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# On the Way of Policy Making to Reduce the Reliance of Fossil Fuels: Case Study of Iran

**Morteza Aien [1,*] and Omid Mahdavi [2]**

[1] Department of Engineering, Vali-e- Asr University of Rafsanjan, Kerman 93630, Iran
[2] Department of Energy Engineering, Sharif University of Technology, Tehran 11155, Iran; omidmhdv@gmail.com
* Correspondence: aien@vru.ac.ir

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**Abstract:** Nowadays, fossil fuels are well known as a predominant source of energy in the planet. Located in the Middle East region, Iran holds one of the largest fossil fuel reservoirs in the world. The country has abundant oil and natural gas fields in various regions; some of them are shared between other countries and have not reached their operational capacity yet. Meanwhile, during recent years and due to global warming followed by environmental global contracts such as Kyoto protocol, using fossil fuels is being criticized to a large extent around the world. Therefore, the global interest has been focused toward clean energy resources. Furthermore, endowed with sundry geographical pattern throughout its land, Iran has adequate renewable energy potentials. So, there will be a serious paradox affecting its whole energy policy: more exploration and extraction of conventional fossil fuels or take advantage of renewable and sustainable energy resources? In this paper, energy structure of Iran is generally overviewed, followed by study of renewable energy potentials in various parts of the country. Afterwards, policy making in renewable energy market, systems, and applicable strategies are elaborated. Furthermore, a number of barriers obstructing the development path of renewable energy schemes and initiatives are presented and discussed in detail.

**Keywords:** energy challenge; energy planning; energy policy; renewable energy potential

## 1. Introduction

Currently, fossil fuels fulfill a predominant portion of required energy for the human society. However, devastating impacts due to their utilization such as global warming, environmental pollution, and rise in sea levels are generally well-understood. As energy and environment issues are getting more and more attention, clean energy resources such as renewable energies (REs) have been getting more attractive. However, the REs are inherently intermittent resources and their utilization development needs mid-term and long-term programs. So, this paper intends to investigate this subject in Iran. In the literature, renewable energy systems are discussed and reviewed. In this paper, a comprehensive overview of REs in Iran is carried out and various aspects including technology, policymaking, resources, and potentials are elaborated in different locations of the country. A SWOT (strength-weakness-opportunities-threats) analysis is also accomplished and obstacles in the way of investment and effective solution to overcome them and develop REs are scrutinized. In fact, an all-embracing reference has formed for REs assessment.

### 1.1. Iran Energy System and Structure

Iran is located in the Middle East and has borders with Persian gulf and gulf of Oman to the south, Turkmenistan, Azerbaijan, and Armenia, along with the Caspian sea to the north, Turkey and Iraq to the west, and Pakistan and Afghanistan to the east [1]. With the population over 80 million and area of

1,648,195 km$^2$, the country ranks 18th and 17th in the world, respectively, and 2nd among Middle East countries [2]. Its population is continuously and rapidly increasing and the rate of urban population is obviously greater than that of rural areas [3].

Most of the land areas are classified as arid and semi-arid, with the average temperature of 19 to 38° in summer, 10 to 25° in winter, and average annual rain precipitation of 228 mm [4]. Yet, Iran enjoys a variety of climate conditions. In the north and west part of the country, there exist "Alborz" and "Zagros" mountain ranges, the former stretching from northeast to northwest and the latter stretching from northwest to southwest. Except for northern and southern coastal areas, which experience high humidity, precipitation and humidity reduce from north to south, and from west to east as well [5]. Figure 1 illustrates the topographic map of Iran, including mountains, seas, forests, and so on.

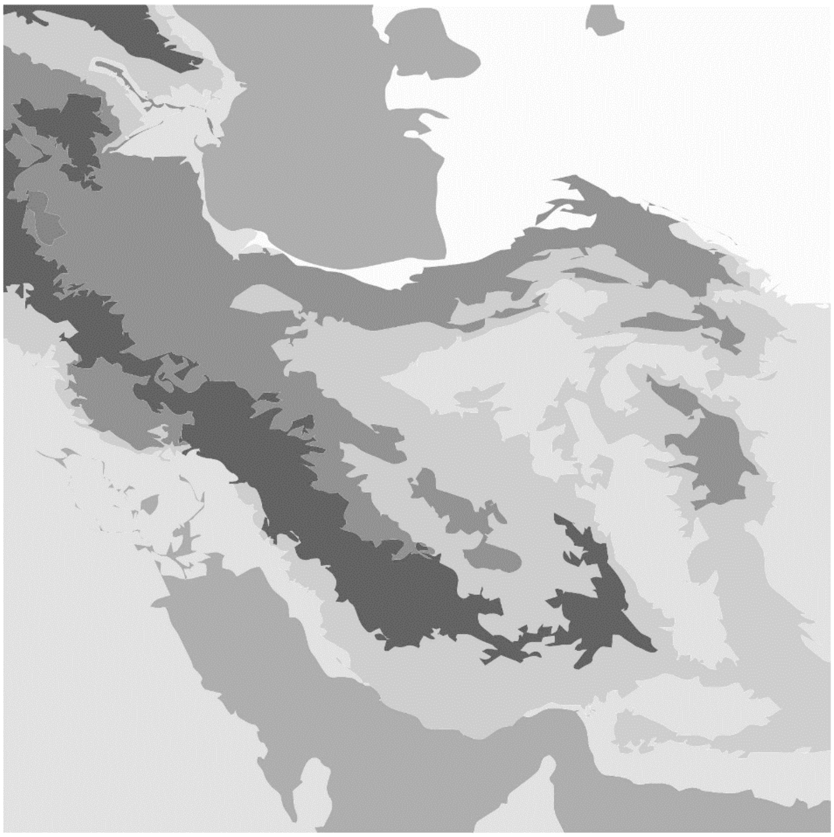

**Figure 1.** Topographic map of Iran (created by CorelDraw).

The Middle East region and especially Iran benefits from a huge amount of fossil fuel reserves, which makes it one of the wealthiest countries in the world [6]. Today, there exist 22 offshore and 12 onshore crude oil fields in Iran, while onshore fields include 71% of the whole oil reserves [7]. The country has 10.5% of total global crude oil reserves. Number of offshore, onshore, and shared oil fields with neighboring countries are 62, 16, and 18 respectively, totaling 96 fields. South Pars natural gas field, recognized as one of the largest gas fields in the Earth, is shared between Iran and Qatar and contains 325 trillion cubic feet (Tcf) natural gas (equivalent to 27% of proved natural gas fields in Iran) and 33% of total gas production. While Qatar has invested enormously on its side of the field (south side), Iran's side has remained underdeveloped, mainly due to strict sanctions imposed on its energy and economic sector [7]. According to OPEC (Organization of the Petroleum Exporting Countries), annual statistical bulletin published in 2017, Iran's proven oil reserves are estimated as 157.2 billion barrels, equivalent to about 13% of reserves held by OPEC [8]. With a production over 4.7 million barrels per day, which accounts for 5% of worldwide oil production, Iran is regarded as the second largest producer of crude oil among all countries in this organization [9]. However, in recent years, this amount has fallen remarkably [10]. This country is also endowed with rich and plentiful natural gas fields with total proven capacity of 812 trillion $m^3$, making it the second gas-rich country in the world after Russia [11]. The country's natural gas production per day had approached 7.2 trillion $m^3$ in 2017 [10]. In Figures 2 and 3, largest holders of proved crude oil (in billion barrels) and natural gas (in trillion cubic feet) reservoirs by country in 2017 are depicted, respectively. Iran also has considerable amount of coal resources. In 2014, the total estimated reserve of recoverable coal was reported as 1203 million tons [12].

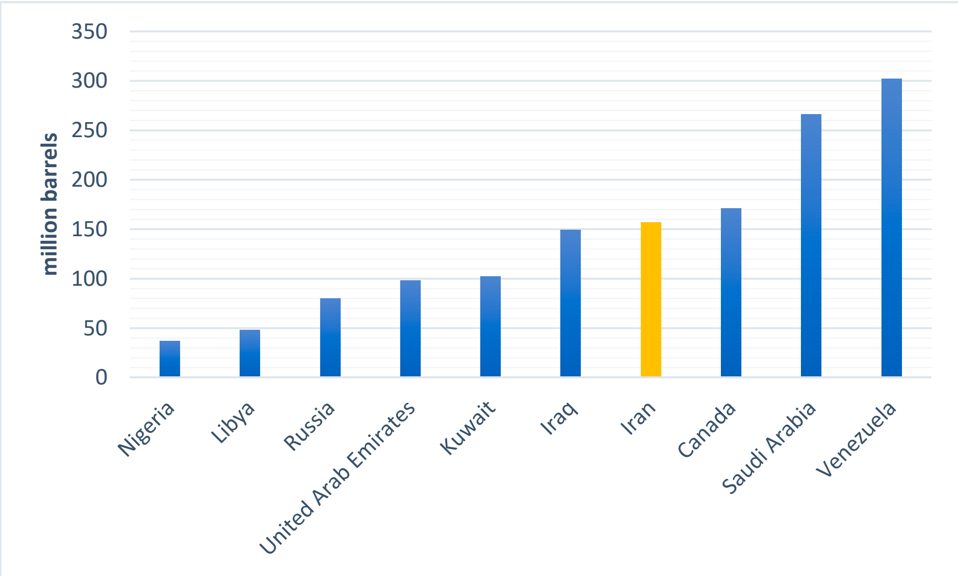


**Figure 2.** Largest holders of proved crude oil reservoirs by country (billion barrels) in 2017 [10].

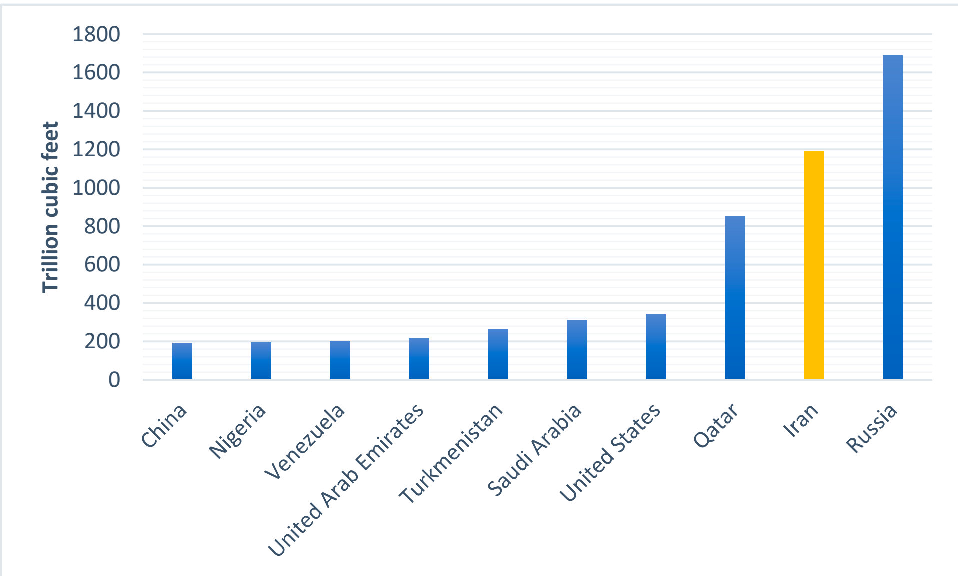


**Figure 3.** Largest holders of proved natural gas reservoirs by country (trillion cubic feet) in 2017 [10].

Currently, non-renewable energy sources including crude oil, natural gas, and coal contribute to 99% of Iran's energy pattern [13]. It is worthwhile to mention that a lifetime of 94 years has been estimated for crude oil reserves in Iran [14]. This developing country had a total energy consumption equivalent to 1318 million barrels of oil in 2015 [15]. Total cost for energy consumption in Iran had reached $157 billion in 2020 [16]. Figure 4 demonstrates Iran's total final energy consumption in 2015 by sector [17]. Moreover, Iran undergoes negative environmental impacts and massive greenhouse gas emissions. Due to high potential for renewable energies, replacing the fossil fuel energy systems with green sources has been in great notice by Iran's energy society [14]. According to last updated data, renewable energy contributes to less than 8% of the overall electricity generation capacity in the country and owing to the accessible potential, it is predicted to reach approximately 38% in 2030 [10,18]. Capacity of electricity production from various energy sources in 2016 is shown in Figure 5 [10].

