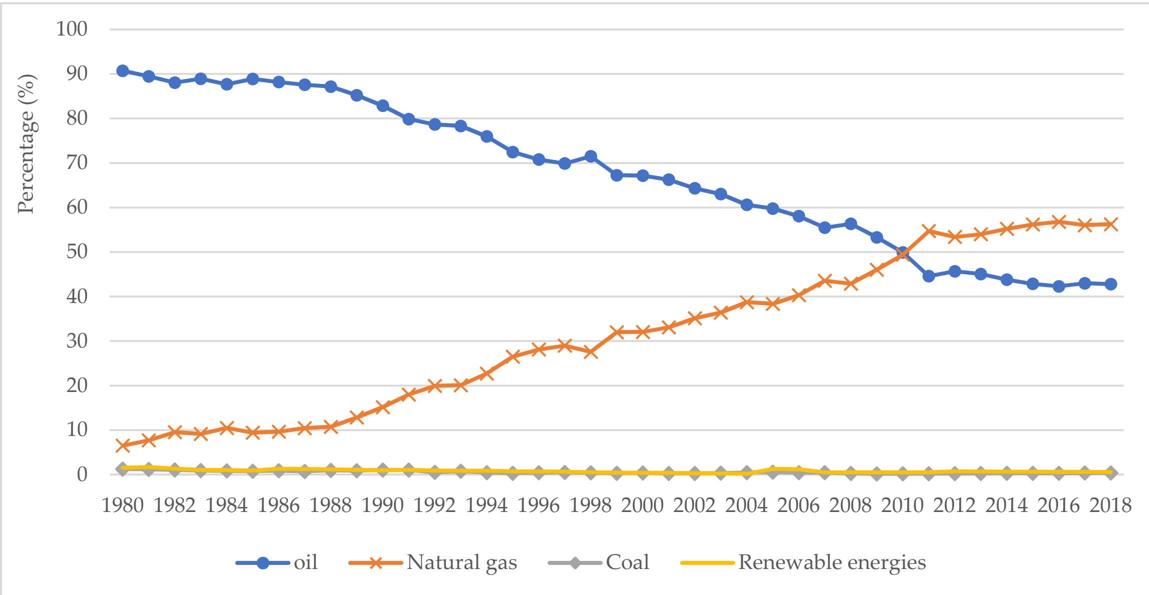

Figure 1. The share of consumption of the various energy sources in total final energy demand in Iran. Source: [2].

To predict the energy mix, which includes all kinds of fossil fuel resources and available renewable options, it is necessary to take into account current and future energy demand and key figures relating to current energy resources. This study aims to review the status and current trends in potential resources and to investigate main policies in Iran to suggest some solutions to help the government to achieve its sustainable energy security goals. These suggestions can simplify the application of sustainable inventions, and formally examines how biomass can contribute to the structure of the energy mix in Iran.

The contribution of this study is that it investigates all kinds of energy sources in Iran which compare to other studies that focus on renewable energy sources or specific energy. Along with reviewing current trends and policies, it estimates the relationship between energy demand and economic growth using an econometric model. Therefore, it makes a significant contribution to the literature as an in-depth study of all kinds of renewable energy sources and their policies since the late 1940s.

The rest of the study is organized as the next section introduces the research methodology. Section 3 provides an overview of Iran's current energy demand and structure. Section 4 discusses Iran's current energy supply situation. Section 5 looks at the current and future state of renewable energy sources and their policies, and Section 6 summarizes the analyses.

2. Research Method

This study uses two methodologies, a review of the current situation of energy and energy policies in Iran and an econometric method. The review method describes the facts and the general energy trends, particularly renewable energy, using the library research method based on Iran's energy statistics. The econometric method uses a Granger causality technique to analyze the relationship between pairs of variables in the model. The data used in this study were collected from a variety of sources, such as the energy balances of the Ministry of Energy, documents and programs of the Plan and Budget Organization and the Research Center of Iran's Parliament.

Econometric Model

In the literature, many studies have investigated the relationship between energy and economic growth. Some studies have focused on the relationship between energy demand and industry growth in Iran, such as Mozayani et al. [3] and Charatin and Goltbar [4]. They found a positive relationship between energy use and the growth in value-added of the industrial and transport sectors.

According to Abdoli and Hammami [5], a 1% increase in energy consumption will increase Iran's economic growth by 0.548%. Furthermore, the simulated projections made by Mirzaei and Bakri [6] show that Iran's total energy consumption will reach 2150 million barrels by 2025; with an annual growth rate of 4.3%, that quantity was equal to 1910 million barrels in 2010. Ghaseminejad et al. [7] also predicted that a 1% increase in energy consumption would lead to a 1.29% increase in long-run agricultural growth. GDP growth also means more purchasing power and higher living standards, and ultimately poverty reduction [8]. This condition leads to increased car ownership and demand for gasoline, natural gas and electricity.

Furthermore, many studies applied the Granger causality technique to investigate the relationship between energy and other variables. For example, Tugcu and Topcu [9] introduced GDP as a function of labor, fiscal capital, energy and other variables and estimated this function by applying some techniques such as Granger causality. Rahman and Velayutham [10] also used this function in causality analysis but separated energy into renewable and nonrenewable sources. Sunde [11] also performed a Granger causality analysis between energy consumption and economic growth for the Southern Africa Development Community. Other studies that have used economic growth as a function of primary inputs and energy in the causality context are Aydin [12], Rahman and Abul Kashem [13] and Akadiri et al. [14].

Therefore, based on the above literature, a Cobb–Douglass production function is considered as a function of primary inputs, labor and capital, and energy, which can be separated into nonrenewable and renewable energy sources.

$$\mathrm{GDP} = f(\mathrm{LF, K, NREN, REN}) \tag{1}$$

where GDP is gross domestic product (IRR billion based on 2010 prices), LF denotes labor force (1000 people), K shows capital which in this study is gross fixed capital formation (GFKF) (USD million based on 2010 prices), NREN is the non-renewable energy (ktoe), and REN denotes renewable energy (ktoe). The natural logarithmic form of Equation (1) is as follows:

$$LGDP_t = (LLF_t,\ LGFKF_t, LNREN_t, LREN_t) \tag{2}$$

All possible pairs of variables in Equation (2) will be estimated based on the following equations, which have the Vector Autoregression (VAR) form.

$$GDP_t = \sum_{i=1}^{p} \propto_i LLF_{t-i} + \sum_{j=1}^{q} \beta_j GDP_{t-j} + \varepsilon_{GDP_t} \tag{3}$$

$$LLF_t = \sum_{i=1}^{p} \gamma_i LLF_{t-i} + \sum_{j=1}^{q} \delta_j GDP_{t-j} + \varepsilon_{LF_t} \tag{4}$$

where p and q are the maximum number of lags that each variable has taken. The reported F statistics are the Wald statistics for the joint hypothesis, i.e., $H_0 : \sum_{i=1}^{p} \propto_i = 0$. Causality methods are very important in energy economics in defining whether energy conservation policies have a negative impact on economic growth or not [15]. Engel and Granger [16] argued that if two variables are cointegrated, there will always be a vector error correction pattern between them. As a result, this type of model can be used to investigate the Granger causality relationship between variables.

3. Current Energy Supply

3.1. General Overview

Many studies have investigated different aspects of the energy system in Iran [17–19]. In terms of energy supply, Figure 2 represents the main component of the primary energy supply of various types of energy used in Iran. Natural gas has remained the largest contributor to Iran's total final energy consumption since 2003, followed by crude oil. Over the past decade, the share of natural gas has increased by 61.9% from 110.8 Mtoe (5 × 109 GJ) in 2008 to 179.3 Mtoe (3.5 × 109 GJ) in 2017. The share of oil and petroleum products decreased by 12.3% from 87.8 Mtoe (3.9 × 109 GJ) in 2008 to 77 Mtoe (3.5 × 109 GJ) in 2017. Interestingly, as a result of the abundance of fossil fuels in the country, the share of renewable energy sources in the same decade increased by 131.9% from 1.17 Mtoe (0.01 × 109 GJ) in 2008 to 2.7 Mtoe (0.12 × 109 GJ) in 2017. This may occur because of rising world crude oil prices, high concerns about the adverse environmental effects of fossil fuels or more use of these resources in remote areas of Iran.

