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Review Article

Assessing Economic, Social, and Environmental Impacts of Wind Energy in Iran with Focus on Development of Wind Power Plants

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ABSTRACT

As a key economic element, energy plays an important role in the development of societies. Economic growth and its urgent need for energy highlight the need for optimal energy use. Wind energy is an energy source that has become an increasingly common source of electricity. In this study, socio-economic impacts of the cost of electricity generated by wind power plants were assessed with Iran as the focus of this study. The environmental impacts of wind energy were also considered by reviewing and analyzing research papers. Studies showed that although the use of wind energy in Iran began in Manjil in northern Iran, no significant progress has been made in this field despite all the efforts over the past years. The results indicated that the initial cost of launching wind turbines was the most important factor in the failure of this technology. The costs of purchasing turbines, construction of roads, provision of electrical infrastructure, project management, installation of turbines, insurance premiums, grid connections, and power lines were shown to affect costs of energy production. Furthermore, operation and maintenance costs, the choice of installation location, increasing production capacity, expansion of the energy market, and policies in the country can play an essential role in determining the cost of wind energy production. Given that power generation using wind turbines are economical, it is recommended that turbines be installed in suitable windy locations. In addition, considering that one of the crises facing the world and especially Iran is environmental pollution, utilizing energies such as wind energy for generating electricity is advised due to their lower pollutant emissions and lower economic and social costs.

1. INTRODUCTION

Globally, the wind power industry has been growing at a staggering rate of nearly 30 % per year for the last 10 years. The major portion of this development is occurring in European, North American, and Asian markets. Such worldwide success has put exceptional pressure on the manufacturers of wind turbine components such as towers, rotor blades, gearboxes, bearings, and generators. In general, wind turbine components are large and heavy and their production process is complex and has long production cycles. These attributes are reflected clearly in the supply chain processes [1].

Even though wind power is more expensive than other forms of renewable power generation, using wind energy reduces the exposure of countries' economies to fuel price volatility. This risk reduction is presently not accounted for by the standard methods used by experts when calculating the costs of energy production. However, wind power is shown to be a long-term investment if public authorities calculate energy costs while taking risk reduction costs into account [2].

Today, issues such as climate change, rising fuel costs, security of energy supply, conflicts over oil and water, pollution, and other environmental crises are very common [3]. Annually, there are numerous conventions and agreements on energy use. In recent decades, increasing population and the rising demand for energy as well as fear of fossil fuel depletion have underlined the importance of paying attention to new and renewable energies. As a result, application of renewable energies is hailed as one of the most important methods of demand reduction and crisis management in the field of energy [4, 5, 6].

Energy and environment are highly interconnected [7] because energy is generated through the environment and can have a negative effect on it. Raising awareness of the impact of human activities on the natural environment leads to the sustainable use and conservation of energy [8]. Energy sources can be divided into three main groups including fossil fuels (oil, gas and coal), nuclear energy, and renewable energies (wind, solar, geothermal, hydroelectric, and biogas) [9, 10]. Studies show that fossil fuel reserves are limited; globally, more than 11 billion tons of fossil fuels are consumed every year [11, 12, 13]. Meanwhile, oil reserves are consumed at a rate of 4 billion tons per year. The exhaustion of fossil fuels in the near future has necessitated the use of renewable energies [14, 15, 16]. Renewable energies do not cause pollution and environmental degradation associated with fossil fuels, and nuclear energy is unlimited [17, 18].

Since ancient times, people have used wind energy. More than 5,000 years ago, ancient Egyptians used the wind to navigate their ships the Nile. Later, people used wind energy to grind wheat. The first windmills were built in Iran. Several centuries later, the people of the Netherlands improved the

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initial design of this windmill. The wind energy market is a more competitive market than fossil fuel plants. Electricity produced by wind power offers new benefits to nearby people and industries. In addition, efforts have been made by various countries to generate electricity using wind energy [19, 20, 21, 22, 23].

Due to its geographical and climatic variety, Iran has undertaken the Five-Year Plan for Economic, Social and Cultural Development at the national level. In the energy sector the use of new and renewable energies is emphasized [24, 25] through 10,598 MW of renewable power plants (hydro, wind, solar, and biogas) to generate electricity as well as photovoltaic systems with a capacity of 584 KW and production of 40 MWh. Renewable energy has a rich potential for creating jobs in many parts of Iran through construction, installation, and repair of large and small turbines and plants. Further, the rising global concerns about energy insecurity and climate change have created a strong export potential for renewable energy technologies.

Being diverse in geography, Iran is a suitable country for extensive use of renewable energy sources [26]. The use of new energies in Iran and others, which have the potential to be the pioneers of utilizing new energy technologies, can be highly advantageous [27]. In this regard, identification of suitable areas and potential evaluation of wind energy production in the country have become unavoidable necessities for policymakers and planners [28, 29]. Various studies on this issue have been carried out or are under consideration, investigating the development of wind power plants, cost-effectiveness wind energy, its environmental and social impacts, etc. [30].