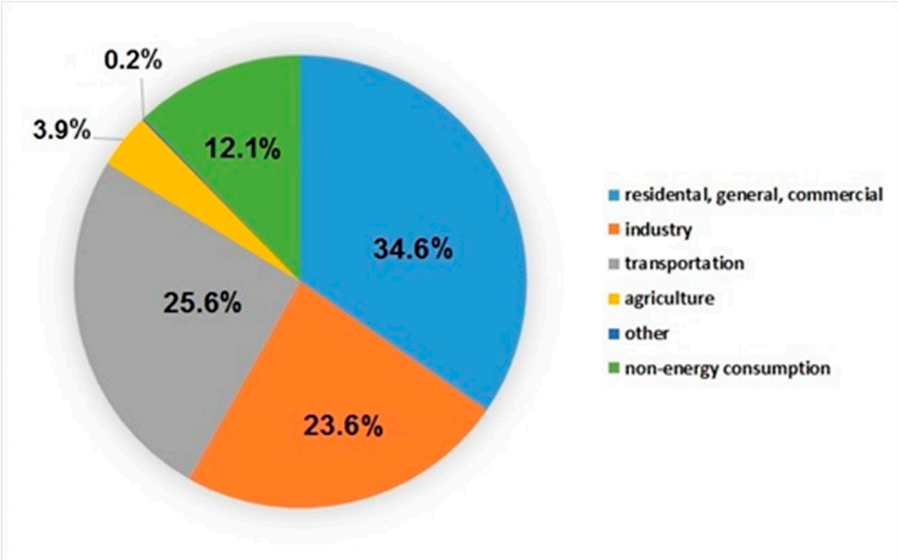


**Figure 4.** Percentage of total final energy consumption by sector [17].

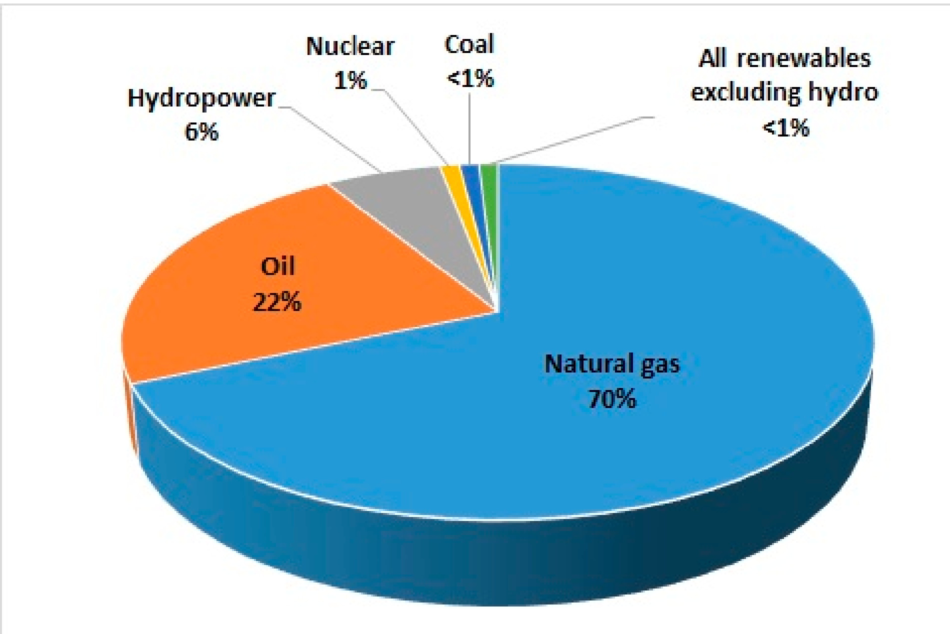


**Figure 5.** Electricity generation capacity of Iran by fuel in 2016 [10].

Thanks to particular geographical conditions of this country, various potentials for different renewable energy utilization are available. Considering air pressure gradient between northwestern and north of the country and the rest, probability of having strong winds in various months of the year is quite high. In summer, eastern winds of the Indian Ocean and western winds of Atlantic Ocean are responsible for well-known 120 days winds of Sistan and Balouchestan province. In the winter, air pressure variations in Atlantic ocean and Mediterranean sea from western side of the country and also, central Asia from the eastern side are the main causes of cold wind flows in the north [3,19,20].

In addition, solar energy has a great potential in Iran in comparison with global status. According to scientific researches done all over the country, the solar energy is probably the most widely suitable RE energy for exploitation in Iran. Average daily solar radiation intensity in Iran has been reported as 19.23 $MJ/m^2$ [21,22]. However, in warm and dry weather of the central portion, in which a minimum 3200 h annual sun radiation has been recorded, solar radiation has a considerably higher value [6,23]. Average daily solar radiation potential has been reported as 5.4 $kWh/m^2$ and 2.8 $kWh/m^2$ in the south and north part of Iran, respectively [3,11].

On the other hand, variety of climate and terrain conditions of Iran is regarded as the most significant stimulus for cultivation of a wide range of crops for bio-energy applications. About 7% of total lands in Iran are covered with forests [24], which is a suitable source for bio-fuel products such as biodiesel and bio-ethanol. Studies indicate that nearly 30% of lands of the country are cultivable. However, statistics show use of this capacity as low as 12%. Enormous volume of residues are also produced (about 20 million tons annually) which has been mostly burnt [3,25].

Lying on geothermal belt, Iran benefits from a remarkable potential for electricity generation from geothermal energy [26–28]. The extensive heat coming from internal layers of the earth beneath some portions of this country has made 8.8% of its total lands feasible for geothermal energy deployment [29]. As a result, many regions have proven capabilities for geothermal energy utilization. Conducted studies have confirmed the potentials of west and east Azerbaijan, Ardebil, and Tehran provinces so far [30].

There are several natural rivers in Iran, flowing in the northwestern and southeastern sides of the country, as well as northeast side which are appropriate sources for hydropower energy [31]. Indeed, Iran has exploited hydropower more than any other renewable sources. Hydropower energy accounts for 1% of total primary energy consumption in Iran, while other renewable energy systems, along with coal and nuclear systems, supply less than 1% [32]. Regarding abundant water reservoirs and rivers in the country, researches reveal that 3000 spots in Iran could be utilized for installation and employment of micro hydropower stations [18].

Furthermore, marine energy can be considered as one of the available renewable energies in Iran, as the country has 657 km marine border with the Caspian Sea, 784 km with the sea of Oman, and 1259 km with the Persian Gulf [33]. Great potential of Iran's sea for wave energy has been approved as well, taking the Caspian Sea for instance with the maximum and average wave power of 30 kW/m and 14 kW/m [34].

Renewable energy infrastructure and technology in Iran allowed part of this abundant potential to be exploited and REs installed capacity has been grown in recent years. For instance, Figure 6 illustrates the installed capacity of wind and solar energy in Iran from 2010 to 2017 reported by IRENA (International Renewable Energy Agency) [35].

### *1.2. Paper Organization*

The rest of the paper is organized as following. Literature review about renewable energy sources and potentials in each part of Iran as well as current progress in exploitation are scrutinized in Section 2. Wind, solar, geo-thermal, bio-energy, fuel cell, and hydropower are amongst the energies we have focused on. A SWOT analysis is accomplished and advantages, disadvantages, and performance of these energy systems along with current and future challenges and improvements are highlighted. Section 3 reviews the energy and technology market in Iran and policy trend towards more renewable energy utilization. The investment process and insurances are also discussed. Section 4 closes the paper providing some concluding remarks.

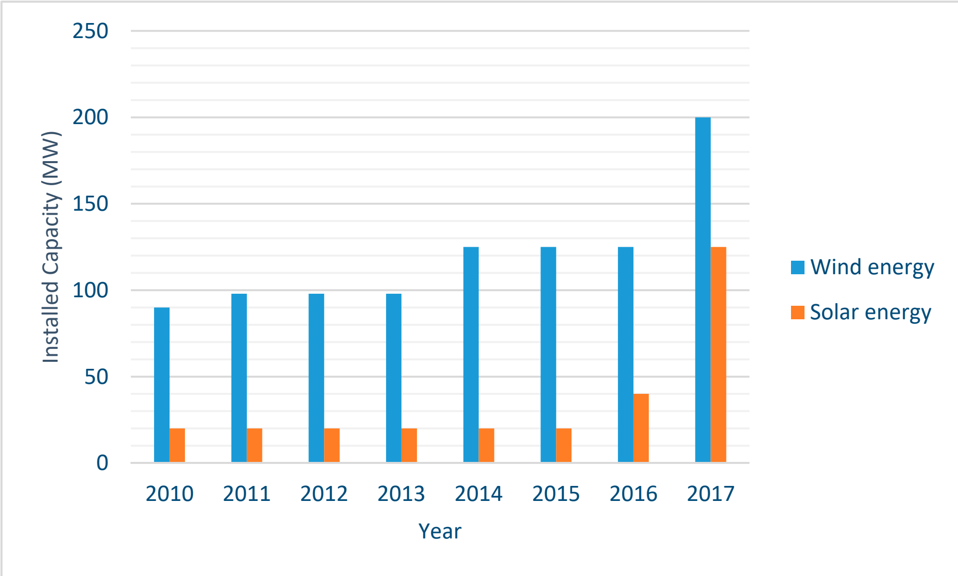


**Figure 6.** Installed capacity of wind and solar energy in Iran recent years [35].

### 1.3. Literature Review

So far, several researches and studies have been carried out regarding renewable energies status, potentials, markets, and applications in Iran which some of them are reviewed here. In terms of social, technological, economic, environmental, and political factors, Tofigh et al. [7] dealt with Iran's energy status and analyzed the various renewable energy potentials in comparison to other countries. The general potential of various green energy sources available in Iran including hydropower, solar, wind, and biomass energies as well as their current situations and to which extent they are being harnessed is reviewed in [3]. Using an hourly resolution model, a 100% renewable sources-dependent program for year 2030 in Iran is envisioned, in which an optimal set of factors comprising least-cost energy supply, renewable energy technologies, mix of capacities, and operational modes are taken into account [36]. Asadi et al. investigated current status, trend, and schemes for renewable energy development in Iran [37]. Assessment of current progress in development of renewable and sustainable energy in Iran with regard to Iran's 4$^{th}$ development plan is carried out in [38]. Nejat et al. also analyzed the growth rate of green energy systems during the Iran's 4th development plan from 2005 to 2010 and substantial evolutions in this field were mentioned. They concluded that in spite of effective policy making, growth of renewable energy systems was suppressed by tremendous fossil fuel reserves in the country and could not fulfill global expectations [14]. With respect to growing energy consumption and progression of renewable energy development, Chaharsoughi et al. proposed four scenarios including fossil fuel, green path, standardization, and subsidies for Iran's energy system in 2025 and compared them with the government's plan to supply 10% of total required electricity in the state via renewable energy in the following 20 years. They showed that standardization and fossil fuel are the most expectable and green path and subsidies are most optimistic and pessimistic scenarios, respectively [39]. Afsharzadeh et al. investigated the situation and importance of renewable energy in rural and national levels, relation between sustainable development of rural regions and renewable energies and the challenges about their application and evolution. It has been deduced that due to numerous advantages such as compensation of insufficient fossil fuel supply, overwhelming accessibility to national power grid in remote areas and related maintenance and transmission costs and converting the energy consumers to energy producers, utilization of renewable energy in the rural level is obviously reasonable. However, they inferred that despite the fact that many rural areas enjoy outstanding potential for renewable energy systems, owing to lack of proper management and socio-cultural infrastructures, their growth has been deferred [18]. Encouragement policies for development of renewable energy in Iran were assessed by Atabi [40]. Effective cooperation between domestic investors and renewable energy companies are stated as optimal strategies in this matter. They introduced an organizational structure assisting the positive collaboration to be established between renewable energy-related entities in developed states and local industries and proposed an applicable platform concerning economic partnership in energy sector and eventually concluded that achieving socio-economic development of renewable energy is possible by making use of proper policy formulas and strategies. Yazdi et al. [41] developed a model to investigate the correlation between economic factors such as economic growth and globalization and renewable energy. The model revealed unequivocally positive effects on economic growth by renewable energy. The present status of energy market in Iran with concentration on fossil fuels and renewable energy as well as available potentials for development of renewable energy were evaluated by Mollahosseini et al. Plans and opportunities for harnessing each kind of energy source were also assessed [28]. They came to the conclusion that planning and technical development of renewable energy should be enriched, while benefits of renewable energies are still in doubt whether these outweigh the deficiencies, as well as environmentally friendliness of bio-fuel. In this context, regarding lack of official governmental reports, which propose a methodical approach, further researches are recommended.

## 2. Renewable Energy Potentials

Due to competitive cost, everlasting availability and harmlessness to the society and environment, renewable energy systems have been widely used and conform a portion of approximately 18% of final energy of the globe [42–44]. In Iran, there exist tremendous potentials for development and exploitation of renewable energy sources and systems. Wind, solar, geothermal, biomass, and wave energy sources are amongst the most widespread renewable sources for sustainable generation of electricity. Accordingly, this section deals with each kind of renewable energy sources and elaborates different aspects of each source.

### *2.1. Wind Energy*

As one of the most promising and reliable sources of energy, air pollution and scarcity of energy resources, especially in large cities, can be addressed by wind energy [45]. In recent years, considerable attention has been drawn to wind energy technology, and various countries have conducted vast researches concerning wind energy utilization [46–49]. Generally, this energy is counted as one of the most economical types of renewable energies for generation of electricity, and its development trend is believed to grow constantly in the future [7,50]. Furthermore, wind energy is considered as a green way to produce electrical energy, as it is estimated that 1 to 2 tons of $CO_2$ can be saved annually by a 2.5 kW wind energy system and 2.5 to 5 tons using a 6 kW system [49]. Statistics show that by 2010, total capacity of 198 GW wind turbine has been installed worldwide [14,51], which ranks this energy as the third highest installed capacity among all renewable energy technologies [42]. Pioneer countries in wind technology are China, US, Germany, and Spain, owning most installed wind turbines in the world until 2010 [20], although Denmark holds the largest wind turbine manufacturers [52,53]. As a result of the geographical and topographical situation of Iran, as well as a steep rise in electricity demand, one of the primary priorities of Iran's government is the development of wind farms throughout the country. Hitherto, there are 15 wind farms in the country and their components are mainly produced locally [54]. Feasibility of manufacturing of small-scale wind turbines (less than 10 kW) has been verified by researches, which are of interest due to their off-grid applications, simple design, and manufacturing technology compared to large-scale turbines. Worthy to mention that Iran enjoys adequate potential of about 6.5 GW for wind power in initial estimations [50], while up to 15 GW increasing potential have been confirmed by further studies [55,56]. In some reports, 100 GW is stated as total potential of the country for installation of wind turbines [56]. However, development of wind power plants in Iran has been below expectations [57]. Average wind power density in Iran has been reported as 275 W/m$^2$, which is considered as an appropriate density for electricity generation [8]. So far, numerous studies have been conducted regarding wind energy potentials in different cities, counties, and regions of Iran such as Tehran and Firoozkuh in Tehran province [58], Zahedan, Chabahar, and Mile-e Nader in Sistan and Balouchestan province [43,59,60], Mahshahr harbor in Khouzestan province [61], Semnan in Semnan province [62], Kish island in Hormozgan province [63], Salafchegan in Qom province [63], Binalood in Khorasan Razavi province [64], Tabriz in east Azerbaijan province [65], Ardebil in Ardebil province [65], Yazd in Yazd province [66], Razineh in Kurdistan province [20], Shahrbabak and Kerman in Kerman province [18,67], and Chalus in Mazandaran province [51]. In Table 1, location, capacity, and construction date of installed wind power plants in different regions are provided.