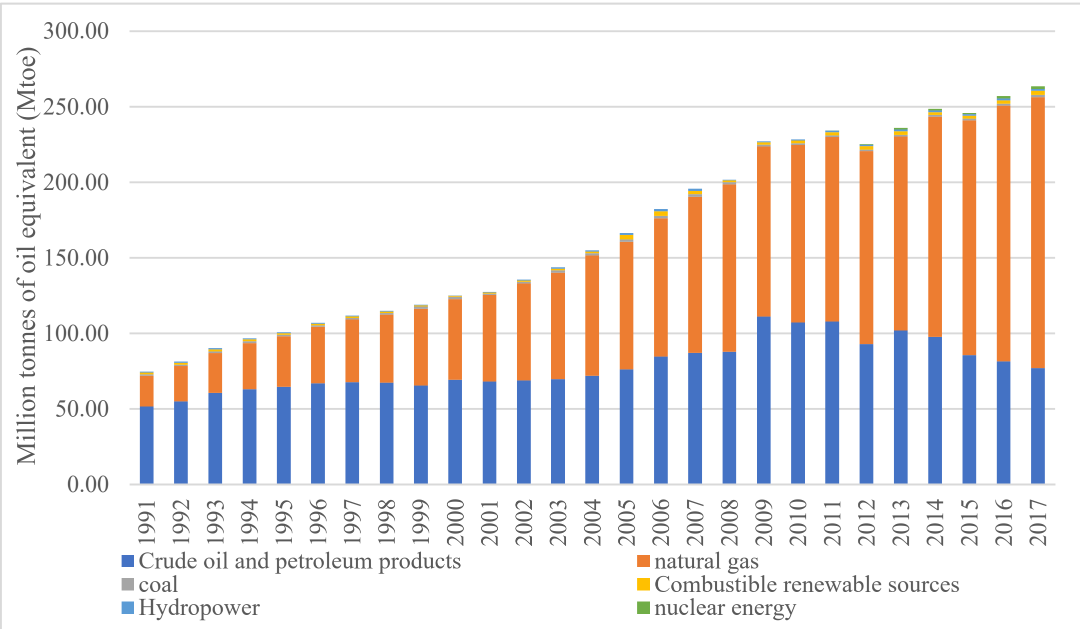

Figure 2. Primary energy supply based on different energy sources in Iran. Source: Ministry of Energy [2].

In spite of various oil and energy laws and regulations, there is still no integrated, comprehensive, purposeful, long-term and coordinated study for the entire country. In this regard, Ghasemi et al. [20] stress the design of a new energy development mechanism, reducing political and economic risks to oil companies, establishing a system for monitoring and evaluating national energy information and the legal mechanism for negotiations, and finally, a specific fiduciary with the ability to pool resources to implement the strategies.

Despite several changes and revisions to energy policies in various documents, there has been a steady trend in economic growth, albeit with some challenges. Real gross domestic product (GDP) (at 2004 constant prices) grew on average by 4.6% from 1991 to 2001 and grew by 6.9% during the 2000s, even though remarkable negative growth rates can be observed in some years of these two decades [21]. In subsequent years, with the exception of negative growth rates in 2012, 2013 and 2015, real GDP growth (based on 2011 constant prices) fluctuated between 4% (in 2011) and 6.6% (in 2016) and in 2017 reached 3.5% [21]. As Figure 3 shows, an increasing trend can be observed in the energy demand of four major energy consumers (residential, public and commercial, industry, transport and agriculture). Total energy consumption in 2017 was about 185.98 million tonnes of oil equivalent (Mtoe; one million tonnes of oil equivalent (Mtoe) = 44.76 GJ (GJ) [2].) (8.3×10^9 GJ), which is the most consumed in industry and transportation [2]. While over the past few decades the transport sector has contributed more to total energy consumption than that of other sectors, the overall increase in the energy demand in recent years occurred with the increase in the share of the industrial sector relative to the other sectors.

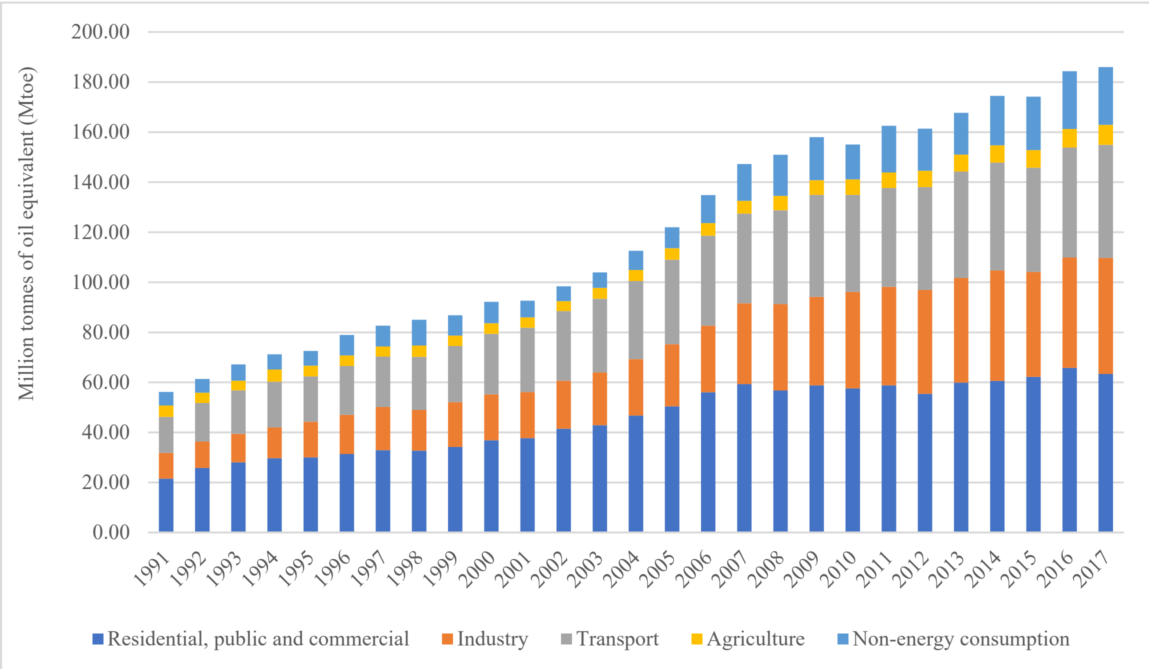

Figure 3. Final energy demand in various economic sectors in Iran. Source: Ministry of Energy [2].

3.2. Crude Oil

As of March 2017, Iran's total reserves of extractable liquid hydrocarbons, including crude oil and gas condensate, were estimated to be 160.1 billion barrels, an increase of 2.9% from the previous year, and the country's natural gas reserves in 2017 were estimated at 33.3 trillion cubic meters, a decrease of 1.2% from the previous year. Besides this, in December 2017, total international oil reserves, including crude oil and gas condensate, were estimated at 1696.6 billion barrels [2].

The Ministry of Petroleum's strategies in the production and supply of crude oil in the horizon of 2041 can be mentioned as follows: (1) increasing the recovery factor for the country's oil fields using over-harvesting and conservation production methods, (2) maximum development and exploitation of all oil and gas fields, (3) the expansion of oil and gas exploration to support the country's oil and gas production, (4) increasing capacity and maintaining the share of oil production in OPEC and the global market and (5) collecting and converting the associated crude oil gases at maximum capacity, taking into account economic and environmental considerations [22]. These strategies will be implemented through national and international investments and partnerships. The goal of the Ministry of Petroleum and the entire energy mix of the country is to continue efforts to increase the country's oil reserves and energy security. Moreover, the efforts of the National Oil Company and the Ministry of Petroleum should be to strengthen its global position in international markets so that it can play an important role in the international arena under appropriate circumstances. With regards to unconventional energy sources, scientific studies show that success in this area requires very close cooperation between national and international companies and the training of the labor force.