New Energy Deputy of Ministry of Energy and the Office of Wind and Wave of Iran's New Energy Organization are responsible for the development and implementation wind energy initiatives. The activities of organizations include potential assessment, preparation of the country's wind atlas, promoting and planning the implementation of plans to harvest wind energy, installing wind monitoring stations to study feasibility of building wind farms, and design management. The organizations also installed wind turbines in Manjil, Dizbad (Khorasan Razavi Province in eastern Iran) and Bojnourd (North Khorasan Province in northeastern Iran) and cooperate with the Global Environmental Facility Fund to develop wind power plants and identify the associated challenges [30, 31, 32].

Recently, there has been a dramatic increase in the investment of governments and the private sector in research and development of renewable energies. A variety of new technologies are also available for use in renewable energies, which has reduced the cost of generating electricity using renewable sources and has made renewable energies more competitive than traditional power generation systems [33, 34]. At present, the cost of generating electricity using some renewable sources, such as wind energy, is competitively better than that of fossil fuels [35]. Therefore, it is necessary for Iran to make further progress in this regard.

The growing economies of Asian countries, including Iran, have increased electricity demand of these countries and encouraged them to start generating electricity from non-fossil sources. The lack of a nationwide power network in many Asian countries has also increased the use of wind power systems for power generation in villages. Using wind energy in Iran has conserved oil products, helped preserve the environment, and reduced environmental pollution, along with providing sustainable social and economic development. Wind energy is essential to increasing household income in Iran. Also, access to electricity generated by wind energy is one of the key services with the largest poverty-reducing potential. While the annual electricity consumption per capita in EU27 countries averages 6,000 KWh, it is only 3,000 KWh in Iran [36].

In this study, reliable sources have been consulted on the important factors influencing the process of power generation using wind energy and its environmental impacts. In addition, experts' opinions have been also consulted. Valid scientific websites and scholarly references were included in the research, as well.

2. END OF FOSSIL FUELS

Currently, the major portion of the world's energy comes from fossil fuels [37, 38]. Therefore, due to the depletion of fossil fuels in the near future and increased energy consumption, concerns have been raised for its replacements [39]. Supplying energy for the next generations will be a major challenge [40, 41]. In 2030, global energy consumption will have doubled. Global demand for energy between 2000 and 2030 will increase by 1.8 % annually [42]. Currently, the question is whether fossil fuels will meet the global energy needs for survival and development in the next century.

Studies show that the expected life span of underground energy sources will not last for more than a hundred years on average, hence paying attention to alternative sources is necessary [43]. An increase in per capita demand and population growth have led to more pressure on natural resources. These resources include surface and underground water, clean air, and natural landscapes. According to the World Health Organization, 2.4 million people die each year due to air pollution. Demand for energy will affect the quality and quantity of non-renewable natural resources through the environmental damage caused by mining, depletion of underground aquifers due to excessive use, and degradation of surface soil which can lower crop yields and impact public health. Many environmental issues related to energy are associated with climate change, which is mainly the result of fossil fuel consumption and its direct impact on greenhouse gas emissions. In recent years, there has been an increasing trend in various commercial sources of renewable energy [44, 45, 46].

3. THE NEED TO DIVERSITY THE ENERGY SECTOR

Supplying energy in a country like Iran requires accurate and scientific planning. However, what has happened in practice is provision of energy as mainly oil and natural gas. In the past, more than 95 percent of the country's energy sector consisted of these two sources [47]. Change in energy sector of the country in recent years and the replacement of oil with gas have led to the ongoing development of the country's natural gas transmission network. In 2011, natural gas consumption in Iran increased by 6 % compared to 2010 [48]. The diversification of the energy sector with a move towards renewable energies has been the target in developed countries [49, 50]. Disturbances in the natural gas production system will affect the entire energy supply system, in turn causing political and social crises, even in the short term [51].

In the global energy basket, the role of renewable energies has been expanding, leading the global energy sector to move towards diversification and use of indigenous energy sources [52]. In this regard, the European Union adopted a plan on

January 23, 2008 whereby the share of renewable energies will reach 20 % in the average basket of member states by 2020 [53, 54, 55].

The use of energy is strongly linked to various social issues such as poverty reduction, population growth, urbanization, and opportunities for women. Poverty is the most important social concern for developing countries and one of the main threats to political stability in many countries. About 1.3 billion people in developing countries live on less than $1 a day. Although income is the only indicator used to measure the inferior social conditions of poor people, their energy use patterns, i.e., their dependence on traditional fuels, have also contributed to their poverty. Consequently, increasing income through energy production, employment, access to safe drinking water, and diminished need to collect fuel are the social benefits of generating energy from renewable sources [56].

Although it is generally accepted that population growth contributes to increasing energy demand, broadly speaking, access to appropriate energy services can reduce birth rates. Energy services can change the relative costs and benefits of childbearing toward the reduction of the desired number children in a family. Achieving low mortality and fertility (as is the case in industrialized countries) depends on realizing the vital goals of development including improving the local environment, training women, and decreasing extreme poverty [56, 57, 58].