**Table 1.** Location, capacity, and construction date of installed wind power plants in Iran [68].

| Location | | Construction Date * | Aggregate Capacity Megawatts (MW) |
|---|---|---|---|
| **Province** | **City/Town** | | |
| Ardebil | Sarein | 2012 | 0.66 |
| | Nir | 2014 | 0.66 |
| East Azerbaijan | Aqkand | 2017 | 25 |
| | Sarab | 2014 | 0.66 |
| | Tabriz | 2009 | 1.98 |
| Fars | Shiraz | 2010 | 0.66 |
| Qazvin | Siahpoosh | 2017 | 61.2 |
| | kahak | 2013–2016 | 55 |
| Gilan | Manjil | 1994–2014 | 92.26 |
| Isfahan | Safeh | 2011 | 0.66 |
| Khorasan-e Razavi | Khaf | 2013–2015–2016 | 4.71 |
| | Binalood | 2010 | 28.38 |
| | Neyshaboor | 2015 | 4 |
| Khuzestan | Mahshahr | 2010 | 0.66 |
| Sistan and Balouchestan | Zabol | 2009 | 0.66 |

* For rows with multiple construction dates, either a project is accomplished in multiple phases or multiple projects have been done in the location.

According to recent studies, there are at least 26 regions consisted of 42 sites in Iran which are endowed with proper status and potential for construction of wind power plants [7,69,70]. There are numerous wind energy sites in Iran such as Manjil and Binalood, in Gilan and Khorasan Razavi provinces respectively. The largest number of wind turbines have been installed in Manjil, Gilan province [71]. Although the amount of electricity generated by wind energy is negligible in comparison with other sources of energy, governmental development plans aim to increase its production capacity. These aims have arisen from the obvious fact that Iran has an excellent potential for wind energy. In addition, ministry of energy has made great efforts to promote the wind energy by preparation of wind Atlas of the country utilizing the information gathered from 53 synoptic stations in Iran [29]. Figure 7 illustrates the potential of wind energy in each part of the country. Based on analytical assessment, annual generation of electricity from wind power has experienced an astonishing increase of 27% from 1998 to 2008 [3].

Competitive cost associated with deployment of wind power turbines for electrical energy production (0.04 to 0.07$/kWh) has resulted in remarkable development and technical advancement of wind energy compared to other renewable and even non-renewable energy sources. Moreover, this cost is continuously decreasing and it is projected below 0.04$/kWh in 2020 [72]. Meanwhile, electricity generated by conventional fuels is becoming more uneconomical, so that assuming 0.08$/kWh as environmental expenses, it would cost 0.14$/kWh in 2020 [72]. Similar reasoning can be made for Iran. In Iran, electricity generation price by means of wind turbines is estimated at 4–5 cent/kWh, provided that foreign exchange rate and fuel costs are fixed; while using steam and gas turbines, cost would be 2 and 2.5 cent/kWh. Adding the imposed social expenses arising from production of $CO_2$, $NO_2$, and $SO_2$, the cost would increase to 3 to 4 cent/kWh. A comparison of these costs reveals the profitability of wind energy systems [7,39].

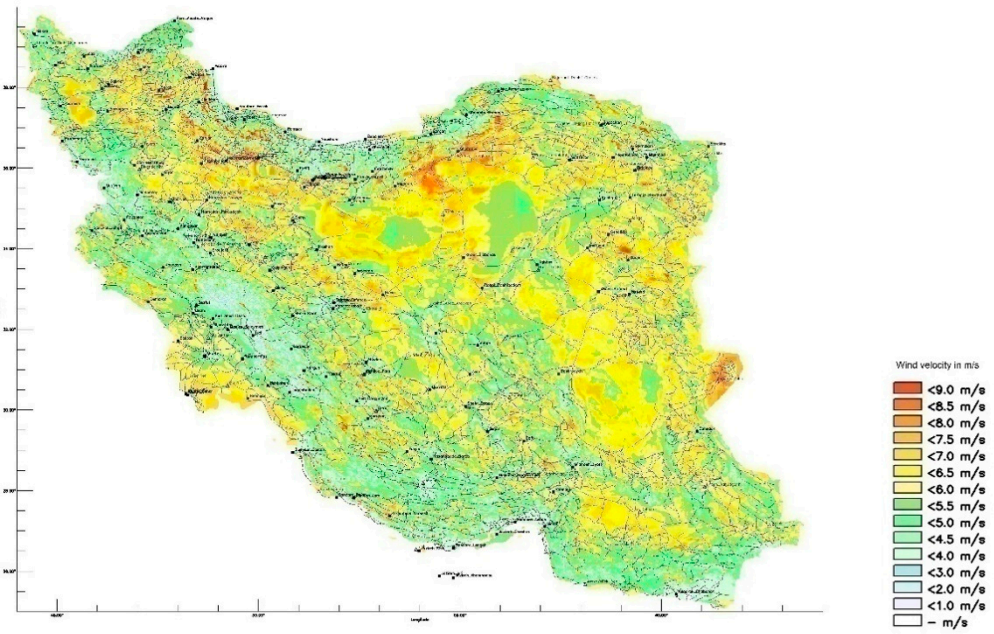


**Figure 7.** Iran's wind energy potential [68].

## 2.2. Solar Energy

Due to playing an important role in reduction of greenhouse gases (GHG) emission and clean electricity generation, and regarding the fact that many other renewable energy sources such as bio, water, and wind depend on solar power, solar energy is of concern for abundant researchers in the world [73]. In this respect, it is noteworthy that approximately 60% of total radiation emitted from the sun arrives at Earth's surface [21]. It can be argued that if solely 0.1% of this energy is converted into electrical energy, considering efficiency of 10% for this conversion, this amount would be four times greater than the total global electricity demand (about 5000 GW) [21]. Solar energy is harvestable in the forms of electricity (Photovoltaic systems) and thermal energy (solar desalination, solar water heaters, solar heating, and cooling, and so on) [74]. Nowadays, solar energy is vastly used in many countries for electrical energy production, as well as thermal energy. It is commonly accepted that fundamental improvement in solar panel efficiency is a contributing factor in the popularity of solar energy systems in the globe. In 2005, global solar market had reached 11.8$ billion which presented a 55% augmentation in total investments in comparison with 2004. In 2006, 2.7 GW solar systems were installed, while the year 2010 saw an astonishing 15 GW installation in total. Furthermore, aggregate PV installation of 1.8 GW has been carried out, whilst in 2011 this amount had stood at 71.1 GW, witnessing a growth rate of 44%. Japan, Germany, UK, China, Spain, and Italy have been dominant harvesters of solar energy for production of electricity by means of PV systems. Total PV installation capacity has been projected to increase from 98 GW in 2012 to 308 GW in 2018 [74]. It has been found that Mediterranean European countries, southwest of US, middle, and near east in Asia, deserts located in India, Iran, Australia, Pakistan, and China are amongst the highly potential regions for solar energy harvesting in the world [74].

According to IEA (International Energy Agency) statistics in 2010, growth rate of solar energy outnumbers other sort of renewable energies in recent years. Among all renewable energies, solar energy has faced the highest growth rate of 43%, followed by wind energy and biogas, with 25.1% and 15.4%, respectively [3]. Technological application of solar energy in Iran has initiated 4 decades ago, while use of this valuable source goes back to ancient eras. There is a considerable increase in solar energy share in Iran's energy mix. In 2014, this country has invested 60$ million in solar energy projects, while this amount has been 12$ million in 2013. Various solar hours in different seasons emphasize adequate solar potential in Iran. Somewhere in the region of 700 h in spring, 1050 h in summer, 830 h in autumn, and 500 h in winter have been recorded as seasonal solar hours in the country. Figure 8 demonstrates the solar energy potential throughout the country. As implied before, regardless of adequate solar potential, this source has been exploited marginally.

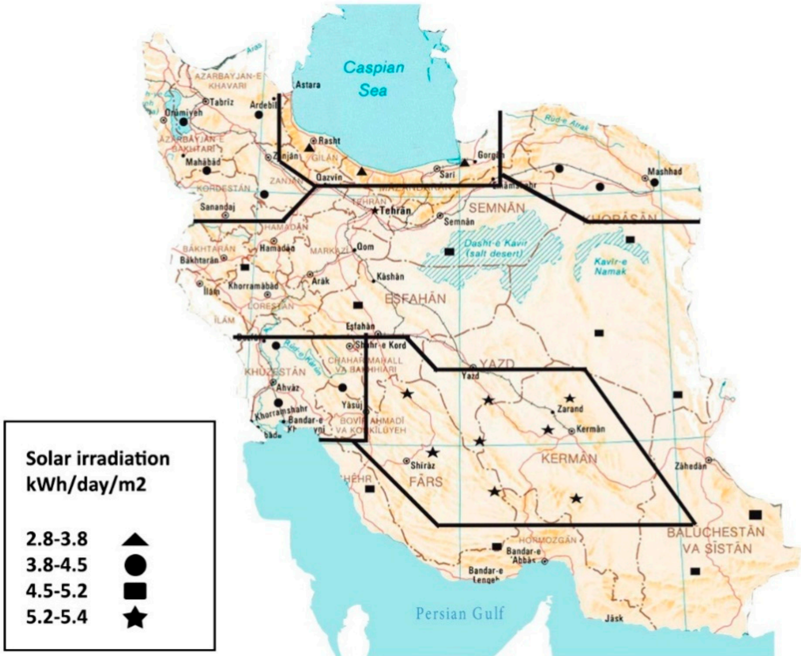


**Figure 8.** Solar energy potential of Iran [68].

Comparatively low fossil fuel price for electricity generation and additionally crude oil export act as the main deterrents to solar energy development [3,74]. However, in the sixth development plan, installation of 500 to 1000 MW (Megawatts) solar panel plants until 2020 is planned. Due to climate conditions and contiguity to the national power grid, the government of Iran prefers the central parts of the country. There are numerous completed solar projects established during recent years. First solar station in Iran with 5 kW DC capacity was established in 1993, followed by a 27 kW AC station founded in 1998 in Hosseinian and Moaleman villages in Semnan province. In the succeeding years, their capacity has soared to 10 kW DC and 92 kW AC, respectively [3]. Currently, Mokran solar complex, located in Mahan near Kerman, with a capacity of 30 MW is the Iran's largest PV power plant. The project will be accompanied by a 100 MW solar power plant nearby which is under construction. Furthermore, plenty of 10 MW solar plants in different regions of the country such as Mehriz, Ardakan, and Ashkzar in Yazd province, Zahedan in Sistan and Balouchstan province, Shahr-e-rey in Tehran province, Khusf in south Khorasan province, Shiraz in Fars province, etc., have been installed [68]. It must be noted that the largest gas-steam-solar power plant in the Middle East with the capacity of 467 MW is located in the Yazd province [75]. Iran's installed solar energy power plants are described in Table 2 [68].

**Table 2.** Location, capacity, and construction date of installed solar power plants in Iran [68].

| Location | | Construction Date * | Aggregate Capacity (MW) |
|---|---|---|---|
| Province | City/Town | | |
| Alborz | Nazarabad | 2017 | 0.63 |
| Chaharmahal and Bakhtiari | Shahrekord | 2017 | 1.5 |
| Fars | Sarvestan | 2017 | 4.6 |
| | Shiraz | 2017 | 10 |
| | Abadeh | 2017 | 2 |
| | Eqlid | 2018 | 10 |
| | Abadeh | 2018 | 10 |
| Hamadan | Qahavand | 2016–2017 | 15.9 |
| | Aq-Bolaq | 2016 | 7 |
| | Kordabad | 2017 | 7 |
| | Famenin | 2017 | 8.5 |
| | Kabudarahang | 2018 | 1 |
| Hormozgan | Qeshm | 2017 | 10 |
| Isfahan | Jarqavieh | 2016 | 10 |
| | Kashan | 2016 | 1 |
| | Shahreza | 2018 | 0.45 |
| Kerman | Mahan | 2016–2017–2018 | 30 |
| | Rafsanjan | 2016 | 1.2 |
| | Bardsir | 2018 | 1 |
| Khorasan-e Razavi | Taybad | 2016 | 0.31 |
| Qazvin | Kahak | 2018 | 2 |
| Qom | Qom | 2016–2018 | 11 |
| Semnan | Damqan | 2017 | 1.31 |
| Sistan and Balouchestan | Zahedan | 2017 | 10 |
| South Khorasan | Khusf | 2017 | 10 |
| | Boshruyeh | 2018 | 1 |
| Tehran | Shahr-e rey | 2017–2018 | 12.5 |
| | Damavand | 2017 | 8.4 |
| | Shams abad | 2016 | 0.22 |
| | Malard | 2014 | 0.51 |
| Yazd | Mehriz | 2018 | 10 |
| | Ashkzar | 2017 | 10 |
| | Ardakan | 2017 | 10 |
| | Dehshir | 2018 | 3.5 |
| | Chahak | 2018 | 10 |
| Small scale systems-whole country | | | 6.5 |
| Systems constructed by electricity Subscribers | | | 20.47 |

* For rows with multiple construction dates, either a project is accomplished in multiple phases or multiple projects have been done in the location.