Iran's most active oil and gas exploration and production areas are located in the south and west of the country. Most of the discovered fields are in the Zagros and the Persian Gulf regions (southwest of the country). Fields have also been discovered or are being explored in the north of central Iran, the south of the Caspian Sea and Kopedagh. Iran has 20 joint oil fields with neighboring countries, including five with Iraq, four with Saudi Arabia, one with Qatar, one with Oman, seven with the UAE, one with Turkmenistan and one with Kuwait [23]. The country needs the local and international capital and technology to use these enormous oil and gas resources.

The actions taken by the National Iranian Oil Company to supply crude oil to the energy stock market are a big step towards the maximum participation of private investors in the upstream oil and gas industries. The first shipment of Iranian light crude oil was offered in the international energy stock exchange ring in November 2017, and according to the plans, the gradual and regular supply of this valuable shipment of hydrocarbon was provided in the stock exchange [24].

Iran—taking advantage of its geographic location, being among the top oil and gas producers in the region, with the existence of a vast market for energy consumption and long and important transport pipelines that connect the southwest of the county and Persian Gulf (in the south) to the Caspian Sea and neighboring countries in the north, such as Russia and Turkey, and southwest to the east—is becoming an important regional storage and trade center, and can also use existing local resources to reduce its dependency on foreign distillates. The capacity of crude oil, petroleum products and gas condensate storage tanks at refineries across the country at the end of 2017 equaled 18,951, 45,058 and 5147 thousand barrels, respectively.

The country's practical refining capacity is about 1.8 million barrels per day (bbl/d) in the 10 largest refineries. This capacity will increase with the completion of two projects of 0.4 million barrels per day at the Persian Gulf Star in the south and 0.2 million barrels per day in the Kermanshah province. It is projected to increase the capacity of current refineries by 0.5 million barrels per day or to improve the quality of their products in the future [2].

We can conclude that Iran has a significant potential capacity for crude oil and natural gas reserves, its transport and storage. It can increase the weak flexibility of the energy system by constructing more transition lines and braking swap with its neighbors [25]. This makes a significant contribution to the export and transport of crude oil regionally and internationally.

3.3. Natural Gas

As of December 2017, 22 onshore and offshore gas fields were active, including 18 onshore and four offshore gas fields [26]. The natural gas transmission system plays a decisive role in the supply of gas to consumers. The main components of this system are gas transmission lines, gas pressure-raising and reducing facilities and distribution networks [27]. At the end of 2017, more than 38.4 thousand kilometers of gas transmission lines have been constructed and 288 turbochargers are operating in 81 gas pressure boosting stations in the country [28].

Natural gas accounts for the largest share (88.4%) of total fuel consumption in the country's power plants [2]. According to the country's energy policy, efforts have been made to use natural gas in power plants because of ease of operation, lower maintenance costs and less adverse environmental effects [27]. The largest consumer of natural gas is the residential sector (39.1%), followed by industry (24.9%) and petrochemical (21.8%) [26]. The study conducted by Rezaei et al. [29] showed that Iran can become a gas hub in the region if the internal and external facilities and barriers to the advancement of this industry are removed. The South Pars gas field is the largest in the world. It is located at the depth of 3000 m below the bottom of the Persian Gulf is jointly in the territorial waters of Iran and Qatar. The area of this field is 9700 square kilometers, of which 3700 square kilometers are in the territorial waters of Iran and the rest are in the territorial waters of Qatar [28]. The field is mainly developed by local companies. The Iranian share of the field is 14 trillion cubic meters of in situ gas and 18 billion barrels of gas condensate (9 billion barrels of recoverable gas), which represents 50% of Iran's proven natural gas reserves and 8% of the world's gas reserves [26]. One of the goals of the National Iranian Gas Company is to increase the export of natural gas to regional and international markets. In this regard, Iran has been exporting gas to neighboring countries for many years, having enough gas for domestic consumption and export. Turkey, Armenia, Azerbaijan, Nakhchivan and Iraq are the current markets of Iranian gas exports [27]. Iran also imports natural gas from Turkmenistan and Azerbaijan, as well as exports to Turkey, Nakhchivan, Azerbaijan, Armenia and Iraq [2]. The country's natural gas imports in 2017 reached about 3.9 billion cubic meters and its exports reached 13.2 billion cubic meters [28].

This leads us to the conclusion that natural gas is a major contributor to final energy consumption. Natural gas is important as a stabilizer for the energy mixes, which are dominated by renewable energies. Due to the lack of storage possibilities for renewable energy, natural gas, as the least polluting fossil fuel, fills the gaps in the renewable energy supply [30]. The country with high reserves from this source can be one of the world's leading exporters of natural gas. If the country wants to be effective in the international natural gas market, despite the use of advanced technologies and more investment, it must provide clear policies in this industry and try to reduce its barriers at the regional and international levels. Hafezi et al. [31] believe that Iran needs to plan for raising production capacity and considering return project in the short-run.

3.4. Coal

Iran's total definite coal reserves measured by 203 mines in 2017 were 1143 million tons with a majority of coking coal [2]. They are located in Mazandaran, Gilan, Golestan, Kerman, Semnan, Northern Khorasan, Southern Khorasan, Razavi Khorasan, Tehran, Alborz, West Azerbaijan and East Azerbaijan [26]. Isfahan Steel is the largest coal user in Iran, with an annual consumption of one million tons [27]. Other coking and tar refining units also use coal. Despite the relatively large coal resources in Iran, coal mining is unfortunately weak and coal imports are therefore high. This is due to the lack of an appropriate mining strategy, old mining technology, the lack of public sector support to these mines for the equipment and modernization of machines and the use of modern technologies [28]. These challenges have reduced the attractiveness of investment in the mining sector, particularly in coal mines. At the same time, developed countries have defined a clear picture for their mines and, through the adoption of strategic policies, determine the direction of investment and development of mines and mining industries.

Due to the abundance of oil and gas resources in Iran and its general policies, there is no desire to establish and invest in the construction of coal-fired power plants. The only coal-fired power plant project is underway in Tabas and its implementation and operation have begun [2]. For this reason, from an energy perspective, coal has not been more considered in Iran, and the main use of coking coal is attributed only to the Isfahan steel plant, where steel and steel products are produced using the blast furnace method. According to the National Energy Document, diversifying the country's energy portfolio is necessary to achieve the sustainability and development of the country's energy structure. Therefore, coal as an abundant and relatively reliable source with a stable price in the country can play the most important role in achieving this goal.

We can deduce that while the country's oil and gas resources are high, it makes no sense to import coal from other countries with a high inventory of coal resources. Therefore, there is a need to amend the upstream energy documents to include coal sources in these documents in order to develop sustainable and effective policies for this industry.

3.5. Wind Enrgy

Wind energy is produced by generating electrical energy from wind or airflow, which occurs naturally in the earth's atmosphere, with windmills or wind turbines. Wind energy usage in Iran goes back to windmills in 200 BC. Regarding wind energy potential, 1.3% of Iran's land (2.1 million hectares) has an average annual wind speed of 8 m per second and above, which makes these areas capable of exploiting this energy source [32]. According to the Atlas of the Renewable Energy and Energy Efficiency Organization (SATBA), the amount of wind energy that can be extracted in the country is estimated at 18,000 MW in all surveyed areas [33]. Meanwhile, a total of 7801.7 MW represents the nominal capacity of all power plants in the country in 2017. The provinces with strong wind energy potential in the country are Gilan, Southern Khorasan (especially Doruh and Khaf regions), Sistan and Balochistan (especially the northern region of Zabol), Semnan and Qazvin, where most of the country's wind farms have been built so far [26]. Zabol is the most appropriate area for large scale wind turbine establishment [34,35]. The first large-scale wind turbine was installed in 1994 in Manjil, Gilan Province, in two phases with generating capacities of 30 and 60 MW, which were completed in subsequent years [2]. In 2020, the farm capacity reached 92.5 MW [33]. Another windfarm is Binalood in Khorasan Razavi Province, which has a capacity of 28.2 MW [2].