4. STATUS OF RENEWABLE WIND ENERGY IN THE WORLD

In recent years, the global average annual growth of wind energy has been reported to be around 30 %, which is the highest growth rate among energy sources [59]. At present, the global wind energy market is dominated by China, United States, Germany, Spain, and India, which all have a production capacity of over 1 GW per year. The following table shows the capacity of wind farms in some of the leading countries in this industry (see Tables 1 and 2).

Table 1. Capacity of wind turbines during 2002-2018 (GW) [59].

Year / Country	2002	2004	2006	2008	2010	2018	Percent of total 2018
China	0.46	0.76	2.59	12.21	42.28	216.87	40.67
United States	4.68	6.72	11.60	25.17	40.18	96.36	18.07
Germany	12	16.62	20.62	239.02	27.21	59.31	11.12
Spain	4.83	8.26	11.63	16.74	20.67	23.41	10.64
India	1.70	3	6.27	9.58	13.06	35.01	6.56
Iran	0.02	0.04	0.06	0.08	0.21	0.70	0.13
World	31.18	47.69	74.12	120.02	194.39	533.12	100

Table 2. Power generated using wind by the top countries in 2017 (TWh) [82].

No.	Country	Wind power generation (TWh)
1	China	305
2	United States	257
3	Germany	106
4	United Kingdom	50
5	Spain	49.1
6	India	47.7
7	Brazil	42.3
8	Canada	28.8
9	France	24.7
10	Turkey	17.9
11	Iran	16

5. INSTALLATION CAPACITY AND CAPACITY FACTOR FOR WIND TURBINE PRODUCTION IN THE WORLD

A report released by World Wind Energy Association in February 2010 which includes wind energy development figures in more than 91 countries shows that the global installation rate reached 19.919 GW in 2010, which means the total installation capacity increased from 1207 GW in 2008 to 1585 GW in 2010. Since wind speed is not constant, the actual annual energy output of a wind generator is not equal to the value of the generator's generating capacity multiplied by the hours [60]. The ratio of actual production in one year to the theoretical maximum is called the capacity factor [61, 62]. A generator located in a very favorable area will have a capacity ratio of about 35 % due to the changing nature of the wind [63].

The capacity factor of other types of power generation sources is dependent on parameters such as fuel cost and the time required for maintaining and supplying the system [64, 65]. Nuclear fuel plants have low fuel costs; in most cases, they work at their maximum capacity and, therefore, have a capacity factor of over 90 % [66]. Fuel-fired power plants are controlled by a steam valve to estimate and keep track of the required load. According to a report released by Stanford University in 2007, connecting 10 or more wind farms in a wide geographic area hardly allows for one-third of the total produced energy to be calculated as a base load [67].

Using storage systems such as pump storage or other types of storage will result in a 25 % increase in wind farm costs, but seem to be necessary to ensure reliable load [68]. Storage of electrical energy effectively balances the lower cost of electricity at times of high production and low demand with the higher cost at times of high demand and low production. The potential income from this compromise should balance the costs of installing and operating storage systems.

Electric power consumption can be coordinated with production changes using tools such as energy management and smart metering tools. This creates a variable electric energy pricing system at different hours of the day. For example, urban water pumps that feed water towers do not need to work continuously and at all hours; therefore, their operation hours can be limited to when electrical energy is abundantly available at low cost. Consumers can also choose the right time to use electrical tools.

Currently, the use of wind pumps in the US is increasing. Many lands in arid and semi-arid areas are irrigated using such pumps. At a wind speed of 24 km/h, a wind pump with a diameter of 3.6 m can produce 0.16 horsepower. This amount of energy can easily raise 159 L of water per minute to a height of 8.7 m. Research by UNESCO has shown that in arid areas, mills with a diameter of 15 m can produce 100,000 KWh of electricity per year at a wind speed of 20 km/h, which can be used for water heaters, pumps, and other uses in a unit of 100,000 people. In Denmark, wind turbines with a diameter of 54 m installed on 53-meter towers can generate 2 MW of electricity at a wind speed of 15 m/s [69, 70].

6. FUTURE PERSPECTIVES AND GLOBAL APPROACH TOWARD USING WIND POWER PLANTS TO GENERATE ELECTRICITY

The objectives and policies of different countries to provide electricity using wind energy in the coming years are as follows: Germany plans to generate 30 % of its electricity through constructing 54 GW worth of wind farms by 2030. The United States plans to meet 6 % of its electricity demand in 2020 by installing 100 GW worth of wind farms. The United Kingdom will supply 20 % of the country's electricity by generating additional 15 GW of energy by 2020. Japan plans to install 11.8 GW of wind power plants by 2030. Australia will generate 20 % of its electricity by wind farms in 2040. Brazil will supply 10 % of its electricity by constructing wind farms by 2022. China will build a 20 GW power plant by 2020 [71, 72, 73, 74].