In order to stimulate the private sector to invest in solar energy business, some subsidies have been paid by the government in recent years. There have been numerous projects sponsored by foreign investment in the field of solar energy. From April 2016, three German companies have conducted negotiation with Iran's decision-makers for investment in solar power stations and solar module manufacturing projects. In addition, a 100 MW purchase contract has been signed by Renewable Energy Organization of Iran (SUNA) and an international company, and also, a German-Spanish investor holds talks with Bakhtar regional electricity company for installation of a solar farm of 50 MW capacity [54]. However, on account of lower prices for fossil fuels, high expenses of PV systems, and scarcity of comprehensive researches on solar energy, senses of insecurity has spread among investors [3]. So, the government of Iran must remove these concerns to help this sharp development.

### 2.3. Geothermal Energy

A tremendous amount of heat is produced by decomposition of internal elements of the earth. In the lower layers, heat intensity can melt the stones and solids. Passing water through and near such regions would soar its temperature up to 150 °C, which is applicable for electrical energy generation [29]. Availability and sustainability of this energy encourages the human to invest in geothermal technology; nevertheless, it still makes a limited contribution to the final energy supply of the world [76]. In contrast to other renewable energy sources, geothermal energy is not dependent on season, time, and climate condition and can be utilized continuously. Geothermal electricity cost is comparatively less than any other renewable and even fossil fuels [77]. In addition, trace of greenhouse gases will be produced using geothermal technology. Until 2010, total geothermal power implemented throughout the world has been reported as 1 GW, equivalent to 67.2 TWh of electrical energy. Now, 82 countries are directly utilizing the geothermal energy, among which some have a long record in investigation and application of the earth's thermal energy—USA, New Zealand, and Iceland, to name a few [78]. Studies on geothermal energy are mostly focused in electricity generation, while direct usage is of least interest. Five leading countries in harvesting geothermal power are USA, Philippine, Indonesia, Mexico, and Italy with 3.1 GW, 1.9 GW, 1.2 GW, ≈1 GW, and 0.9 GW, respectively [3]. Currently, as official reports state, electricity price by geothermal energy ranges between 0.04$/kWh to 0.07$/kWh [72].

Variation of geothermal energy in Iran ranges from 2 °C/100 m in the Zagros belt to 13 °C/100m in proximity of Damavand volcano [76]. Researches indicate that about 8.8% of Iran's land areas boast appropriate potential for geothermal power and there exist 18 high temperature fields. Provided information highlight two regions of Iran as the proper location for geothermal power plants; northwest, where numerous volcanoes are situated and center of the country, due to broad deserts and south part [78]. Iran boasts several geothermal power plants, among which Meshkinshahr's geothermal combined heat and power (CHP) plant with the capacity of 55 MW located in Mehskinshahr, Ardebil province is known as major plant in Iran. Capacity of Meshkinshahr power plant can be boosted to 200 MW in order to annually generate 410 GWh electricity [3]. Investigations confirm the viability of construction of a 400 MW power plant; 17 wells were planned to be drilled for Meshkinshahr power plant and 11 wells have been exploited so far [78,79]. Potential areas for geothermal energy in the country are illustrated in Figure 9.

Before 2014, a geothermal field in Iran was delivering annual electrical energy of 239 billion kWh, which ranks Iran as the second largest country in the Middle East in this subject [30]. Combination of other available sources of energy can boost the efficiency of geothermal power plants. Considering greenhouse gas emissions and other adverse effects on the environment, fossil fuels are not considered as a proper choice in this respect [30].

### 2.4. Hydropower

Hydropower is known as the largest renewable energy source in the world and contributes to 16.4% of total worldwide generated electricity [80]. This amount obviously exceeds the electricity produced by all other renewable sources altogether (5.6% wind, 2.2% bio-energy, 1.9% solar PV and wave, and 0.4% geothermal). In 2017, a staggering 4185 TWh of clean electrical energy has been produced by hydropower, which can satisfy the annual energy demand of 1 billion people [80]. Total hydropower capacity installed globally has been in the order of 1260 GW. It must be noted that China, USA, Brazil, Canada, and Japan with 341, 103, 100, 81, and 50 GW, respectively, are the top five countries with the highest installed capacity. The International Hydropower association (IHA) has placed Iran in the 18th rank in respect of installed hydro-plants. Indeed, with installing 0.52 GW new capacities in

2017, the country boasts the 7th highest growth rate in hydropower technology worldwide and 3rd rank in central and southern Asia in terms of total installed capacity [80].

Drinking water supply, irrigation of agricultural farms and lands, flood control, and power generation are believed as chief aims of hydro-dam constructions [81], the latter responsible for about 1% of total primary energy in Iran [32]. Iran holds 11,811 MW of hydropower plants and in the meantime, numerous projects are in different stages in this respect [80]. Statistics have confirmed 5000 MW of plants are under construction and approximately 16,000 MW are under study, while adding up yields the total potential hydropower plants as 30,000 MW [82]. Small and micro plants (1 kW to 10 MW) provide 674 MW capacity including 45 MW under operation, 47 MW are being constructed, and 582 MW have passed the feasibility study and are ready for investment [82]. Yet, 91% of the hydroelectricity is generated by means of large plants, with capacity surpassed 100 MW [27]. The government and related companies are investing in hydropower locally and internationally. In 2016, Rudbar dam in Lorestan province comprised of a 450 MW power plant was inaugurated [80]. Large-scale projects with capacity of 5831 MW in the aggregate, are under investment in the country, among which are 1000 MW pumped-storage plant in Ilam, 712 MW in Karun, and 584 MW in Khersan [32]. Other 28 high potential projects are also in study phase, totaling 13 GW [32]. Moreover, Iran is expanding its investment borders to neighboring and other overseas states, including a project in Tajikistan and a 134 MW in Sri Lanka and implementation of 48 mini-sized hydropower plants in Indonesia by 2020 [32,83]. It could be argued that the comparative price of hydropower technology (0.04$/kWh, transmission included) as well as its technical advantages are the dominant stimulus of its remarkable growth in comparison with other renewable energies [3]. Table 3 provides information in reference to installed small-scale hydro-power plants in Iran [68].

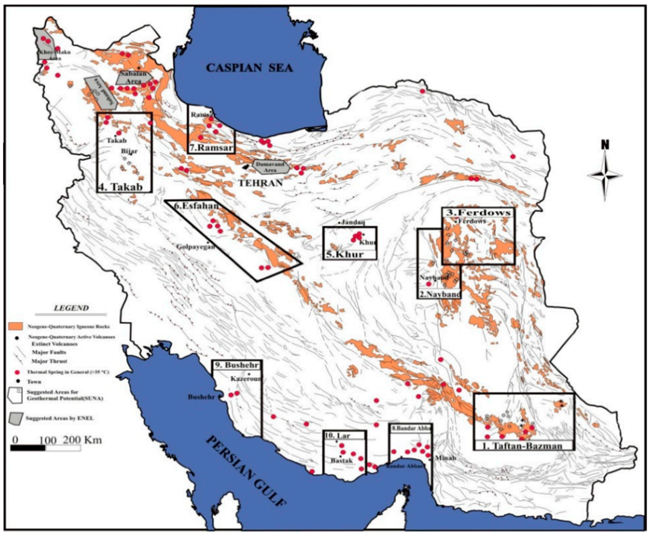


**Figure 9.** Potential areas of Iran for geothermal energy [29].

## 2.5. Bio-Energy

Worldwide tendency towards utilization of biomass as energy source is obviously soaring and nearly 14% of the world's final energy consumption has been attributed to biomass in 2016 [84]. Bio-energy can play a prominent role in global green energy mix, and the projection of biomass-related primary energy of the world by 2050 ranges from 15 to 50% [71,85,86]. It must be noted that among all renewable energy sources, only biomass can be utilized to produce fuels in all possible physical states (gaseous, liquid, and solid) [87].

Municipal solid wastes, forestry, and farming leftovers and livestock wastes can be accounted as dominant source of bio-energy in Iran [88]. Production potential of biomass wastes in Iran is estimated as 8.78 MT agricultural wastes, 7.7 MT animal manures and 3 MT municipal solid wastes per year, which due to population growth and escalation of consumption are accelerating gradually [3,89]. In addition, abundance of cultivating corps and widespread forests as well are counted as the main source of bio-ethanol and biodiesel. Agricultural wastes such as weeds, leaves of plants, hay, gardening products, etc., produced in various steps of food production processes may be considered as a suitable source for green energy [3]. Recently, several researches have been conducted on various biomaterials (from aquatic plants to residues left from different agricultural and food industry processes) for bio-fuel production in Iran, such as bio-fuels from citrus wastes [90], biodiesel from pistachio wastes created in harvesting and peeling processes [91], microalgae [92], local agricultural products, animal fat and fish wastes for biodiesel production [93], rural human and animal wastes for biogas synthesis [94], and okra fruit for biodiesel [95], to name but a handful. In Table 4, installed biomass utilities in Iran are presented in detail [68].

**Table 3.** Location, capacity, and construction date of installed small-scale hydropower plants in Iran [68].

| Location | | Construction Date | Aggregate Capacity (MW) |
|---|---|---|---|
| **Province** | **City/Town** | | |
| Gilan | Bijar | 2017 | 6.3 |
| Khorasan-e razavi | Mashhad | 2015 | 0.44 |
| Lorestan | Boroujerd | 2016 | 0.17 |
| Markazi | Arak | 2016 | 0.24 |
| Qom | Qom | 2016 | 2.7 |
| semnan | Shahmirzad | 2018 | 3 |
| Small-scale whole country | | | 75.35 |

**Table 4.** Location, capacity, and construction date of various installed biomass sites in Iran [68].

| Location | | Construction Date | Aggregate Capacity (MW) |
|---|---|---|---|
| **Province** | **City/Town** | | |
| Fars | Shiraz | 2009 | 1.06 |
| Khorasan-e razavi | Mashhad | 2009 | 0.6 |
| Tehran | Kahrizak | 2016 | 3 |
| | Abali | 2016 | 1.9 |
| | Shahr-e rey | 2010 | 4 |

Biogas is one kind of renewable energy for which popularity is increasing worldwide. Mainly composed of methane and carbon dioxide [96], this flammable fuel is applicable for heating, lighting, cooking, and electrical energy generation by means of engines [97]. In Iran, a staggering amount of 8600 million $m^3$/year is estimated as potential of biogas production from livestock and slaughterhouse wastes [94,98]. Biogas is independent from any specific site and contrary to any other kinds of renewable energies, can be produced anywhere. Prominent sources of biogas in Iran are wastewater and municipal and rural solid wastes, animal manures, and a considerable portion of agricultural remains and residues. Significance of biogas is obvious as its production process avoids residences of towns and cities to be afflicted by the main sources of environmental pollution. Infectious diseases, especially in warm seasons, remains commonplace in the areas where no treatment for municipal and rural wastes are carried out [26].

Iran's total land area is approximately 162.2 million hectares, including 52.3% pasture and agricultural lands and 10.5% forestry areas. Aggregate of about 937.730 $m^3$ forest products has been exploited for energy generation in 2008 in the country [27]. Animal excreta have been employing to a large extent in farms and plantations as fertilizer. Extraction of biogas from these materials is of importance from economy and environment points of view [3,86,99]. According to formal reports, municipal solid waste are produced at the rate of 0.2 to 0.5 kg daily per person [3,86]. Figure 10 shows potential provinces in extraction of biomass energy. Darker icons indicate more capacity for that certain source.


**Figure 10.** Potential of livestock, agricultural, municipal, and forest wastes in different areas of Iran [68] (created by CorelDraw).

Primitive endeavors for biomass projects on Iran were initiated in the 1970s and by 2008, more than 70 projects has been executed [100], while as Renewable Energy Organization of Iran (SUNA) reports, there are only 5 projects that are still running by 2018 [68]. The largest biomass project in Iran has been implemented by Tehran Sewage Company in the south part of Tehran city in 2011, which is a CHP power plant with nominal capacity of 4 MW powered by biogas from urban sewage, wastewater, and sludge in sewage treatment [66,101]. There exist some biomass projects constructed in other cities of Iran including 0.6 MW and 1.06 MW installations located in Mashhad and Shiraz, respectively [14].