Iran plans to increase the share of non-hydro renewable resources in its total electricity generation capacity to 5% (about 4 GW) by 2021 [33]. Aryanpur et al. [36] argued that Iran should increase the share of non-hydro renewables to 32% by 2050. This will not only make it possible to use alternative gas (or liquefied petroleum gas) in other applications that have higher economic benefits, but also contribute to improved air quality in large cities. Wind energy not only can help Iran's energy security, independence and climate goals in the future, but it can also turn a serious energy supply problem into an opportunity in the form of trade interests, technology research, exports and employment. The future of Iran's economy can be planned based on recognized and predictable electricity costs because that electricity comes from indigenous energy and is free from all the security, political, economic and environmental problems associated with oil and gas. The economic growth and population rise show that energy demand is increasing rapidly in Iran. It is estimated that approximately 10 million watts of energy are continually available in the world's wind [37] while the total installed global capacity was 60.4 GW in 2019, an increase of 19% from 2018 [38]. Razavieh et al. [39] recommended the annual average wind energy density of 388 W m^{-2} is suitable for large-scale wind.

Currently, the Ministry of Energy is offering a 20-year Feed-in-Tariff (FIT) contract for renewable energy at rates higher than the selling price of electricity to end consumers. In other words, for power plants with a capacity of less than 10 MW, the rate for wind energy is IRR 7644 per kilowatt-hour, IRR 8918 per kilowatt-hour for solar and geothermal energy and an average of IRR 6930 per kilowatt-hour for various biomass power plants [32]. In recent years, local and foreign investors have installed approximately 350 MW of renewable energy in Iran through the electricity purchase agreement mechanism, while several other energy farms with a total capacity of approximately 700 MW are in various stages of development [32].

Figure 4 represents the trends of wind energy generation and the capacity of wind power plants in Iran. In recent years, there has been significant growth in wind energy production: 186 GWh in were produced in 2014, 223 GWh in 2015, 250 GWh in 2016, 308 GWh in 2017 and 320 GWh in 2018. However, that is far from what the Ministry of Energy wants to achieve. Achieving an acceptable share of the expected target (4 GW by 2021) requires extensive research and significant operational action, and extensive research has been conducted on various dimensions of wind energy in Iran.

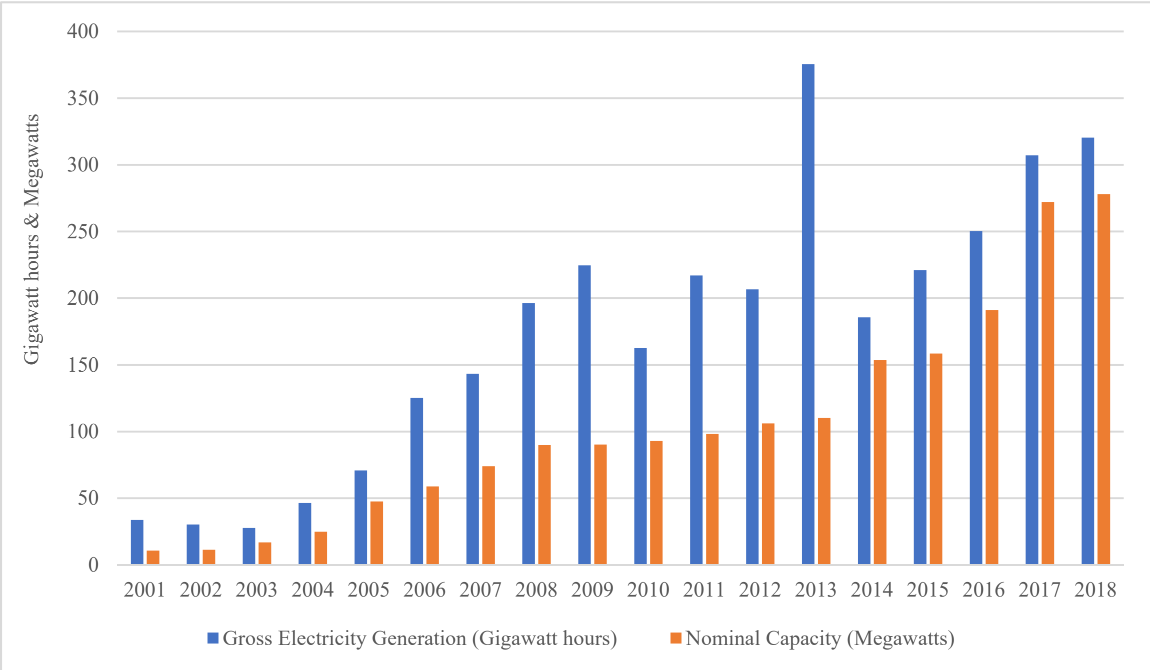

Figure 4. Electricity generation and capacity of wind power plants from 2009 to 2010 in Iran. Source: [26].

We can conclude that Iran's electricity capacity is high and this can help to increase the share of wind energy in the total primary supply of energy. To achieve long-term electricity targets, it is necessary to provide incentives to private investors and to put in place clear and stable policies. The country's electricity demand is growing rapidly due to economic and population growth. Therefore, Iran must make an important decision for the future of the country's environment and electricity generation, particularly through the use of renewable energy resources.

3.6. Hydroelectric Energy

With average rainfall one-third of the global average, Iran is one of the top arid and semi-arid countries in the world [2]. Accordingly, the inadequate temporal and spatial distribution of rainfall is perhaps the most important reason to build dams in Iran. For this reason, hydropower cannot be considered a reliable and sustainable source of electricity generation in the country—but hydropower plants play an effective role in controlling the frequency of the grid.

Hydroelectric facilities in Iran are more than centers for producing renewable energy. Hydroelectric dams also play an important role in socio-economic development, such as irrigating agricultural fields, providing adequate water supply, especially during drought seasons, controlling the situation during the monsoon period and the improvement of major waterways. Currently, electricity is the only renewable energy that is commercially available on a large scale in Iran. The hydropower resources and potential are estimated at 26,000 MW, most of which is provided by the Karun, Karkheh and Dez rivers [40].

Hydroelectricity accounts for about 98.8% of total renewable energy in the country [27]. As of 2017, a total of 15,329.1 GWh of hydropower was generated, which has a share of 5% of total electricity generated and 0.30% of the total energy supply in the country, while on the global scale, hydropower contributes 16.6% of the total energy produced [28]. Table 1 shows total electricity generation and its share of total energy supply in Iran and selected countries and regions in 2016. As can be seen, Iran derives a small portion of its electricity from hydropower compared to other countries and regions.

Table 1. Total electricity and hydropower generation and share of hydropower in different countries and regions in 2016 (TWh).

Country/Region	Total Generation	Hydropower	Share (%)
Iran	308.3	15.4	5
Turkey	274.4	67.2	24.5
Pakistan	114	36.6	32.1
Europe	4941.5	823.1	16.7
Asia	9796.9	1587.9	16.2
Middle East	1147.2	21.2	1.9
United States of America	4322	292.1	6.8
World	25,082	4170	16.6

Source: [26].

The amount of electricity production by hydropower is not stable and depends on the amount of annual rainfall. Therefore, it is used only to help the system in peak times. Since Iran is a country with an abundance of fossil fuels, the choice of the type of power plant seems to be based only on the primary investment and the availability of its primary inputs, which is pointed out in some studies. For example, based on various indicators, Manzoor and Rahimi [41] showed that Iran's priorities for construction and investment in electricity generation and power plants in the future include, in order, wind energy, hydropower, photovoltaic energy, combined-cycle power plants, nuclear power plants and thermal power plants.