7. HISTORY OF WIND ENERGY TECHNOLOGY RESEARCH IN IRAN

Iran was the first country to use wind energy for agriculture 2,500-3,000 years ago. The use of wind energy then spreads to other Islamic countries and Europe. The Americas and other parts of the world also used wind energy for various purposes such as water pumping and irrigation, milling of cereals, electricity generation, and mechanical applications such as sawing wood and making handicrafts. In the 14th century, the Netherlands was the most advanced country in this field and used wind energy for irrigation, but in 1890 Denmark was the first country to use wind energy for electricity generation using a wind turbine. Currently, Iran is well positioned in the region to build wind turbines. The 28.3 MW wind power plant in Binalood Heights in Dizbad area is one of the operational wind farms in Iran. In addition, the 120-day winds of Sistan in eastern Iran and the wind in Manjil and Kahak in Qazvin can be harnessed to generate electricity [75, 76].

Due to the existence of windy areas, design and manufacturing of windmills have been common in Iran since 2000 BC. Similarly, there is a good potential for expanding the use of wind turbines at present. Wind power generators can be a good alternative to gas and steam generators. Studies and calculations to estimate the potential of wind energy in Iran show that in 26 regions of the country, spanning more than 45 sites, the nominal capacity of sites with a total efficiency of 33 % is about 6,500 MW.

Iran has diverse climates and this diversity can be seen when comparing different parts of the country [77]. Iran is surrounded by high mountains on every side and is located between warm regions in the south and temperate regions in the north at the junction of atmospheric streams between Asia, Europe, Africa, the Indian Ocean, and the Atlantic Ocean. The effects of various factors on a given region determine the climate of that region, each factor making a unique contribution to climatic conditions. These factors include latitude (i.e., the distance from the equator and the north and south poles), elevation, topography, the presence of large bodies of water, air pressure and circulation, winds, and precipitation.

Mountainous terrain, the presence of large bodies of water in the north and south, the distance of central regions from open seas, distance from the vast plains of Asia, and the presence of high mountains around and within the country have made Iran a unique country where different climates can be seen. In winter, Iran is exposed to winds that blow from the Atlantic Ocean and Central Asia. In summer, winds originating from Iceland and Scandinavia enter Iran from the northwest and winds rising from the Indian Ocean blow from the south [78, 79, 80].

7.1. Capacity of installed wind turbines

Wind energy can be a suitable source of power generation in eastern Iran. In a new study on wind potential, 45 experimental areas were investigated. The future potential capacity was estimated at 6,500 MW. The installed capacity is currently only 11 MW, compared to 69 MW in Egypt and 54 MW in Morocco [81]. Wind farms have been established in several provinces in Iran to record data on wind potential and determine the true potential of wind energy in Iran. A total of 16 stations can be found in Gilan, West Azarbaijan, East Azarbaijan, and Ardabil.

A 600 KW wind turbine was built in Babian village, Gilan province. This area has a wind potential of 100 MW. The region's average wind speed at 40 m above ground is about 10 m/s. A total of 1250 KW/m^2. y of energy is produced in this area. Considering its potential and its efficient wind patterns, this area is one of the most suitable areas for installing wind turbines. The experimental wind turbine is a 40 m horizontally mounted turbine with an axle to gearbox configuration. A 20-

KW electric power transmission line and a power station is installed to transfer the power generated by the wind turbines. The total capacity of the 1723 wind turbines (660-KW turbines) in Manjil, Herzowil, and Siahpush sites in Gilan province in northern Iran was about 46.24 MW from 2003 to 2007. The capacity of the wind farm installed in the Binalood site in Khorasan province with twenty-three 660-KW turbines was about 28.4 MW from 2006 to 2007 [82].

At the end of 2011, Iran's total installed wind capacity was 93 KW. Over the last two years, only 3 MW has been added to the country's installed capacity, which is considerably behind the government's target of 500 MW by 2009. According to the Iranian ministry of energy, wind power generated around 220 GWh of electricity in 2010. In addition, the Iranian government set a new target of 1.5 GW by the end of 2013, which is much higher than the current statistics. The following table illustrates the total installed capacity in Iran between 2002 and the end of 2011 (Table 3) [83].

Table 3. Potential of wind energy in Iran [83].

Description	Value
Average wind power density (w/m^2)	150
Total wind potential (MW)	152000
Covered area (km^2)	145138
Potential for wind power development (MW)	142000
Available technical potential (MW)	30000-40000