### 2.6. Marine Energy

A variety of ways is available in order to take advantage of oceans and seas for energy generation. Wave energy, tidal energy, sea currents, and concentration and temperature gradients are considered as feasible sources of marine energy [27,102]. Among all these types of marine energy, wave energy has drawn the greatest attention throughout the world. Significant advantages of wave energy compared to other types of renewable energies are predictability, availability, and relatively high energy density as well [28], which enables it to produce more power while consuming less budget [103]. Surface waves or pressure variation under the surface of water are responsible for wave energy generation. As a general fact, wave-driven energy can be presumed as a sort of solar energy [104]. In terms of electricity generation, European Ocean Energy Association in 2010–2050 roadmap report describes the growth rate of wave energy as fast as wind power [104,105]. Additionally, according to statistics published by International Energy Agency (IEA), wave energy technologies are at its infant stages demanding further study and development. The agency predicts 60 TWh of marine energy and installation capacity of 17 GW by 2035 worldwide [34]. The amount of energy deliverable by a wave specifically depends on its length and height. Generally, open ocean waves in the world offer approximate power of 107 MW. Moreover, predictable tidal energy boasts a promising potential as high as 100 GW in the Earth's waters [106]. Multitudinous countries have studied marine potential in-depth, including investigations on global and European potentials, potentials in some European countries such as Sweden, UK, Spain, Portugal, Italy, and Turkey and also wave potential associated with US, Baltic sea, Australia, Indian ocean, and Asian southwest waters [107]. The largest ocean energy harvesting installation in the world has been established in South Korea in 2011, followed by France and Canada. In addition, multiple large projects are under construction in the UK [106]. Several studies have dealt with Iran's potential for wave energy [102–104,107–113]. A mediocre value of 6.1 kW/m was reported as wave energy potential for Persian Gulf, whereas, due to the close proximity to open waters of ocean, the Gulf of Oman is benefited from a greater potential of 12.6 kW/m [107]. Persian gulf islands, nevertheless, enjoy remarkably high average potential of 16.6 kW/m and a maximum of 19 kW/m [111]. Moreover, Caspian Sea is endowed with a great average and maximum wave potential of 14 kW/m and 30 kW/m respectively, thanks to frequent storms and surface winds. Contributing factors in this respect are its large surface area and depth, in addition to variable weather conditions [111]. Orumieh Lake, well known for its extremely salty water, has the potential for saline gradient-driven energy. In spite of abundant studies, wave energy has not been practically deployed in Iran and further research and development is vital for promotion of this precious energy source [28].

### *2.7. Fuel Cell and Hydrogen*

Hydrogen and fuel cell are introduced as potential alternatives for traditional energy systems [114]. The lightest element in the periodic table, hydrogen, offers massive advantages such as carbon-free combustion, efficient utilization in fuel cell systems, and great energy density of around 122 kJ/g [115]. Hydrogen's energy content outweigh that of fossil fuels (about 2.75 times greater), while fuel cell systems provide electricity with the efficiency 3 times greater than conventional gasoline internal combustion engines [116]. As a clean fuel, hydrogen is consumed directly in internal combustion engines or fuel cells and produces water as by-product [117] and covers a wide range of applications from residential to transport, making use of proper storage technology. Contrary to conventional fossil fuels, however, hydrogen is not available in nature freely. Reformation, gasification, and electrolysis are conventional methods that provide pure hydrogen [30] and amongst all, reformation of hydrocarbons is the main method. A considerable portion of total produced hydrogen i.e., 48%, is obtained by reforming natural gas, followed by reformation of oil and coal by 30% and 8%, respectively [117]. Indeed, hydrogen storage systems offer an effective way to produce electricity from fuel cell [114]. Gaseous hydrogen can be stored in compressed gas tanks or in solid hydrides (especially metal hydrides) or become liquefied through a cryogenic process [118–120].

Nowadays, hydrogen annual production market is estimated to be approximately 50$ billion, equivalent to 40 Mt production, mostly utilized as a chemical agent in oil refining processes and production lines of chemicals such as ammonia, methanol, and medicines, rather than fuel [121]. Generally, pure hydrogen is produced, utilizing electrolysis, while tremendous electricity consumption of these systems has led to high hydrogen prices. On the other hand, using fossil fuels for electricity generation can raise $CO_2$ emission accordingly. Therefore, electricity generated from renewable energy systems such as hydro, solar, and wind power can run electrolyzers in order to produce the cleanest energy carrier [118]. Commercialized Alkaline electrolyzers can generate 380,000 kg of $H_2$ per year, consuming energy of 53.4 kWh/kg $H_2$ with 73% efficiency [122].

In Iran, hydrogen and fuel cell have been of interest for many researchers, institutes, and organizations. In addition to universal activities on renewable energy-based hydrogen [115,117,121,123], a quantity of researches have dealt with potential of sustainable energy systems for hydrogen generation in Iran. In [124], potential of wind energy generation and hydrogen extraction from desalinated seawater in the north and south coasts of Iran were assessed. Analysis of various coastal cities unearths that Anzali harbor, Gilan province, placed in the south border of Caspian sea with the adequate wind power density of 327 W/m$^2$, has the largest hydrogen production capacity among all studied locations [124]. Following evaluation of diverse renewable systems, Super Critical Water Gasification (SCWG) of biomass is proposed as the most economical procedure among existing renewable thermo-chemical methods for generation of hydrogen by Ehsan et al. [115]. Low efficiency and high expenses were mentioned as obstacles hindering the commercial progress of sun-driven hydrogen systems. With the aim of hydrogen production, the authors of [125] investigated wind power capacity in Fars province in detail. Four selected cities were statistically evaluated in terms of wind energy to find out to what extent hydrogen can be created [125]. Similarly, Alavi et al. have analyzed wind potential of the Sistan and Balouchestan province for running an alkaline electrolyzer and yield of hydrogen consequently. They assumed four different wind turbines with capacities from 300 to 900 kW in five locations in this study [126]. Taleghan solar-hydrogen plant, located in Tehran, is an example of practical utilization of renewable sources for hydrogen generation. This stand-alone facility comprises 10 kW solar panels, electrolysis system of 5 kW capacity with nominal hydrogen generation rate of 1 m$^3$/h, 2.1 kW PEM fuel cell, 1 m$^3$ hydrogen tank, and other subsystems. Techno-economic analysis of the site has been conducted by Shiroudi et al. [127].

Three stages can be defined as evolution steps for fuel cell science in Iran. The first stage is comprised of studies, plans, and initiatives done in sundry subjects in the field of fuel cell with the aim of extending the boundaries of knowledge. Lack of oriented and purposeful plans for the financial support of projects was the weakness point of this stage, whilst most of the activities were attributed to universities. In the second step and along with the "National Fuel Cell Development Plan" drafting, the government focused on organization of activities in particular. This led to collaborative proceedings by active sectors and individuals in order to define priorities in the field. After approval of the National Fuel Cell Development Plan, all activities were concentrated on two specific types of fuel cells, PEMFCs (Proton-Exchange Membrane fuel cell) and SOFCs (Solid Oxide fuel cell), resulted in researches alignment and convergence accompanied by proper monetary management between projects [128]. However, predominantly owing to the absence of necessary support and convenient investment, entire activates in the fuel cell field in Iran have not fulfilled the National Fuel Cell Development Plan. Uninterrupted assistance and funding by government has apparently an undeniable leading role in reinforcing the infrastructural progress of fuel cell technology in various aspects, from primary studies to construction of pilot systems and facilities [129].

### 2.8. Summary

In Table 5, reviewed literature is summarized in nine categories.

**Table 5.** Summary of literature review.

| Number | Subject Area of Study | Reviewed Papers |
|---|---|---|
| 1 | Iran and its whole energy system | [1,2,15–17,26,27,38]. |
| 2 | Renewable energy in Iran | [3–7,14,18,22,23,26–28,35–37,40,53,71,89,107]. |
| 3 | Wind energy in Iran | [11,19,20,42,51,55–70]. |
| 4 | Solar energy of Iran | [11,21,61,73–75]. |
| 5 | Hydro, wave, and tidal power in Iran | [31–34,81–84,103–105,107,109–115]. |
| 6 | Biomass energy and bio fuel in Iran | [13,24,25,88,89,91–96,99–102]. |
| 7 | Geothermal energy of Iran | [29,30,76,78,79]. |
| 8 | Fuel cell and hydrogen energy | [114–129]. |

## 3. Renewable Energy Policy, Market, and Status

### *3.1. World Status*

Energy policy has been defined as a technique utilized to address difficulties associated with production, distribution, consumption, and environmental issues in the energy sector. Although low-carbon energy production is highly dependent on renewable energy utilization and exploitation in the world, exact and accurate factors for efficient policymaking in this matter are not fully comprehended yet [130]. Countries that have employed any type of strategy in furtherance of renewable energy development and set certain national targets are estimated 100 countries at the beginning of 2010, whereas in early 2005 this amount had stood at just 55 countries [131]. Subsequently, statistics indicate that in 2017, nations with renewable target has risen to 176 countries [132]. Renewable portfolio standard, tax exemption, energy generation credit, feed-in tariffs, direct subsides, discounts, and financial supports are among the most functional strategies used worldwide to attract investors and guarantee green energy's growth. The main objective of these supportive initiatives are shrinkage of the dependence on fossil fuels and avoiding the detrimental effect on the nature and humanity. The most widely utilized ways are Feed-in Tariff (FIT) and Renewable Portfolio Standard (RPS). At least 61 countries in the word are employing FIT, in which a particular price is paid for electricity generated via green energy sources during a certain period (typically 20 years). This strategy reduces the risk of long-term investment in the market [14]. Thus, the countries should choose the most adaptable and compliant policies with regard to their capabilities and culture, as there does not exist a single optimum procedure appropriate for whole states. Sweden has achieved the assigned goal prior to other countries, reaching 2020 goal in the year 2010 [14].

### *3.2. Iran Status*

#### 3.2.1. Iran's Policymaking

First steps for exploiting green energy sources in Iran were taken in 1994 and ever since, interest among governmental organs and scientific societies for contribution to this promising field has been augmented. Aimed at investigation and analysis of renewable energy potential and status and private sector encouragement by bringing guaranteed electricity purchase to bear, Renewable Energy Organization of Iran (SUNA) was established in 1996. Subsequently, its responsibility was expanded to involve making rules and regulations, issuance of licenses for renewable energy projects, and entering contracts with developers and investors [133]. Later in 2016, this organization was merged with Energy efficiency organization of Iran (SABA) and formed Renewable Energy and Energy Efficiency Organization (SATBA). In 2005, first attempts to develop a structured plan for renewable energy development in Iran were made, following the drafting of renewable energy plots in fourth national development plan (2005 to 2010). The goal had been set as provision of 1% of total energy demand from renewable sources, and subsequently a 10% share in the country's energy market by 2025 [14]. In the mentioned plan, feed-in tariff strategy was introduced and sustainably-generated power were bought from private sector for 0.09$/kWh in regular hours and 0.13$/kWh in peak hours. In order to achieve the goal of 20 year outlook, strategies such as taking support of private renewable energy entities, assistance to the companies active in localization of energy-related products, encouragement of institutions, universities and research centers to expand renewable energy projects, and preparation of power for remote and inaccessible villages and towns had been implemented. Nevertheless, an unsatisfying 38% of the goal was met eventually. The main reasons for failure in attaining fourth development plan's goals are lack of academic involvement in practical projects, infrastructural and managing problems and incompatibility of determined goals with country's technical and managerial potentials [13,134].

Later, in the fifth development plan (2010 to 2015), the government proclaimed the intention to augment the renewable energy installation capacity to 5 GW, with the aid of offering the encouraging incentives such as lower tariff rates to private investors. However, due to substandard infrastructures and imposed economic sanctions, the goal remained unfulfilled [133]. In accordance with the sixth 5-year development plan (2016 to 2020) approved by Islamic Consultative assembly (Majlis), government and ministry of energy are obliged to extend the installed capacity of renewable power plants to 5000 MW within 5 years (hydropower is excluded) in addition to 2500 MW more by 2030 [135]. Currently, as SUNA has reported, total installed capacity of renewable power stations, counting out hydroelectricity power stations, is about 560 MW [68]. Moreover, as policy of ministry of energy relies on avoiding governmental investment on the power generation market, the private sector is considered as the chief investor in this field. Revision on feed-in tariffs, as the most important stimulus to promote renewable energy, can result in unprecedented development of renewable plans. Since the first introduction into energy industry, feed-in tariff approach has been improved gradually. Before March 2015, renewable electricity was purchased based on three factors: cost of saved fossil fuel, cost of avoided environmental pollutants (such as $CO_2$), and cost of energy conversion in electricity market. Thus, generated electricity from various renewable technologies was purchased by a similar fixed price for the first 5 years of plant establishment. As from 2015, power plant type and size have been considered as contributing factors in determination of purchase price, and in addition, purchase period has been extended to 20 years. Recent feed-in tariffs for various technologies are presented in Table 6. As shown in the table, for the second decade of power purchase agreement (PPA), purchase price will be reduced by 30% in relation to first 10 years (with the exception of wind power) [135]. In the case of wind energy, after the 11th year, payment will be correlated with capacity factor. Capacity factor, a tool for prompt analysis of the power plant, is calculated as annual energy yield in kWh divided by product of nominal power in kW and annual hours (8760 h). For instance, for a power plant with a capacity factor of 40% and greater, solely 40% of original incentive (paid in the first 10 years) would be given, whilst those with a capacity factor of 20% or less would enjoy the total original incentive. For that of between 20% and 40%, linear extrapolation will determine the percentage of original payment after the 11th year of PPA [135]. Moreover, if the power plant is being constructed utilizing localized technology, materials, and components, a bonus of 30% will be awarded to the developer.