4. Renewable Energy Sources

The Ministry of Energy, as the governing body, is responsible for all issues related to electricity and renewable energies, such as developing, planning, organizing, legislating and implementing policies and initiatives related to renewable energy. Although the Office of New Energy was established in previous years before 1995 in the Ministry of Energy, Iran's New Energy Organization was established in 1995, and in 2000 it was officially supervised by the Ministry of Energy to reduce the harmful effects of fossil fuel used on the environment and the diversity of the country's energy sources for sustainable development. However, in 2016, the Renewable Energy and Energy Efficiency Organization was formed by integrating the New Energies Organization and the Energy Efficiency Organization. As a result of the process of structural change that took place in 2000, green technology was added to the ministry's energy portfolio to reflect the growing emphasis on sustainability and renewable energy options. As discussed earlier and summarized in Table 2, a shift towards renewable energy is essential to meet increased demand while maintaining environmental and energy security. Moreover, rural areas have used low levels of renewable energy [42]. International sanctions, emphasis on the development of conventional energies, lack of adequate government policies on the development of renewable energy and the lack of sustainable energy security and environmental policies are impediments to the development of renewable energy [43].

Table 2. Potential of various types of renewable energy sources in Iran.

Renewable Energy	Potential (MW)
Hydropower	26,000
Solar energy	86,198.2
Wind energy	18,000
Biomass and biogas	19.04
Geothermal energy	187

Source: [2].

4.1. Energy Diversity Policy and Other Energy Policies

Because of its diverse environment and climate, Iran is can obtain energy from a variety of renewable sources. Unfortunately, policies and measures associated with renewable energy sources have been neglected due to more government attention on fossil energy fuels because of their abundance as sources of revenue and given high past investments. As well, there was no specific program for renewable energy resources in the country's policy documents until the late 1990s. According to Pirasteh et al. [44], due to the low price of energy from fossil sources in Iran, managers, civil servants, craftspeople and consumers have little interest in the use of renewable energy sources.

Iran's general policy, which was introduced in 2000, is the first document concerning these types of energies. In this document, two of the twelve articles address the issue of renewable energy sources [45]. These two articles emphasize the diversity of the country's energy resources with regards to environmental issues, trying to increase the share of renewable energy with the priority of hydroelectricity and attempting to acquire technology and technical knowledge of new energies and power plants such as wind and solar, fuel cells and geothermal energy in the country [45]. In the law of the Fifth Five-Year Economic Development Plan (2011–2015), only the replacement of fossil fuels and renewable energies with firewood is sufficient and no achievable goal has been considered for it. The first document that highlighted the achievement of a specific target for renewable energy is the law of the Sixth Five-Year Economic Development Plan (2017–2021). It obliges the government to increase the share of renewable and clean power plants with the priority of nongovernmental investment (domestic and foreign investors) with the maximum use of domestic capacity to reach at least 5% of the country's electricity capacity by the end of the implementation of the program law.

In 2011, the Energy Model Reform Act was endorsed. Chapter 10 and Articles 61 and 62 of this act outline the use and investment in renewable energy and nuclear energy. Under this law, the Ministry of Energy is required to support the expansion of the use of renewable energy sources, including wind, solar, geothermal, small-scale hydropower plants (up to ten megawatts), marine and biomass (including agricultural and forest wastes, municipal waste and wastewater, industrial waste, livestock waste, biogas and biomass). To facilitate and consolidate these issues, it can do so through the relevant organization to make a long-run contract for guaranteeing the purchase of non-governmental renewable electricity producers. The Ministries of Energy and Petroleum are also obliged to publicly announce the necessary supports for promoting the economical use of renewable energy sources in separated systems from the grid, such as solar water heaters, solar baths, air pumps, wind turbines, photovoltaic systems, gas extraction from biomass sources and cost efficiency in supply and distribution of fossil fuels publicly announces the necessary support. Accordingly, the Ministry of Energy has a plan to increase the production capacity of hydropower and renewable power plants by 5% by 2021. Under this plan, a small-scale renewable energy program has been launched to encourage the private sector to invest in small-scale power generation projects using biomass, biogas, mini-hydroelectric, solar and wind energy.

The impact of renewable energy policies and electricity efficiency in recent years has resulted in the construction of 134 power plants and 4038 generators for consumers [26]. This has resulted in the generation of 5035 million kWh electricity, the reduction of 468 million kWh in losses in the electricity network and 3417 thousand tons of CO_2 emissions (which itself reduces the external effects of reducing CO_2 emissions), and the non-emission of 21.3 thousand tons of other local pollutants [27]. Improving energy structure and energy efficiency in Iran can significantly reduce the level of CO_2 emissions [46]. It also saves 1108 million liters of water consumption, creates 31,271 jobs and attracts IRR 143.5 trillion of nongovernmental investments [33]. Meanwhile, SATBA has 78 power plants and 1000 generators for subscribers under construction. Figure 5 shows the share of renewable energy capacity and electrical energy efficiency up to July 2020. The construction of these power plants will not only create jobs and generate revenue for renewable energy businesses but will also increase tax revenues for the government [33].

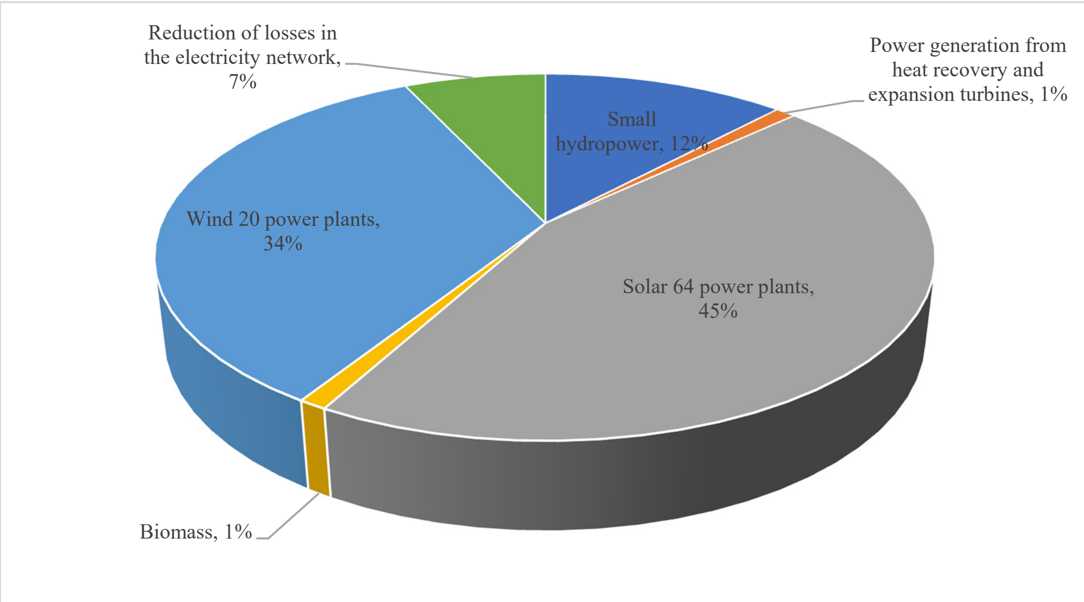

Figure 5. Share of renewable energy capacity and electrical energy efficiency in Iran. Source: [32].

Potential sources of renewable energy in Iran are summarized in Table 2. In high-rainfall and mountainous regions of Iran, large rivers' adequate water levels promote the development of hydropower plants. Moreover, the high share of desert and arid areas, which provides more than 300 sunny days per year, makes solar energy a suitable option as an important source of renewable energy. Furthermore, the existence of large biomass resources in Iran can be used to produce electricity and fuel. Although Iran ratified the Kyoto Protocol and the Paris Agreement, the government should seek to create clean and sustainable fuels to not only guarantee energy security independence but also to maximize available natural resources. Evidence has predicted energy independence in Iran by using non-fossil fuels. For example, Aghahosseini et al. [47] showed that an energy system based on 100% renewable resources is not a dream but is a safe and low-cost option up to 2030.