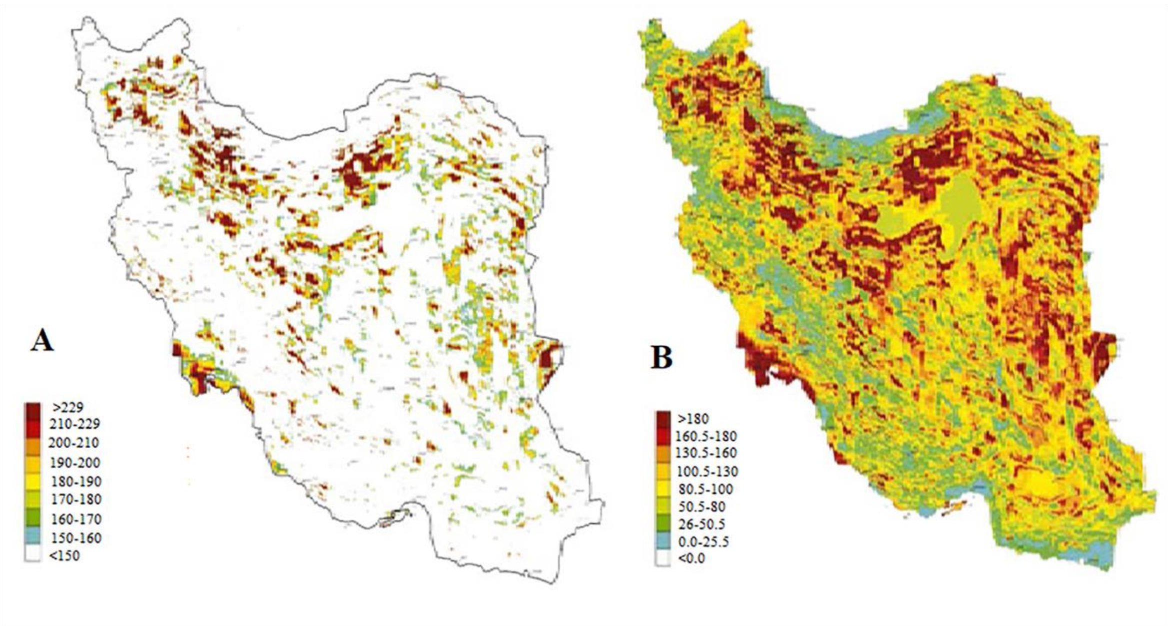

Figure 1. Regions with wind energy greater than 150 W/m^2 at 60 m above ground (A) and wind energy density at 60 m (B) [83]. Note that Figures 1A and 1B show regions with wind energy greater than 150 W/m^2 at 60 m above ground and wind energy density at 60 m, respectively.

Based on the current research and the existing technology of wind turbines, it is estimated that wind energy potential of Iran is more than 15,000 MW for power generation. Since swamps are commonly found in Iran, using wind energy is not only possible but also economically feasible [83, 84].

7.1.1. Optimal location of wind turbines

As a general rule, the use of wind turbines is practical where the average wind speed is 5.4 m/s (16 km per hour) or more. Location of wind power plants is usually pre-selected using a wind atlas and is confirmed by wind measurements. Meteorology plays an important role in determining possible locations for installing wind power plants, but meteorological data on wind alone are not adequate for accurate placement of large wind farms [85]. Meteorological data of an area are important for determining its potential. The ideal location to install wind turbines is a site with almost constant wind circulation throughout the year and the smallest possible change of wind. An important factor in locating wind turbines is access to local load or transmission capacity (i.e., access to transmission lines with empty capacity). A very critical stage in the development of a high potential location is collecting accurate and verifiable data on the speed and direction of wind, along with other parameters [86].

7.2. Small-scale wind power

Small-scale wind power equipment (100 KW or less) is usually used to provide electricity for houses, agricultural lands, or small businesses. In remote locations that depend on diesel generators, people might prefer to use wind turbines to reduce fuel dependency [87]. In some cases, wind turbines are also used to reduce the cost of purchasing electricity or to generate clean electricity. Providing electricity for remote houses is achieved by connecting wind turbines to batteries. In the United States, the use of wind turbines in the 1-10 KW range is becoming increasingly common for houses that are connected to the network as well. Network-connected turbines eliminate the need for network power when the turbine is active. In systems that are not connected to the network, power should be used periodically or a battery should be used to store the energy. In urban areas where wind cannot be used on a large scale, wind energy can be used for applications such as parking meters or wireless internet hotspots by using a battery or a solar battery to eliminate the need for network connectivity.

7.3. Trends in cost and growth

Figures from the Global Wind Energy Council (GWEC) show that the global installed capacity increased to 51.3 GW by 2018. Total installed wind energy capacity was 591 GW in 2018, a growth of 9.6 % compared to the end of 2017. Despite the limitations of wind turbines, the wind energy market continued to grow at 32 % after 2005 and reached 41 % growth in 2019. In terms of economic value, the wind energy sector was valued at about 18 billion euros or 23 billion dollars in 2006, including the value of newly installed equipment, which makes wind energy one of the most important players in the energy market [88, 89]. Based on installed capacity in 2019, the China had the highest capacity (237029 MW) followed by United States, Germany, India, Spain, United Kingdom, and France with capacities of 105433, 61357, 37529, 25808, 23515, and 16646 MW, respectively.

In 2004, the cost of wind energy was one-fifth of its cost in the 1980s. Some experts expect further decline in cost as larger turbines with higher capacities are put in to service. However, the cost of facilities increased in 2005 and 2006. According to the American Wind Energy Industries Business Group, the average cost of wind energy per kilowatt is $1,600, which is comparable to $1,200 per kilowatt a few years ago.