**Table 6.** Feed-in tariffs regulated by Renewable Energy and Energy Efficiency Organization (SATBA) for various renewable energy technologies.

| Row | Technology Type | | Guaranteed Power Purchase Tariff (IRRs Per kWh) |
|---|---|---|---|
| 1 | Biomass | Landfill | 2700 |
| | | The anaerobic digestion of manure, sewage and farming wastes | 3500 |
| | | Incineration and waste gas storage | 3700 |
| 2 | Wind farm | above 50 MW capacity | 3400 |
| | | capacity of 50 MW and less | 4200 |
| 3 | Solar farm | capacity above 30 MW | 3200 |
| | | capacity of 30 MW and less | 4000 |
| | | capacity of 10 MW and less | 4900 |
| 4 | Geothermal | including excavation and equipment | 4900 |
| 5 | Waste recycling | waste recycling in industrial processes | 2900 |
| 6 | Small hydropower plants (capacity of 10 MW and less) | Installation on the rivers and side facility of dams | 2100 |
| | | Installation on the pipelines | 1500 |
| 7 | Fuel cell systems | | 4948 |
| 8 | Turbo expanders | | 1600 |
| 9 | Wind systems | 1 MW capacity or less | 5700 |
| 10 | Solar systems | 100 kW capacity or less | 7000 |
| | | 20 kW capacity or less | 8000 |

TAVANIR (Iran Power Generation, Transmission and Distribution Management), the body in charge of generation, transmission, distribution, and management of power, estimates that 10% of Iran's energy demand would be met by renewable energy systems within five years [133].

#### 3.2.2. Investment Trend and Procedure

Revocation of sanctions targeted on energy sector in the recent years has resulted in escalation of foreign capital and number of PPAs signed such as southwest wind farm with 48 MW capacity and total of 1250 MW solar energy projects ran in different regions of the country (including 500 MW near Tehran). Additionally, two solar plants with 1 GW and 50 MW capacity are being built in Gheshm Island and Khuzestan province respectively in collaboration with Asian and European foreign investors.

Applicants for renewable energy development shall take four stages to trade produced electricity, as follows:

Project registration

- Presentation of technical and financial plans in detail (including the site) and feasibility study of the project
- Registration of the project and construction permission issuance following meeting the criteria such as investor's Iranian nationality and non-governmental identity and verification of feasibility study and site location as well.

Permits and certifications

- Obtaining grid connection, environment, and site land permits from authorities for all power plants and water flow allocation for hydropower plants
- Signing a long term power purchase agreement (PPA) following confirmation of permits.

Power plant construction

- Initial and operational development of the project along with financial support by developer
- Coordination for connection to power grid after the completion of the power plant.

Operation period

- Commencing power plant operation and preparation of monthly bill with regard to renewable energy price by developer
- Payment of bills by SATBA (Renewable Energy and Energy Efficiency Organization) applying adjustment coefficient [136].

The mentioned procedure is well illustrated in Figure 11.

#### 3.2.3. Challenges and Obstacles

There are a number of notable challenges that hinder the promotion and advancement of renewable energy programs in Iran, mentioned as follows [133]:

Finical issues

One of the most remarkable challenges in the context is lack of appropriate financing. The banking system in Iran is not well-prepared to offer adequate monetary support for renewable energy sector, as loans are given at relatively high interest rates. Additionally, due to soaring oil prices, investment in exploration and extraction of fossil fuels are locally preferred. Meanwhile, US sanctions prohibit foreign capitals and generally, only small-sized banking bodies would accept the risk of investment in Iran's energy sector.

Credit validity of SATBA

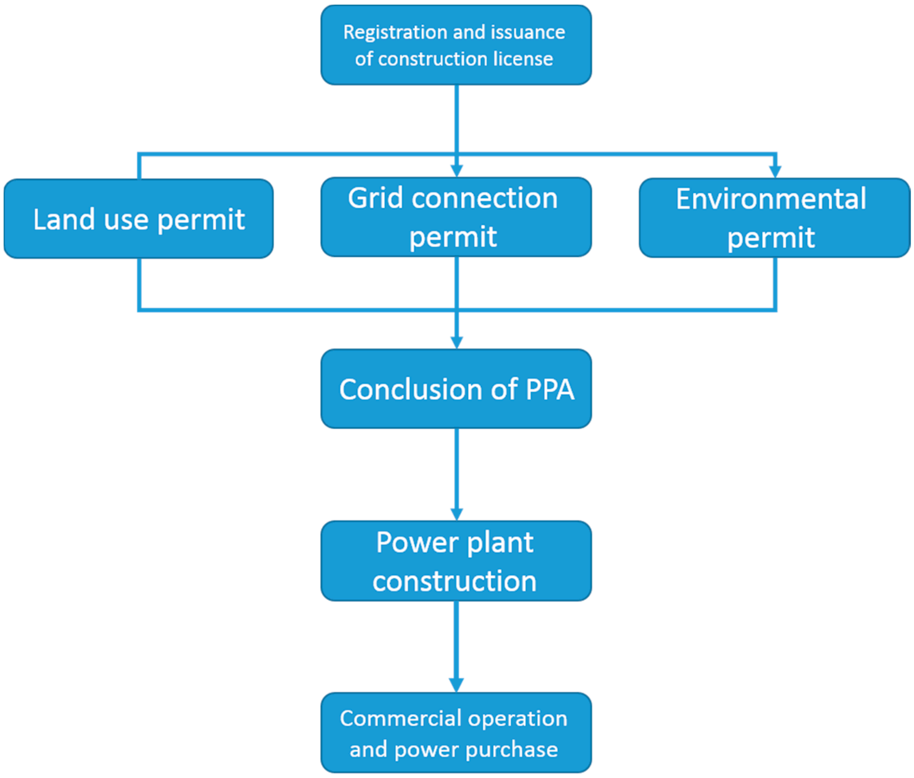


**Figure 11.** Diagram for registration and completion of power purchase agreement (PPA) by SATBA [68].

SATBA has verified secured feed-in tariff payment in return for green electricity produced. However, numerous investors are doubtful about remittance commitment of SATBA to be fully met, as Central Bank and government of Iran have not authenticated any obligation on payment.

Shortage of Knowledge and experience

Owing to more knowledge and awareness about fossil fuel-based energy system, fields associated with conventional fuel are more of interest to government and authorities, while benefits of renewable energy for rural areas in particular have remained unknown.

Bureaucracy and regulations

In view of the fact that renewable energy is still at the infant phase in Iran, proper comprehensive regulations has not come into effect yet. On the other hand, a complicated official system in Iran discourages investors to proceed.

Land acquisition

While numerous governments offer lands to developers for renewable energy projects according to market standards in the world, in Iran, owing to tremendous prices, preparation of a fitting land is usually time-consuming and expensive. This issue could finally result in investors' loss of vim and vigor.

Table 7 presents a SWOT analysis of REs technologies and their implementation in Iran.

**Table 7.** Strength-weakness-opportunities-threats (SWOT) analysis of renewable energies (REs) technologies and their implementation in Iran.

| Strengths | Weakness |
|---|---|
| • High potential of REs in Iran, specifically solar energy<br>• Suitable for remote locations due to systems being modular<br>• Reduction of environmental pollution<br>• Competitive and low-cost technologies for domestic applications<br>• Abundant well-equipped and powerful universities and research centers in this field<br>• Availability of oil export | • High expenses for investment<br>• Lack of motivation for private section to engage<br>• Absence of stable effective policies and promising incentives<br>• Dearth of necessary cooperation between various private and governmental sections<br>• Absence of research sectors and universities in development processes of technology<br>• Economic instability of the country specifically fluctuation of foreign currencies |
| Opportunities | Threats |
| • Engagement and development of private section<br>• Stepping toward economical and sustainable development<br>• Creation of potential market for technology introduction and maturation<br>• Reduction in reliance on fossil fuels<br>• Possibility for energy export to neighboring countries<br>• Possibility of scientific and practical development of research centers and universities for initiation of essential technologies | • Low prices of fossil fuels<br>• Enormous accessible reservoirs of fossil fuels, especially in shared fields with neighboring countries<br>• Personalized and impromptu decision making by managers<br>• Lack of comprehension of necessity for development of this sector<br>• Shortage of social awareness<br>• Political problems such as imposed sanctions and consequent lack of motivation for investors to proceed |

## 4. Conclusions

In the present work, energy framework in Iran is analyzed and studied from three viewpoints: resources, technology, and policy making with the SWOT analysis in this context. Currently, energy as well as the economic system of the country is mostly based upon fossil fuel resources. The country has relatively great potentials and enormous reservoirs of conventional fuels, but as statistical assessments reveal, Iran has not achieved nominal energy exploitation capacity yet, mainly due to inadequate policymaking and multi-objective incessant sanctions imposed on energy and economy sectors. Meanwhile, recent years have witnessed considerable interests in utilizing renewable and alternative energy sources among human society, mainly due to their innocuous nature for the environment. It is worth mentioning that Iran, benefited from diverse climate regimes, has generally appropriate potential for channeling renewable energy sources such as wind energy in the east, south east, north, and north east parts of the country, solar energy in east, south east, and center, hydropower in west, south west, and north east, marine energy in north and south of the country, and so on. Nevertheless, the country has confronted a dispute over priority of capitalization on alternative or conventional power sources, which has not led to a joint resolution on the technology development and utilization. As a rationale, controversial and occasionally personalized decisions of some authorities in reference to upstream documents of a country's development plan can be mentioned. Nonetheless, in recent years, remarkable attempts have been made in order to expand utilization of renewable energy sources in Iran, among which increase in guaranteed renewable power purchase price during tenure of former energy minster (2013–2017) has been the most significant step so far. This effective measure, accompanied by proper cultural promotion, led to substantial growth of installed renewable capacities, experiencing more than 10 times increase during these five years. Unfortunately, there still exist numerous difficulties in this regard, such as complicated bureaucracy for power plant construction, land selection issues, imposed economic sanctions, problems for technology transfer, energy subsides, relatively inconsistent economic status of the country, and discouraging doubts spread among investors regarding guaranteed purchase of green power. Addressing these problems would lead to a momentous mutation in this context and would open the gates towards a clean and sustainable future.

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## References

1. Sáenz, R.; Embrick, D.G.; Rodríguez Editors, N.P. *International Handbooks of Population 4 The International Handbook of the Demography of Race and Ethnicity*; Springer: New York, NY, USA, 2015.
2. United Nations Website 2018. Available online: http://data.un.org/en/iso/ir.html (accessed on 15 October 2018).
3. Hosseini, S.E.; Andwari, A.M.; Wahid, M.A.; Bagheri, G. A review on green energy potentials in Iran. *Renew. Sustain. Energy Rev.* **2013**, *27*, 533–545. [CrossRef]
4. Fathi, S.; Lavasani, A.M. A Review of Renewable and Sustainable Energy Potential and Assessment of Solar Projects in Iran. *J. Clean. Energy Technol.* **2017**, *5*, 126–130. [CrossRef]
5. Sabetghadam, M. Energy and Sustainable Development in Iran. *Sustain. Energy Watch* **2005**, *1*, 1–41.
6. Norouzi, N.; Fani, M. The prioritization and feasibility study over renewable technologies using fuzzy logic: A case study for Takestan plains. *Res. Artic. J. Energy Manag. Technol.* **2020**, *5*, 12. [CrossRef]
7. Tofigh, A.A.; Abedian, M. Analysis of energy status in Iran for designing sustainable energy roadmap. *Renew. Sustain. Energy Rev.* **2016**, *57*, 1296–1306. [CrossRef]
8. OPEC (Organization of the Petroleum Exporting). *Annual Statistical Bulletin*; Organization of the Petroleum Exporting: Wienna, Austria, 2004; ISSN 0475-0608.
9. BP. BP Statistical Review of World Energy-Oil. 2018. Available online: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (accessed on 20 December 2018).
10. EIA (Energy Information Administration). *Country Analysis Brief: Iran*; Energy Information Administration: Washington, DC, USA, 2018.
11. Kazemi Karegar, H.; Zahedi, A.; Ohis, V.; Taleghani, G.; Khalaji, M.; Karegar, H.K. Wind and solar energy development in Iran. North Amir Abad, Tehran/Iran. *Cent. Renew. Energy Res. Appl.* **2006**, *1*, 1–6.
12. Brown, C.E. *World Energy Resources 2016-Coal*; Springer: Berlin/Heidelberg, Germany, 2016. [CrossRef]
13. Ghobadian, B. Liquid biofuels potential and outlook in Iran. *Renew. Sustain. Energy Rev.* **2012**, *16*, 4379–4384. [CrossRef]
14. Nejat, P.; Morsoni, A.K.; Jomehzadeh, F.; Behzad, H.; Saeed Vesali, M.; Majid, M.Z.A. Iran's achievements in renewable energy during fourth development program in comparison with global trend. *Renew. Sustain. Energy Rev.* **2013**, *22*, 561–570. [CrossRef]
15. Iran's National Institute of Statistics—Statistics of Iran. Available online: www.amar.org.ir (accessed on 21 October 2018).
16. Kamran Azadi, A.; Yarmohammad, M.H. Analysis of Iran's crude oil export future capacity. *Energy Policy* **2011**, *39*, 3316–3326. [CrossRef]
17. Ministry of Energy. *Energy Balance Sheet of Iran*; Ministry of Energy: Tehran, Iran, 2015.
18. Afsharzade, N.; Papzan, A.; Ashjaee, M.; Delangizan, S.; Van Passel, S.; Azadi, H. Renewable energy development in rural areas of Iran. *Renew. Sustain. Energy Rev.* **2016**, *65*, 743–755. [CrossRef]
19. Mostafaeipour, A.; Sedaghat, A.; Dehghan-Niri, A.A.; Kalantar, V. Wind energy feasibility study for city of Shahrbabak in Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2545–2556. [CrossRef]
20. Arefi, F.; Moshtagh, J.; Moradi, M. The Wind Energy Potential of Kurdistan, Iran. *Int. Sch. Res. Not.* **2014**, *2014*, 1–10. [CrossRef] [PubMed]
21. Omidiani, A.; HashemiHezaveh, S. Solar Energy and Its Future Role in India and Iran. *Int. J. Sci. Res. Publ.* **2015**, *5*, 1–8.
22. Meisen, P.; Hunter, L. Renewable Energy Potential of the Middle East, North Africa vs. the Nuclear Development Option. *Glob. Energy Netw. Inst.* **2007**, *1*, 1–33.
23. Hamid, B.; Bagher, A.M.; Reza, B.M.; Mahboubeh, B. Review of sustainable energy sources in Kerman. *World J. Eng.* **2016**, *13*, 109–119. [CrossRef]