High energy losses and efforts to address this gap (for example, the use of sunlight in buildings) have overshadowed the use of renewable energy. Waste reduction and the use of renewable energy sources can lead to significant increases in energy efficiency across the country's sectors. Relatively cheap fuel prices and low private and public investment in renewable energy production are the main factors behind the low share of renewable energy in the total energy mix of the country. The National Renewable Energy Policy can be introduced as an important step in increasing the investment and extraction of renewable energy in the total energy mix. Furthermore, to increase the use of local renewable energy sources, increasing the share of renewable energy in the composition of electricity generation can be achieved through facilitating the growth of the renewable industry, ensuring the reasonable cost of renewable energy production and creating public awareness of the importance of sustainable energy and clean technology.

4.2. Small-Scale Hydropower

Small-scale hydropower plants have received considerable attention in recent years, particularly in Iran's water-rich regions, because of relatively low capital and maintenance costs. These types of dams also reduce the environmental effects of clearing land and forests to build a reservoir of large dams. The construction of small hydropower plants is suggested in mountain areas, because of the high costs of medium-sized electricity transmission lines, long distances between villages and high energy losses. These kinds of dams have been considered because of providing cost-effectiveness benefits, no environmental pollution, long life, fast and easy installation and non-use of fossil fuels [48].

A small-scale hydroelectric dam can be defined as a facility that generates up to 10 megawatts of electricity. In 2020, about 14 small-scale hydropower plants in 10 provinces of the country with a total generating capacity of 261 MW began to operate. Most of these projects are located in the northern regions and the water-rich slopes of the Zagros, including the provinces of Gilan, Mazandaran, Lorestan, Kohkiluyeh and Boyer-Ahmad. Haji Ghafouri Bukani [49] believes that including hydropower programs in the country's energy development programs will lead to economic prosperity in villages, increase industrial and commercial activities in villages and prevent villagers from migrating to cities. This is consistent with the results of the study conducted by Sovacool and Walter [50]. The reason for this is the highly suitable zones for the construction of such power plants and their economic and social characteristics. Therefore, to reduce the use of fossil energy sources, it is suggested to use of this type of power plant in water-rich areas.

4.3. Solar Energy

Iran is a rich country in solar energy. The country's priority for renewable energy sources is solar energy, averaging 300 sunny days per year [51]. The average daily sunlight in Iran is about 5.5 to 8.5 kWh per square meter, particularly in the central regions [19,52]. The technical potential for solar thermal energy is estimated to be 91,000 TWh [53]. July, August and September are the months with the highest solar radiation of 1050 h, and January, February and March have the lowest solar radiation of 500 h [52]. The installed capacity of cumulative renewable energy sources is projected to be 2.8 GW by 2030. This represents an investment of more than USD 2.8 trillion from 2010 to 2030 [52].

The central, southern, eastern and southeastern parts of Iran, such as the provinces of Yazd, Kerman, South Khorasan, Zahedan and Kerman, have high solar radiation throughout the year. Cities in the north of the country present the greatest potential for investment in photovoltaic energy [54].

Photovoltaic (PV) systems similar to small hydroelectric power stations can meet needs with off-grid power supply systems (electricity supply for residential houses, nomadic tents, rural cottages) and generally meet the electrical needs of areas without a national electricity grid. As a result of the very high cost of mass production of electricity from photovoltaic systems, commercial supply is not yet possible. Currently, the majority of photovoltaic users are high-income groups, representing a very small percentage of the total population. Furthermore, to encourage the private sector collaboration to invest in photovoltaic systems, the government announced incentives and preferential prices in 2015 and guaranteed the purchase of renewable electricity produced. The adoption of these policies brought the private sector's contribution to electricity production from 8.71 MW in 2015 to 300.86 MW in 2018 [33]. Solar energy has numerous applications such as cooking and drying food, air conditioning and refrigeration, space heating and water heating, and industrial applications, i.e., solar thermal energy generation [55,56].

The localizing of the production of photovoltaic systems, which in turn lowers end-user prices, raising public awareness of the use of renewable energies (for traditional and industrial applications) and government incentives can all help reduce the use of fossil fuels. Gorjian et al. [57] and Edalati et al. [58] state that technology, weather conditions for photovoltaic installation, government policies and the lack of a specific roadmap are the most significant barriers in the development of PV systems in Iran.

4.4. Biomass

Biomass is defined as all plant resources and plant residues and human biological activities capable of generating energy. Wood, human waste, sawdust, animal waste, food waste and wastewater are utilized for biomass. The process of converting biomass and other renewable resources into energy is called biotechnology [59]. This energy is mostly used for cooking, heating, lighting and electricity production. The focus of the National Renewable Energy Policy is to emphasize the importance of transitioning to renewable energy sources that have the least impact on the environment. In these conditions, biomass has become a very attractive and practical option. Municipal waste that has remained from previous years is the largest source of biomass in Iran (Table 3).

Table 3. Biomass power plants in operation in 2018.

Type of Power Plant	Province	Year of Operation	Capacity (MW)
Extraction of methane gas and construction of biogas power plant to generate electricity from municipal waste	Razavi Khorasan	2009	0.6
	Fars	2009	1.06
	Tehran	2014	1.9
	Tehran	2010	4
	Tehran	2014	3
Total			10.56

Source: [32].

The German DLR (Deutsches Zentrum für Luft- und Raumfahrt) center in 2002 estimated Iran's biomass energy potential at about 3500 MW by 2050 [60]. Moreover, the potential to generate electricity from municipal waste in Iran's provinces is predicted in Table 4. Since electricity generation from waste is a costly method, the government guaranteed to buy the electricity generated by these power plants at a reasonable price to encourage investment in this field.

Table 4. Biomass energy potential in the selected provinces in 2018.

City	Ardabil	East Azerbaijan	West Azerbaijan	Fars	North Khorasan	Razavi Khorasan	South Khorasan	Gilan	Sistan and Baluchestan	Kerman	Bushehr	Hormozgan	Total Potential (Theory)	Total Economic Potential with 10% Capacity
No. of sites	4	8	5	6	2	8	4	5	4	4	1	5		
Production (MW)	10	25	15	30	1	65	2	15	10	1	3	25	208	20

Source: [29].

Due to climatic diversity and water availability in most agricultural regions, over 80% of agricultural products are agronomic products and the rest are horticultural products. Major agricultural products in Iran include wheat (13.26%), corn (10.83%), sugarcane (6.66%), beets (6.37%) and Lucerne (6.18%) from 16.5 million hectares of cultivated land (14.7 million hectares of arable land and 1.8 million hectares of garden lands, i.e., 8.78% of the total land area of Iran) [61]. The amount of waste produced from the agricultural products will be around 24 million tons per year, taking into account the average of 30% of the waste for these crops. Given that an average of 450 cubic meters of biogas waste is produced per ton [62]. About 10,800 million cubic meters of biogas from these wastes will be produced, which is a huge source for use in simultaneous heat and power (CHP) plants. The findings from Samadi et al. [63] showed that the total energy obtained from agricultural waste using degassing technology was 341,290 Terajoules (TJ) and the amounts of electricity and heat generated by this energy were 66,075 and 399,112 Terajoules (TJ), respectively.

Finally, one of the proposed projects for the effective use of renewable energies is wind–solar power plants, which provide higher wind energy during the wind season and higher solar energy during the solar season [64]. The production of valuable gas for clean thermal and electrical energy, along with many other benefits, encourages energy policymakers to consider the construction of biomass power plants as a necessity in energy supply policies. The Renewable Energy and Energy Efficiency Organization of Iran (SATBA) plan is focusing on the participation of small and medium-sized companies to develop innovation, knowledge and business activities to create a sustainable production system in the high-value industry. In this regard, the government has a significant role to promote accessibility, affordability and sustainability of energy security by preparing appropriate renewable energy development [65]. Therefore, using a waste stream should also include food processing waste or post-harvest agricultural residues such as fruits.