The main methods of generating electricity are expensive, meaning that they need large investments at the beginning of the project and less investment later on (e.g., fuel and maintenance costs). These conditions are true for both wind power and hydroelectricity. However, fuel costs are close to zero for these two methods and the maintenance cost is negligible [90]. According to the Iranian Wind Energy Industries, the average cost of wind energy per kilowatt is $0.6, with a five-year return on investment. So far, 135 MW worth of wind turbines has been installed, of which 95 MW is installed in government projects. The private sector has not invested heavily in wind energy [91].

8. POSITIVE ENVIRONMENTAL EFFECT OF WIND ENERGY

The most important advantage of wind energy is that it does not release chemicals and pollutants into the environment. In contrast, power plants using fossil fuels release carbon dioxide, sulfur dioxide, and nitrogen oxides into the atmosphere. Toxic heavy metals and suspended particles are also produced by these power plants. Combustion gases of coal-fired power plants are desulphurized using limestone/gypsum. In this process, 90 % of the sulfur dioxide is captured, but the remaining 10 % is still above the standards.

The emission of pollutants from fossil fuels depends on the type of fuel and its quality. For example, in a gas-fired power station, the emission of sulfur oxides is relatively low. In these power plants, the problem is the release of nitrogen oxide, carbon dioxide, and other nitrogen oxides. Ten ppm of sulfur dioxide and nitrogen oxide can cause acid rain, subsequently causing environmental damage.

Seventy-five percent of the global carbon dioxide emission is due to combustion of fossil fuels. The release and accumulation of this gas in the atmosphere and the resulting intensification of the greenhouse effect are the main cause of global warming. Global warming causes changes in meteorological patterns and land use as well as rising sea levels.

Another problem caused by combustion of fossil fuels is the formation of smog. Similarly, suspended particles and toxic heavy metals in the atmosphere cause asthma and lung cancer. Fossil fuel plants consume a large amount of water in the thermodynamic cycle. Moreover, a large volume of water is used to wash coal. This is a serious problem when there is a shortage of water. The need for water in wind power plants is insignificant and only a small amount of water is needed to clean the blades. Nuclear power plants pose environmental hazards, as well. Wind energy does not produce pollutant gases or suspended particles and does not have the problem of radiation and waste management [92,93].

Natural gas is Iran's primary fuel source for electricity generation, accounting for 70 % of total generation. In 2016, Iran generated almost 276 billion KWh of electricity, of which 93 % was from fossil-fuel sources. Wind power does depend on gas or oil; therefore, wind power conserves fossil fuels [94].

Iran is a dry country and the average water consumption in Iranian power plants is 1.05 m^3/mWh. These power plants generate 262,000 GWh/year of electricity, requiring 275 million m^3 of water annually. Wind turbines do not need water for power generation and could save 275 million m^3 of water annually [95,96].

9. NEGATIVE ENVIRONMENTAL IMPACT OF WIND ENERGY

Human intervention in every natural environment will have environmental consequences and wind energy is no exception in this regard. Although wind is one of the cleanest sources of energy, it is associated with several environmental issues. These issues include death of birds as a result of collision with wind turbines, noise, and undesirable visual effects [97].

9.1. Death of birds due to collision with wind turbines

A report in 1980 on the death of birds due to collision with wind turbines at a wind farm 90 km from San Francisco, California, brought attention to this issue [97]. The most commonly used method for investigating this problem is to study the mortality of birds before and after the installation of wind turbines [97]. Some of the most important precautions that can be considered to reduce the risk of bird-turbine collisions include [98, 99]:

A- Turbine blades narrow than 60 cm
B- A distance of 1000 m between turbines
C- Painting the blades if possible (this is especially useful in the direction of birds' migration)
D- Using sound to drive birds away from turbines

In general, the risk of death due to collision with wind turbines is not severe enough to merit several projects. For example, 1250000 birds die from collision with tall buildings, skyscrapers, and telecommunication towers around the world. Similarly, nearly 98 million birds die every year as a result of collision with windows. In addition, 57 million birds are killed in collisions with cars. A four-year study showed that 54 % of deaths were due to collisions with power generation systems and transmission lines, while 38 % were caused by wind turbines. While discussing death of birds due to collision with wind turbines, the effects of other energy generation technologies on the environment should also be considered such as emission of greenhouse gases and acid rain, which have more destructive effects on the environment. Although the death toll of wind turbines is relatively small, organizations around the world have to try to minimize the losses. For this purpose, activities are ongoing in the United States and the United Kingdom [99].

9.2. Noise pollution

Noise is defined as any unwanted sound. In the past, due to the small number of turbines, the problem of noise was not an issue. Nowadays, however, due to the increasing development of these systems in industrialized and developing countries, it has become an important concern. Hence, researchers seek to design and construct turbines with the lowest noise level [63]. The easiest way to determine the level of noise pollution is to visit the turbine installation site. To measure it more precisely, a sound meter can be used. The American Wind Energy Association [63] has defined standards to minimize the error in sound measurements. According to this standard, the sound intensity of a wind turbine with a speed of 8 m/s should be measured at 8 m from the ground.