24. *Country Programming Framework (CPF) for Iran's Agriculture Sector Prepared by Government of Islamic Republic of Iran (GOI)/Ministry of Jihad-e-Agriculture (MOJA) and Food and Agriculture Organization (FAO) of the United Nations*; MOJA: Tehran, Iran, 2016; Available online: http://www.fao.org/fileadmin/user_upload/faoweb/iran/docs/CPF_Iran_FAO_2012-2016.pdf (accessed on 17 September 2019).
25. Kim, S.; Dale, B.E. Global potential bioethanol production from wasted crops and crop residues. *Biomass Bioenergy* **2004**, *26*, 361–375. [CrossRef]
26. Ghorashi, A.H.; Rahimi, A. Renewable and non-renewable energy status in Iran: Art of know-how and technology-gaps. *Renew. Sustain. Energy Rev.* **2011**, *15*, 729–736. [CrossRef]
27. Mohammadnejad, M.; Ghazvini, M.; Mahlia, T.M.I.; Andriyana, A. A review on energy scenario and sustainable energy in Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 4652–4658. [CrossRef]
28. Mollahosseini, A.; Hosseini, S.A.; Jabbari, M.; Figoli, A.; Rahimpour, A. Renewable energy management and market in Iran: A holistic review on current state and future demands. *Renew. Sustain. Energy Rev.* **2017**, *80*, 774–788. [CrossRef]
29. Najafi, G.; Ghobadian, B. Geothermal resources in Iran: The sustainable future. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3946–3951. [CrossRef]
30. Ramazankhani, M.E.; Mostafaeipour, A.; Hosseininasab, H.; Fakhrzad, M.B. Feasibility of geothermal power assisted hydrogen production in Iran. *Int. J. Hydrogen Energy* **2016**, *41*, 18351–18369. [CrossRef]
31. Kumar, A. Small Hydropower Development in Iran: An IWPC Input To Ministry of Energy, IRI Ministry of Energy: Tehran, Iran. 2005, pp. 1–55. Available online: https://www.iwpco.ir (accessed on 7 October 2019).
32. International Hydropower Association/Iran. 2017, pp. 1–2. Available online: https://www.hydropower.org/country-profiles/iran (accessed on 20 October 2018).
33. Khojasteh, D.; Kamali, R. Evaluation of wave energy absorption by heaving point absorbers at various hot spots in Iran seas. *Energy* **2016**, *109*, 629–640. [CrossRef]
34. Khojasteh, D.; Khojasteh, D.; Kamali, R.; Beyene, A.; Iglesias, G. Assessment of renewable energy resources in Iran; with a focus on wave and tidal energy. *Renew. Sustain. Energy Rev.* **2018**, *81*, 2992–3005. [CrossRef]
35. IRENA-Interntional Renewable Enrgy Agancy. 2020. Available online: https://www.irena.org/ (accessed on 28 March 2020).
36. Aghahosseini, A.; Bogdanov, D.; Ghorbani, N.; Breyer, C. Analysis of 100% renewable energy for Iran in 2030: Integrating solar PV, wind energy and storage. *Int. J. Environ. Sci. Technol.* **2018**, *15*, 17–36. [CrossRef]
37. Asadi Asad Abad, M.R.; Moharrampour, M.; Abdollahian, H.; Shir Ali, M.; Mohagheghzadeh, F. Developing Renewable Energies in Iran. *Int. J. Energy Inf. Commun.* **2012**, *3*, 17–28.
38. Ghobadian, B.; Najafi, G.; Rahimi, H.; Yusaf, T.F. Future of renewable energies in Iran. *Renew. Sustain. Energy Rev.* **2009**, *13*, 689–695. [CrossRef]
39. Chaharsooghi, S.K.; Rezaei, M.; Alipour, M. Iran's energy scenarios on a 20-year vision. *Int. J. Environ. Sci. Technol.* **2015**, *12*, 3701–3718. [CrossRef]
40. Atabi, F. Renewable energy in Iran: Challenges and opportunities for sustainable development. *Int. J. Environ. Sci. Technol.* **2004**, *1*, 69–80. [CrossRef]
41. Khoshnevis Yazdi, S.; Shakouri, B. Renewable energy, nonrenewable energy consumption, and economic growth. *Energy Sources Part B Econ. Plan. Policy* **2017**, *12*, 1038–1045. [CrossRef]
42. Kumar, A.; Prasad, S. Examining wind quality and wind power prospects on Fiji Islands. *Renew. Energy* **2010**, *35*, 536–540. [CrossRef]
43. Mostafaeipour, A.; Jadidi, M.; Mohammadi, K.; Sedaghat, A. An analysis of wind energy potential and economic evaluation in Zahedan, Iran. *Renew. Sustain. Energy Rev.* **2014**, *30*, 641–650. [CrossRef]
44. Gökçek, M.; Bayülken, A.; Bekdemir, Ş. Investigation of wind characteristics and wind energy potential in Kirklareli, Turkey. *Renew. Energy* **2007**, *32*, 1739–1752. [CrossRef]
45. Liu, C.; Li, Q.; Zhao, W.; Wang, Y.; Ali, R.; Huang, D.; Lu, X.; Zheng, H.; Wei, X. Spatiotemporal Characteristics of Near-Surface Wind in Shenzhen. *Sustainability* **2020**, *12*, 739. [CrossRef]
46. Islam, M.R.; Saidur, R.; Rahim, N.A. Assessment of wind energy potentiality at Kudat and Labuan, Malaysia using Weibull distribution function. *Energy* **2011**, *36*, 985–992. [CrossRef]
47. World Wind Energy Association. *World Wind Energy-Report 2009*; World Wind Energy Association: Bonn, Germany, 2009.
48. U.S. Department of Energy. *Wind Power Today: 2010*; U.S. Department of Energy: Washington, DC, USA, 2010.

49. Saidur, R.; Rahim, N.A.; Islam, M.R.; Solangi, K.H. Environmental impact of wind energy. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2423–2430. [CrossRef]
50. The Wind Power. Wind Energy Market Actors. 2018. Available online: https://www.thewindpower.net/statistics_en.php (accessed on 4 November 2018).
51. Nedaei, M. Wind energy potential assessment in Chalus County in Iran. *Int. J. Renew. Energy Res.* **2012**, *2*, 338–347.
52. Mostafaeipour, A.; Mostafaeipour, N. Renewable energy issues and electricity production in Middle East compared with Iran. *Renew. Sustain. Energy Rev.* **2009**, *13*, 1641–1645. [CrossRef]
53. Zarma, L. The status of wind energy in Nigeria and its technology overview. In Proceedings of the World Wind Energy Conference, Copenhagen, Denmark, 26–28 October 2005.
54. International Persian Group (IPG). The Renewable Energy Market of Iran. 2017, pp. 1–11. Available online: http://ipg-co.com/blog/the-renewable-energy-market-of-iran.html (accessed on 1 February 2019).
55. Global Wind Energy Council. *Global Wind Energy Outlook 2010*; Global Wind Energy Council: Brussel, Belgium, 2010.
56. Fadai, D. The feasibility of manufacturing wind turbines in Iran. *Renew. Sustain. Energy Rev.* **2007**, *11*, 536–542. [CrossRef]
57. Moslem Mousavi, S.; Bagheri Ghanbarabadi, M.; Bagheri Moghadam, N. The competitiveness of wind power compared to existing methods of electricity generation in Iran. *Energy Policy* **2012**, *42*, 651–656. [CrossRef]
58. Kamali, S.M.; Manshadi, M.D. Assessment of Wind Energy Potential for City of Firoozkooh in Iran. In Proceedings of the International Conference on Mathematics and Computers in Sciences and in Industry, Varna, Bulgaria, 13–15 September 2014. [CrossRef]
59. Mostafaeipour, A.; Mohammadi, K.; Sabzpooshan, M. Wind-solar energy potentials for three free trade and industrial zones of Iran. In Proceedings of the Fifth International Conference on Industrial Engineering and Operations Management (IEOM 2015), Dubai, UAE, 3–5 March 2015. [CrossRef]
60. Tizpar, A.; Satkin, M.; Roshan, M.B.; Armoudli, Y. Wind resource assessment and wind power potential of Mil-E Nader region in Sistan and Baluchestan Province, Iran—Part 1: Annual energy estimation. *Energy Convers. Manag.* **2014**, *79*, 273–280. [CrossRef]
61. Nedaei, M.; Assareh, E.; Biglari, M. An extensive evaluation of wind resource using new methods and strategies for development and utilizing wind power in Mah-shahr station in Iran. *Energy Convers. Manag.* **2014**, *81*, 475–503. [CrossRef]
62. Mirhosseini, M.; Sharifi, F.; Sedaghat, A. Assessing the wind energy potential locations in province of Semnan in Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 449–459. [CrossRef]
63. Mohammadi, K.; Mostafaeipour, A.; Sabzpooshani, M. Assessment of solar and wind energy potentials for three free economic and industrial zones of Iran. *Energy* **2014**, *67*, 117–128. [CrossRef]
64. Mostafaeipour, A.; Sedaghat, A.; Ghalishooyan, M.; Dinpashoh, Y.; Mirhosseini, M.; Sefid, M.; Pour-Rezaei, M. Evaluation of wind energy potential as a power generation source for electricity production in Binalood, Iran. *Renew. Energy* **2013**, *52*, 222–229. [CrossRef]
65. Fazelpour, F.; Soltani, N.; Soltani, S.; Rosen, M.A. Assessment of wind energy potential and economics in the north-western Iranian cities of Tabriz and Ardabil. *Renew. Sustain. Energy Rev.* **2015**, *45*, 87–99. [CrossRef]
66. Mostafaeipour, A. Feasibility study of harnessing wind energy for turbine installation in province of Yazd in Iran. *Renew. Sustain. Energy Rev.* **2010**, *14*, 93–111. [CrossRef]
67. Tezerjani, M.D. The Analysis of Wind Power Potential in Kerman Synoptic Stations, Iran—An Estimation Using the Weibull Density Function. *J. Climatol. Weather Forecast* **2015**, *3*, 1–13. [CrossRef]
68. SATBA (Renewable Energy and Energy Efficiency Organization). 2018. Available online: http://www.satba.gov.ir (accessed on 14 December 2018).
69. Fazelpour, F.; Markarian, E.; Soltani, N. Wind energy potential and economic assessment of four locations in Sistan and Balouchestan province in Iran. *Renew. Energy* **2017**, *109*, 646–667. [CrossRef]
70. GWEC (Global Wind Energy Council). *Global Wind Energy Outlook 2014*; Glob Wind Energy Council: Brussels, Belgium, 2014; pp. 1–60. [CrossRef]
71. Bahrami, M.; Abbaszadeh, P. An overview of renewable energies in Iran. *Renew. Sustain. Energy Rev.* **2013**, *24*, 198–208. [CrossRef]
72. Delucchi, M.A.; Jacobson, M.Z. Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies. *Energy Policy.* **2011**, *39*, 1170–1190. [CrossRef]