4.5. Biofuels

Biofuels are types of renewable energies derived from organic matter (living matter or biomaterials) and, in fact, their energy content is from biomass, which can be found in the form of liquids (bioethanol and biodiesel), solids (dry plant material) and gases (biogas). Biofuels, such as biodiesel and bioethanol, can be used in motor vehicles due to their high energy content and compatibility with fuel infrastructure, and therefore, are more important [66]. The diversity of Iran's land and climate causes the production of various energy sources suitable for the production of liquid biofuels. The current bioethanol sources in Iran are sugarcane molasses and sugar beet which are easily available [67]. The use of biofuels in Iran is relatively low. South Khorasan is the best place for biogas establishment [68]. Although efforts have been made to include renewable energy sources in electricity generation, renewable fuel transportation has not been given any priority because of higher transportation fuel demand than electricity generation and high fuel subsidies to the market. It is worthy to note that the removal of energy subsidies can decline energy consumption, which in turn decreases CO_2 emissions in the country [69].

Having the potential to use different types of biomass as raw materials can be very attractive for investment and the government can use various conversion methods to fit the needs and resources that existed in each region. Despite the progress in advanced biofuel conversion techniques and the high potential of using different biomass due to their abundance, currently, there is no large-scale or even small-scale production of any type of biofuel in Iran. Therefore, we reviewed studies that have examined the potential of producing various biofuels in the country.

Abyaz et al. [66] analyzed the use of lignocellulosic materials and suggested that the amount of bagasse produced in seven units of the sugarcane and ancillary industries development plan of Khuzestan during a year is equal to 231 million tons; this amount of bagasse can produce 57,750 million liters of bioethanol annually. Hajinejad and Katooli [65] also showed that the use of Nowruzak in the edible oil extraction industry is possible and its residues can be used directly in the biofuels industry with an average oil content of 56%. Nowruzak has the potential to produce 3348.8 L per hectare of biodiesel. Ghobadian [70] also believes that there are about 17.86 million tons of agricultural residues in Iran, of which about 5 billion liters of bioethanol can be produced annually. According to the estimated amount of various biomass sources reported in Figure 6, such as vegetable oils (i.e., palm, jatropha, castor, cellulose, algae), the production of bioethanol in Iran, which can be an optimal alternative fuel for gasoline engines using alcoholic gasoline, in various ratios can be predicted until 2026.

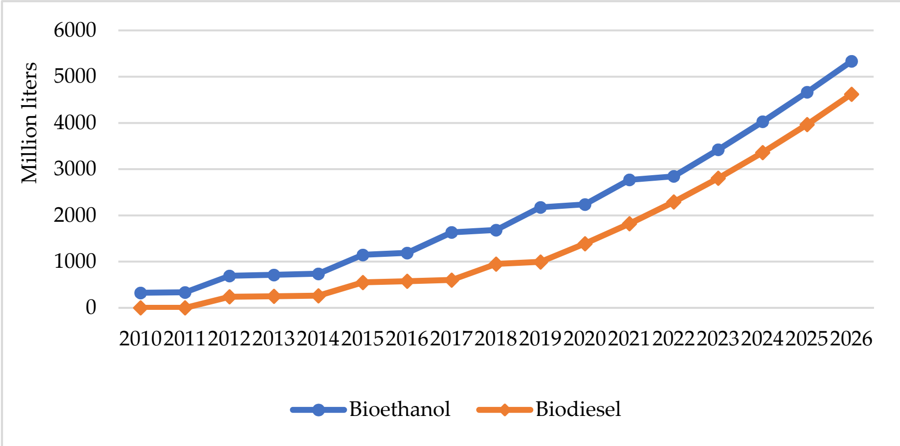

Figure 6. Prospects for liquid biofuels share in Iranian transport. Source: [70].

According to Table 5, it is predicted that Iran's potential in 2018 to produce bioethanol from grain residues, sugar beet molasses and sugarcane as well as some fruits such as apples, grapes and dates is about 4.827 billion liters per year.

Table 5. Biomass energy potential (ethanol) of agricultural residues in Iran in 2018.

	Production (Million Tons)	Waste (%) *	Waste (Million Tons)	Conversion Factor (Liters per Ton) *	Total Bioethanol (Billion Liters)
Wheat	13	50	6.5	400	2.6
Sugarcane molasses	0.3	100	0.3	300	0.09
Rice	3	25	0.75	400	0.3
Barley	3	20	0.6	350	0.21
Corn	10	30	3	360	1.08
Potatoes	5	30	1.5	110	0.165
Dates	1.3	40	0.52	360	0.1872
Beet molasses	0.25	100	0.25	300	0.075
Grapes	3	30	0.9	70	0.063
Apple	2.9	30	0.87	65	0.0566
Total	42.75		15.49		4.827

* The waste percentage and conversion factor is taken from [70].

Moreover, based on the calculated made in Table 6, it is predicted that Iran's potential in 2018 to produce biodiesel from oilseeds residues, such as cotton, soybean, rapeseed, sesame and corn, is about 526 thousand tons per year.

Table 6. Production potential of biodiesel from the major edible oilseeds in Iran in 2018.

Oilseeds	Area under Cultivation (Hectares)	Production (Tons)	Oil Content (%) *	Returns (Tons of Biodiesel per Year)
Cotton	70,800	165,295	20	33,059
Soy	40,327	83,303	20	16,660.6
Rapeseed	191,251	329,843	40	131,937.2
Sesame	30,017	30,649	50	15,324.5
Corn	126,971	946,021	10	94,602.1
Olive	90,000	102,648	20	20,529.6
Sunflower	10,756	11,960	50	5980
Safflower	5239	4470	32	1430.4
Almond	200,000	142,000	55	78,100
Walnut	166,000	200,000	60	120,000
Hazelnut	27,000	15,000	55	8250
Total	958,361	2,031,189	—	525,873.4

* The oil content is obtained from [71].

Sepaskhah [72] believes that the use of fodder and sugar and starch products to produce biogas due to the lack of organic matter in Iranian soils and the lack of water and fodder is unreasonable. It is worthy to note that the country must not use agricultural products for the production of bio-energies while it needs food and organic matter. If there is agricultural waste, the first priority is its use to strengthen the organic matter of Iranian soils. These residues can be collected and their contained energy can be extracted with conventional and advanced technologies. Moreover, fossil fuels are finite and their consumption harms the environment and countries must concentrate their long-run policies and efforts on using more renewable, clean and sustainable energy sources. In addition to these cases, as Rashidikia and Moradi [73] stated that these resources provide many national advantages, such as (1) increasing job opportunities in rural areas, which reduces the migration of indigenous people to cities and other regions, (2) increasing the public health of rural communities and (3) providing new investment opportunities for indigenous people.

Finally, it can be concluded that although world oil prices are uncertain and fluctuate widely over time, the fact that Iran is heavily subsidizing all types of energies for public consumption leads to the introduction of biofuels with a slightly higher cost in the household energy basket mix, which would be a viable option to reduce government subsidies. In the case of sufficient production and availability of biofuels in the country, the use of biofuels in cities requires the obligation and acceptance by the consumer. Thus, it is necessary to increases public awareness to use renewable energies.

4.6. Geothermal

The Meshkinshahr area was introduced as the first priority for geothermal exploratory studies and the first geothermal wells were drilled in this area in 2004 [74]. The capacity of the project is 25 MW [2]. Since the only investor is the government in this field, it is necessary to provide some incentives for private investors. The hot underground water temperature of 85 °C is accessible in geothermal areas [75]. The geothermal heating system is used in food production, at the tourist center, for district heating, at greenhouses and at fish farms [75,76]. The main geothermal development barriers are lack of legislation, poor human resources management and improper technology transfer [77].

5. Econometric Results

This section presents the estimated results of the econometric model. To reduce the number of tables in the main text, we provided a descriptive statistics table and a stationary table in Appendix A. The unit root results show that we cannot reject the null hypothesis of unit roots for all variables in the model; the variables are stationary after difference 1 and they are integrated in order 1, I(1).

Another test is co-integration analysis; in this study, we used the Johansen test. The cointegration results show that the model has one cointegrating vector (Table 7). Therefore, we can conclude that a cointegration relationship exists among variables.