The two types of sound created by a wind turbine are mechanical and aerodynamic. Mechanical sound is created by relative movement of parts such as the gearbox, generator, right-to-left motors, cooling fans, hydraulic pumps, and other accessories. For example, intensity of the noise from the gearbox, generator, and other accessories in a wind turbine is 97.2 dB, 87.2 dB, and 76.7 dB, respectively. Therefore, a change in the design of these three parts can reduce noise pollution. Assessing the effects of the noise emitted by the wind farm in Manjil, Iran on the general health of the staff showed that low frequency sound (60 dBA) can cause harmful effects on the health of workers [78].

10. ECONOMIC IMPACT OF WIND ENERGY

Since the Industrial Revolution, humankind has achieved remarkable economic growth and attained more prosperity and comfort. Total energy consumption has increased in tandem with economic and population growth and in the meantime, environmental problems associated with human activities have become more intense [99].

The economy plays an important role in choosing the right option for energy production by the market. One of the major constraints on the use of renewable energy is the high cost of the technology [99, 64, 77]. However, technological developments in the field of wind turbines have made the use of wind energy a more viable option than other sources such as solar energy, thermal energy, biomass, and hydroelectricity. Figure 2 shows the cost of wind energy in a 40-year period.

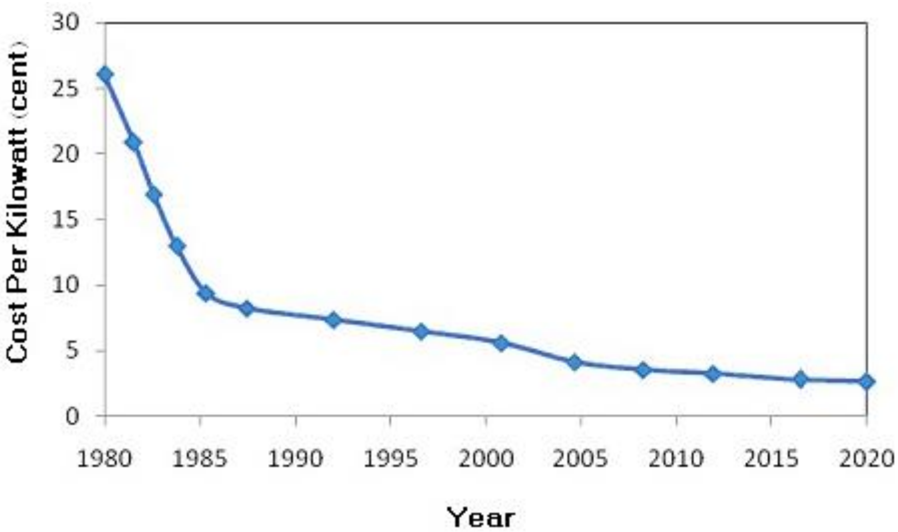

Figure 2. Changes in the cost of wind energy generation between 1980 and 2020 [25].

As is shown in Figure 2, the per-kilowatt cost of energy was 26.5 cents in 1980 and 5 cents in 2005. This means that expenses have decreased by 84 % over 23 years. There is hope that this decline will continue further with advances in our knowledge about wind turbines.

10.1. Factors affecting the cost of energy

Studies show that small wind turbines with a capacity of less than 100 KW used in residential areas are estimated to cost approximately $3,000 to $8,000 per kilowatt. The cost of a 10-KW wind turbine (suitable for use in a large residential building) varies between $50,000 and $80,000, depending on the type and height of the tower, among other variables [99]. It should be noted that the primary costs include the cost of turbines, construction of roads, electrical infrastructure, project management, installation, insurance premiums, access to turbines, and the cost of network connections and power lines, while the operational and maintenance costs include the annual costs of repair and maintenance.

Recent studies have shown that there is a relationship between a country's gross domestic product (GDP) and its use of renewable energy. This suggests that investing in renewable energies will have a positive impact on GDP [78]. Similarly, business growth depends on energy; some studies have shown that renewable energy projects are likely to create jobs [34]. In general, factors such as the location of installation, increased production capacity, and countries' markets and policies can contribute to the cost of energy generated by wind, which will be discussed in the following sections.

10.2. Location of installation

For wind turbines to work best, wind speeds should usually be higher than 12 to 14 mph. The energy in the wind flow is determined by the third power of its speed. For example, if speed increase by 2 m/s, its energy will increase 8 times. The cost is reduced by about 50 % as wind speed increases from 7 to 9.5 m/s. Such speeds are needed to spin turbines fast enough to generate electricity. Usually, each wind turbine generates about 50 to 300 KW. With 1,000 W of electricity, one hundred 10-watt lamps can be turned on. Thus, a 300-KW wind turbine can light up to three thousand 100-watt lamps. Therefore, a small wind turbine in a desert can be used to power a house or a school.