73. Gulaliyev, M.G.; Mustafayev, E.R.; Mehdiyeva, G.Y. Assessment of solar energy potential and its ecological-economic efficiency: Azerbaijan case. *Sustainability* **2020**, *12*, 1116. [CrossRef]
74. Najafi, G.; Ghobadian, B.; Mamat, R.; Yusaf, T.; Azmi, W.H. Solar energy in Iran: Current state and outlook. *Renew. Sustain. Energy Rev.* **2015**, *49*, 931–942. [CrossRef]
75. Dehghan, A.A. Status and potentials of renewable energies in Yazd Province-Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1491–1496. [CrossRef]
76. Noorollahi, Y.; Yousefi, H.; Itoi, R.; Ehara, S. Geothermal energy resources and development in Iran. *Renew. Sustain. Energy Rev.* **2009**, *13*, 1127–1132. [CrossRef]
77. Fridleifsson, I.B. Geothermal energy for the benefit of the people. *Renew. Sustain. Energy Rev.* **2001**, *5*, 299–312. [CrossRef]
78. Ramezani, A.; Torshizi, M.V.; Attari, A.; Tabarsa, F. Generating Electricity Using Geothermal Energy in Iran. *J. Renew. Sustain. Energy Rev.* **2018**, *4*, 42–55.
79. Youse, A.; Sasaki, K.; Youse, H.; Pirasteh, S.; Sugai, Y. GIS aided prediction of CO 2 emission dispersion from geothermal electricity production. *J. Clean. Prod.* **2011**, *19*, 1982–1993. [CrossRef]
80. International Hydrpower Association. *2018 Hydropower Status Report*; International Hydrpower Association: Romford, UK, 2018.
81. Bartle, A. Hydropower potential and development activities. *Energy Policy* **2002**, *30*, 1231–1239. [CrossRef]
82. Iran Water Resources Managment. Hydropower Plants in Iran. 2017. Available online: http://www.wrm.ir/SC.php?type=static&id=562 (accessed on 18 November 2018).
83. Iran to Build Dozens of Small Hydro Plants in Indonesia Through 2020. 2017. Available online: http://www.hydroworld.com/articles/2015/05/iran-to-build-dozens-of-small-hydro-plants-in-indonesia-through-2020.html (accessed on 11 November 2018).
84. World Energy Resources Bioenergy. 2016. Available online: https://www.worldenergy.org/publications/entry/world-energy-resources-2016 (accessed on 11 November 2019).
85. Kazem, H.A. Renewable energy in Oman: Status and future prospects. *Renew. Sustain. Energy Rev.* **2014**, *15*, 3465–3469. [CrossRef]
86. Kumar, A.; Kumar, K.; Kaushik, N.; Sharma, S.; Mishra, S. Renewable energy in India: Current status and future potentials. *Renew. Sustain. Energy Rev.* **2010**, *14*, 2434–2442. [CrossRef]
87. IRENA. *REmap: Roadmap for a Renewable Energy Future, 2016*; International Renewable Energy Agancy: Bonn, Germany, 2016; p. 172. [CrossRef]
88. Madadi, M.; Hoseini, S.M.; Khalili, I.; Abbas, A. A review on renewable energy resources in Iran. In Proceedings of the IInternational Conference on Sustainable Development, Strategies and Challenges, with a Focus on Agriculture, Natural Resources, Environment and Tourism, Tabriz, Iran, 7–9 March 2017.
89. Huu Hoang, N.; Fogarassy, C. Sustainability Evaluation of Municipal Solid Waste Management System for Hanoi (Vietnam)—Why to Choose the 'Waste-to-Energy' Concept. *Sustainability* **2020**, *12*, 1085. [CrossRef]
90. Taghizadeh-alisaraei, A.; Hasan, S.; Ghobadian, B.; Motevali, A. Biofuel production from citrus wastes: A feasibility study in Iran. *Renew. Sustain. Energy Rev.* **2016**, 1–13. [CrossRef]
91. Taghizadeh-Alisaraei, A.; Assar, H.A.; Ghobadian, B.; Motevali, A. Potential of biofuel production from pistachio waste in Iran. *Renew. Sustain. Energy Rev.* **2017**, *72*, 510–522. [CrossRef]
92. Ghorbani, A.; Rahimpour, M.R.; Ghasemi, Y.; Raeissi, S. The Biodiesel of Microalgae as a Solution for Diesel Demand in Iran. *Energies* **2018**, *11*, 950. [CrossRef]
93. Mohammad, S.; Ardebili, S.; Khademalrasoul, A. An Analysis of Liquid-Biofuel Production Potential from Agricultural Residues and Animal Fat (Case Study: Khuzestan Province). *J. Clean. Prod.* **2018**. [CrossRef]
94. Zareei, S. Evaluation of biogas potential from livestock manures and rural wastes using GIS in Iran. *Renew. Energy* **2018**, *118*, 351–356. [CrossRef]
95. Moosavi, S.A.; Aghaalikhani, M.; Ghobadian, B.; Fayyazi, E. Okra: A potential future bioenergy crop in Iran. *Renew. Sustain. Energy Rev.* **2018**, *93*, 517–524. [CrossRef]
96. Balat, M.; Balat, H. Biogas as a Renewable Energy Source—A Review. *Energy Sources Part A Recover. Util. Environ. Eff.* **2009**, *31*, 1280–1293. [CrossRef]
97. Enea Consulting. *Domestic Biogas Development in Developing Countries: A Methodological Guide for Domestic Biogas Project Holders in the Early Stages of Setting up Projects in Developing Countries*; Enea Consulting: Paris, France, 2013.

98. Afazeli, H.; Jafari, A.; Rafiee, S.; Nosrati, M. An investigation of biogas production potential from livestock and slaughterhouse wastes. *Renew. Sustain. Energy Rev.* **2014**, *34*, 380–386. [CrossRef]
99. Hosseini, S.E.; Wahid, M.A. Biogas utilization: Experimental investigation on biogas flameless combustion in lab-scale furnace. *Energy Convers. Manag.* **2013**, *74*, 426–432. [CrossRef]
100. Adl, M.; Omrani, G.-A. Background of biogas technology and its recent developments in Iran. *Int. J. Glob. Energy Issues* **2008**, *29*. [CrossRef]
101. Tehran Swage Company. The Largest Combined Heat and Power Plant of Biomass Energy in the Country. Available online: https://ts.tpww.ir (accessed on 4 January 2019).
102. Zanous, S.P.; Shafaghat, R.; Alamian, R.; Shadloo, M.S.; Khosravi, M. Feasibility study of wave energy harvesting along the southern coast and islands of Iran. *Renew. Energy* **2019**, *135*, 502–514. [CrossRef]
103. Babajani, A.; Jafari, M.; Hafezisefat, P.; Mirhosseini, M.; Rezania, A.; Rosendahl, L. Parametric study of a wave energy converter (Searaser) for Caspian Sea. *Energy Procedia* **2018**, *147*, 334–342. [CrossRef]
104. Fadaee Nejad, M.; Shariati, O.; Bin Mohd Zin, A.A. Feasibility study of wave energy potential in southern coasts of Caspian Sea in Iran. In Proceedings of the 2013 IEEE 7th International Power Engineering and Optimization Conference (PEOCO), Langkawi, Malaysia, 3–4 June 2013; pp. 57–60. [CrossRef]
105. European Ocean Energy Association. *Oceans of Energy—European Ocean Energy Roadmap 2010–2050*; European Ocean Energy Association: Brussels, Belgium, 2010.
106. Bilgili, M.; Ozbek, A.; Sahin, B.; Kahraman, A. An overview of renewable electric power capacity and progress in new technologies in the world. *Renew. Sustain. Energy Rev.* **2015**, *49*, 323–334. [CrossRef]
107. Soleimani, K.; Ketabdari, M.J.; Khorasani, F. Feasibility study on tidal and wave energy conversion in Iranian seas. *Sustain. Energy Technol. Assess.* **2015**, *11*, 77–86. [CrossRef]
108. Radfar, S.; Panahi, R.; Javaherchi, T.; Filom, S.; Mazyaki, A.R. A comprehensive insight into tidal stream energy farms in Iran. *Renew. Sustain. Energy Rev.* **2017**, *79*, 323–338. [CrossRef]
109. Zabihian, F.; Fung, A.S. Review of marine renewable energies: Case study of Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2461–2474. [CrossRef]
110. Kamranzad, B.; Etemad-shahidi, A.; Chegini, V. Assessment of wave energy variation in the Persian Gulf. *Ocean Eng.* **2013**, *70*, 72–80. [CrossRef]
111. Alamian, R.; Shafaghat, R.; Miri, S.J.; Yazdanshenas, N. Evaluation of technologies for harvesting wave energy in Caspian Sea. *Renew. Sustain. Energy Rev.* **2014**, *32*, 468–476. [CrossRef]
112. Naghiloo, A.; Abbaspour, M.; Mohammadi-ivatloo, B. Modeling and design of a 25 MW osmotic power plant (PRO) on Bahmanshir River of Iran. *Renew Energy* **2015**, *78*, 51–59. [CrossRef]
113. Saket, A. Wave energy potential along the northern coasts of the Gulf of Oman, Iran. *Renew Energy* **2012**, *40*, 90–97. [CrossRef]
114. Veras, T.D.S.; Mozer, T.S.; Santos, D.D.C.R.M.D.; César, A.D.S. Hydrogen: Trends, production and characterization of the main process worldwide. *Int. J. Hydrogen Energy* **2017**, *42*, 2018–2033. [CrossRef]
115. Ehsan, S.; Wahid, M.A. Hydrogen production from renewable and sustainable energy resources: Promising green energy carrier for clean development. *Renew. Sustain. Energy Rev.* **2016**, *57*, 850–866. [CrossRef]
116. Momirlan, M.; Veziroglu, T. The properties of hydrogen as fuel tomorrow in sustainable energy system for a cleaner planet. *Int. J. Hydrogen Energy* **2005**, *30*, 795–802. [CrossRef]
117. Nikolaidis, P.; Poullikkas, A. A comparative overview of hydrogen production processes. *Renew. Sustain. Energy Rev.* **2017**, *67*, 597–611. [CrossRef]
118. Mori, D.; Hirose, K. Recent challenges of hydrogen storage technologies for fuel cell vehicles. *Int. J. Hydrogen Energy* **2009**, *34*, 4569–4574. [CrossRef]
119. Aardahl, C.; Rassat, S. Overview of systems considerations for on-board chemical hydrogen storage. *Int. J. Hydrogen Energy* **2009**, *34*, 6676–6683. [CrossRef]
120. Eberle, U.; Felderhoff, M.; Schüth, F. Chemical and Physical Solutions for Hydrogen Storage. *Angew. Chem. Int. Ed.* **2009**, *48*, 6608–6630. [CrossRef]
121. Dincer, I. Green methods for hydrogen production. *Int. J. Hydrogen Energy* **2012**, *37*, 1954–1971. [CrossRef]
122. Dieguez, P.; Ursua, A.; Sanchis, P.; Sopena, C.; Guelbenzu, E.; Gandía, L.M. Thermal performance of a commercial alkaline water electrolyzer: Experimental study and mathematical modeling. *Int. J. Hydrogen Energy* **2008**, *33*, 7338–7354. [CrossRef]
123. International Renewable Energy Agancy (IRENA). *Hydrogen from Renewable Power Technology Outlook for the Energy Transition*; International Renewable Energy Agancy: Bonn, Germany, 2018.

124. Rezaei, M.; Mostafaeipour, A.; Qolipour, M.; Arabnia, H.-R. Hydrogen production using wind energy from sea water: A case study on Southern and Northern coasts of Iran. *Energy Environ.* **2018**, *29*, 333–357. [CrossRef]
125. Mostafaeipour, A.; Khayyami, M.; Sedaghat, A.; Mohammadi, K.; Shamshirband, S.; Sehati, M.-A.; Gorakifard, E. Evaluating the wind energy potential for hydrogen production: A case study. *Int. J. Hydrogen Energy* **2016**, *41*, 6200–6210. [CrossRef]
126. Alavi, O.; Mostafaeipour, A.; Qolipour, M. Analysis of hydrogen production from wind energy in the southeast of Iran. *Int. J. Hydrogen Energy* **2016**, *41*, 15158–15171. [CrossRef]
127. Shiroudi, A.; Reza, S.; Taklimi, H. Demonstration project of the solar hydrogen energy system located on Taleghan-Iran: Technical-economic assessments. In Proceedings of the World Renewable Energy Congress-Sweden, Linköping, Sweden, 8–13 May 2011; pp. 1158–1165.
128. Moallemi, E.A.; Ahamdi, A.; Afrazeh, A.; Bagheri, N. Understanding systemic analysis in the governance of sustainability transition in renewable energies: The case of fuel cell technology in Iran. *Renew. Sustain. Energy Rev.* **2014**, *33*, 305–315. [CrossRef]
129. Alipour, M.; Sheykhan, A. A vision for Iran's fuel cell and hydrogen development. *Int. J. Environ. Sci. Technol.* **2017**, *14*, 193–210. [CrossRef]
130. Németh, K.; Birkner, Z.; Katona, A.; Gölléný-Kovács, N.; Bai, A.; Balogh, P.; Gabnai, Z.; Péter, E. Can Energy Be a "Local Product" Again? Hungarian Case Study. *Sustainability* **2020**, *12*, 1118. [CrossRef]
131. Renewable Energy Policy Network for the 21st Century. *Renewables 2010 Global Status Report*; Renewable Energy Policy Network for the 21st Century: Paris, France, 2010.
132. Renewable Energy Policy Network for the 21st Century. *Renewables 2018 Global Status Report*; Renewable Energy Policy Network for the 21st Century: Paris, France, 2018.
133. Kordvani, A.; Hassan, M. Renewable Energy in Iran. 2016. Available online: http://www.satba.gov.ir/suna_content/media/image/2017/02/5196_orig.pdf?t=636219021775330000 (accessed on 6 June 2019).
134. Fadai, D.; Esfandabadi, Z.S.; Abbasi, A. Analyzing the causes of non-development of renewable energy-related industries in Iran. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2690–2695. [CrossRef]
135. Imolauer, K. Renewable Energies in Iran—A Market of the Future? Rödl Partn. 2017. Available online: https://www.roedl.com/insights/erneuerbare-energien/2016-04/renewable-energies-in-iran (accessed on 9 February 2018).
136. Renewable Energy and Energy Efficiency Organization (SATBA). Application and Permit Issuance Process. 2019. Available online: http://www.satba.gov.ir/en/investmentpowerplants/applicationandpermitissuanceprocess (accessed on 9 February 2019).