Table 8 reports the results for the Granger causality analysis. The results fail to reject the null hypothesis that economic growth does not Granger-cause labor force and gross fixed capital formation, but rejects it that economic growth Granger-causes non-renewable energy and renewable energy. This means that there is unidirectional causality from economic growth to renewable and non-renewable energy and its inverse is not correct. These findings are consistent with the findings of the study conducted by Khoshnevis and Shakouri [78]. Moreover, Li and Solaymani [79] argued that economic growth is the main contributor to energy consumption in Malaysia in the short- and long-run. Razmi et al. [80] also showed that renewable energy consumption cannot Granger-cause economic growth in Iran. The results also cannot reject the null hypothesis that labor force does not Granger-cause gross fixed capital formation and non-renewable energy, but rejects that labor force Granger-causes economic growth and renewable energy. This means that there exists a one-way causality from labor force to real GDP and from labor force to renewable energy, which their inverses are not correct. This finding supports the results of the study conducted by Salmanzadeh and Fatemi [81]. Regarding the variable gross fixed capital formation, we cannot reject the null hypothesis that gross fixed capital formation does not Granger-cause real GDP, labor force and non-renewable energy, but it can be rejected that gross fixed capital formation Granger-causes renewable energy. The null hypothesis fails to reject when testing Granger causality from non-renewable energy to real GDP, labor force and gross fixed capital formation, but does not reject runs from non-renewable energy to renewable energy. This means that a unidirectional causality exists between non-renewable energy and renewable energy. Finally, the null hypothesis of no renewable energy Granger-causes real GDP, labor force, gross fixed capital formation and non-renewable energy cannot be rejected.

Table 7. Johansen co-integration test.

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob. ****
None *	0.501697	78.37974	69.81889	0.0088
At most 1	0.300879	43.5524	47.85613	0.1197
At most 2	0.257474	25.65581	29.79707	0.1393
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob. ****
None *	0.501697	34.82734	33.87687	0.0384
At most 1	0.300879	17.8966	27.58434	0.5038
At most 2	0.257474	14.88488	21.13162	0.297

Source: estimated results. * shows rejection of null hypothesis at 5% level. ** Mackinnon-Haung-Michelis *p*-value.

Table 8. Results of the Granger causality test.

Null Hypothesis	**F-Stat. [Prob.]**	**Null Hypothesis**	**F-Stat. [Prob.]**
LGDP → LLF	0.563 [0.573]	LNREN → LLF	1.517 [0.230]
LLF → LGDP	2.448 [0.097] ***	LLF → LNREN	1.313 [0.279]
LGFKF → LGDP	0.286 [0.753]	LREN → LLF	0.909 [0.410]
LGDP → LGFKF	1.303 [0.282]	LLF → LREN	5.649 [0.007] *
LNREN → LGDP	1.893 [0.162]	LNREN → LGFKF	0.773 [0.468]
LGDP → LNREN	2.664 [0.081] ***	LGFKF → LNREN	0.588 [0.560]
LREN → LGDP	0.183 [0.834]	LREN → LGFKF	1.213 [0.307]
LGDP → LREN	3.692 [0.033] **	LGFKF → LREN	3.829 [0.029] **
LGFKF → LLF	0.416 [0.662]	LREN → LNREN	0.597 [0.555]
LLF → LGFKF	0.816 [0.448]	LNREN → LREN	3.664 [0.034] **

*, **, *** denotes significant level at 1%, 5% and 10%, respectively. Source: estimated results.

6. Conclusions

This study, using a review methodology, investigated current and future energy demands and existing renewable energy resource policies in Iran by employing the latest available data from the Ministry of Energy, Ministry of Petroleum and national laws and documents. Then, using Granger causality analysis, it estimated the direction of relationships among considered variables.

The econometric results showed that there exists a unidirectional causality relationship between economic growth and renewable and renewable energy demand. This means that economic growth helps the development of renewable and non-renewable energy consumptions, but other sides are not correct. Labor force and gross fixed capital formation do not Granger-cause non-renewable energy demand, but they cause renewable energy demand. Finally, renewable energy demand does not Granger-cause non-renewable energy demand, while non-renewable energy demand Granger-causes renewable energy demand.

The study's analyses showed that Iran can access sustainable, clean and renewable energy sources. It is logical that fossil fuels have better and more valuable applications than heating and lighting. Therefore, Iran has acceptable and compelling incentives to pursue renewable and sustainable options, although it remains a leading exporter of crude oil and is exploring and developing new oil fields. The annual cost of subsidies for energy commodities for public consumption in 2009 was about IRR 442 thousand billion. High fuel prices harm food prices and other macroeconomic indices, and the government should look for better options to reduce public discontent. Although international agreements and environmental policies, such as the Kyoto and Paris agreements, emphasize reducing CO_2 emissions and Iran is a party to some of these agreements, there is still a commitment to reducing CO_2 emissions and preparing Iran's infrastructure for clean energy use. The overall outlook for the future of renewable energies seems unclear, at least regarding the effectiveness of government policies. Although some policies seem to be of particular benefit to some people (for example, the use of solar panels in remote rural areas), the overall prospects of these policies have been minimal. At present, renewable energy technologies do not play an important and appropriate role in Iran's energy supply. This also has been experienced in another high energy resources country, i.e., Saudi Arabia [82]. The main barriers to renewable energy development in Iran include the absence of suitable and effective government policies, international sanctions and low public awareness.

The current Iran development plan (Sixth Economic, Social and Cultural Development Plan, 2017–2021) aims to increase the share of renewable energy sources in the electricity generation mix to 5%. However, the evidence and data from the Renewable Energy and Energy Efficiency Organization indicate a severe lag in the goal of this program. With a closer look at the energy mix, the decision to make greater use of fossil fuels, especially natural gas, when it is less environmentally friendly seems to contradict the goal of reducing greenhouse gas emissions, as well as weakening energy security by relying on fossil resources. The development of renewable energy sources under the guidelines of the current Iranian program can be considered a step in the right direction, albeit a more active position needs to be taken to develop potential renewable energies, such as biomass. Implementation of biomass exploitation techniques under the current framework can be facilitated in relevant government organizations such as SATBA, the Niroo Research Institute, large city municipalities and the Agricultural Research, Education and Extension Organization. A country with many fossil fuel resources needs appropriate policies and guidelines for the future of renewable energy development and reduced international barriers to the use of advanced technologies and the experiences of other countries in the use of renewable energies. At the local level, it needs to use crude oil export revenues to make a significant investment in various and high potential renewable energies for the future without fossil energy resources. It is also necessary to reduce energy subsidies, raise public awareness and offer substantial and suitable incentives to motivate private investors. Salam and Khan [83] also showed that increasing public awareness through media is crucial for renewable energy development in Saudi Arabia. The use of the wind–solar hybrid plant is also suggested to generate both energies more effectively than single power plants. The hybrid renewable energy system is also suggested by Mohammed [84] for Iraq and by Marchenko and Solomin [85] for Russia.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A

Table A1. Descriptive statistics.

	LGDP (IRR Billion)	LLF (1000 People)	LGFKF (USD Million)	LNREN (ktoe)	LREN (ktoe)
Mean	15.09776	9.492841	10.74469	10.78031	7.042203
Median	15.02835	9.493683	10.88931	10.95113	6.900351
Maximum	15.75293	10.0981	11.84446	12.04142	8.356657
Minimum	14.19673	8.824737	9.019639	8.690626	6.365443
Std. Dev.	0.392414	0.41071	0.739127	0.97287	0.525495

Source: estimated results.

Table A2. Results for the Unit root test.

Variable	Dickey Fuller GLS		Phillips–Perron		Augmented Dickey Fuller	
	Level	First Difference	Level	First Difference	Level	First Difference
LGDP	0.104	−5.098 *	−0.558	−5.098 *	−0.743	−5.071 *
LLF	0.430	−2.433 **	0.759	−4.497 *	0.170	−2.601 ***
LGFKF	0.987	−6.103 *	−0.044	−6.012 *	0.110	−6.054 *
LNREN	0.849	−2.451 *	2.456	−5.496 *	3.006	−2.686 ***
LREN	-0.467	−6.194 *	0.020	−5.151 *	−0.473	−6.174 *

*, **, *** denotes the level of significant at 1%, 5% and 10%, respectively. Source: estimated results.

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