The coordination of wind-driven machines with wind speed plays an important role in keeping costs down. Costs of land, equipment transfer, and workers' wages vary from site to site. Also, the cost of constructing the foundation depends on soil resistance. When turbines are connected to a network system, the cost of the transfer will also be added. As wind speed increases with altitude, taller towers should be used. Construction of towers is one of the main costs of installing wind turbines. The presence of corrosive substances and other harmful factors will shorten a turbine's life, which increases maintenance costs [61, 51, 97, 98, 73, 99].

10.3. Increasing production capacity

The cost of wind turbines is significantly reduced by increasing their scale. As capacity increases from 20 to 50 KW, the cost is reduced by 18 %. Another factor is the lifespan of turbines. The average lifespan of a turbine is between 20 and 30 years [46]. With a lifespan of more than 25 years, cost will fall by 20 %.

10.4. Financial analysis of a 100-MW power plant with 50 wind turbines

In accordance with the provisions of Article 139 of the Five-Year Development Plan, the Iranian government is required to provide special support for wind energy with the help of private and cooperative sectors. In order to examine the role of government's support in this regard, it is first necessary to conduct financial analysis of the construction of wind power plants to determine the state of investment without government support [83, 94]. In other words, how attractive is the construction of a wind power plant without using and applying for government support and subsidies?

Financial evaluation of the plan includes calculating fixed investment costs and financing sources. In addition, the income from sales and all operating costs (fixed and variable) are calculated. Subsequently, the indices of internal rate of return, net present value associated with investment, and return period of investment are calculated. All of the above steps are taken using COMFAR (Computer Model of Feasibility Analysis and Reporting).

After identifying incomes and costs during construction and operation, cash flows of the project were extracted and financial indices were calculated and analyzed. Finally, the sensitivity of the model was analyzed by changing the independent variables to achieve the expected return rate.

Project schedule: The construction phase of the wind power plant and its operating life were estimated to be 2 and 20 years, respectively.

Estimated nominal capacity and anticipated production: The plant is capable of generating electricity with an annual nominal capacity of 337260 MW. Due to the reduction of carbon dioxide emissions, the project can benefit from the advantages of a clean development plan.

Utilization phase: Nominal capacity is assumed to be 337,260,000 KW and carbon dioxide reduction is assumed to be 0.0006 tonne per KWh. For estimation of incomes, the income from the sale of generated electricity and the dollar value of greenhouse gas reduction are calculated. Based on the guaranteed purchase tariffs, the sales price of electricity is estimated at 1300 rials per KWh (roughly $0.04 at the time of writing) on average and the price of carbon dioxide per tonne is taken to be 80000 rials (roughly $0.24 at the time of writing). In this paper, the annual growth rate of electricity sales is assumed to be 13 % and the average annual growth rate of energy prices and the annual growth rate of wages are assumed to be 10 %.

By applying a 25 % discount rate, net present value is set at $ 63251205, which indicates that the project is not justifiable and should not be selected.

The return period represents the number of years after investment within which the original cash flows invested in the project will return to the company. In other words, it is the number of years needed to reach positive cash flow. The smaller this index is, the faster the output cash flow is replaced by the inflow cash. Calculations for this project indicate that the return period of investment under normal conditions is more than 10 years and longer than the life of the project under a moving condition (considering the time value of money). According to these results, the project is not justified and thus will be unattractive to investors.

10.5. Potential benefits of using wind energy for electricity generation

10.5.1. Existence of deserts

Iran has 34 million ha of deserts (one-fifth of the total area of Iran) which are generally windy and flat. The desert areas of Iran are endless resources of clean energies such as wind energy and can function as strong infrastructure for socio-economic development. Deserts have the required conditions for installation of wind turbines [73]. Regarding Iran's potential for wind power, 1.3 % of the country's land area (2.1 million ha) has a mean annual wind speed of 8 m/s or higher, which is suitable for harnessing wind energy [76]. The studies show that the nominal estimated capacity of only 28 areas of Iran is almost higher than 6500 MW (compared to total nominal capacity of Iranian power plants). Capacity of 163 wind turbines embedded in Iran is higher than 92MW [76].

11. SOCIO-ECONOMIC BENEFITS AND ENERGY SUPPLY SECURITY

Using the right policies to introduce wind energy will create an extensive market for the export of electricity. National and international investments in local production will employ local residents. Easy access, high security, and affordable sources of energy will stimulate the economy in desert areas. It should to be noted that current and future increases in energy demand will result in conflicts over fossil resources such as political conflicts and tensions over common oil reserves in western and southern Iran. Therefore, the use of wind energy can promote regional peace as well as economic interactions [95].

In addition, due to intense mechanization, surface mines may require fewer workers than underground mines with similar production. Therefore, the impact of human populations on surface mines will be less significant than their impact on underground mines. However, the local population cannot provide the required labor in less populated areas and migration due to new jobs in the mine is likely [88, 99].

11.1. Energy market

If wind-generated electricity is completely utilized, the economic benefits of wind energy are achievable. Utility companies can encourage customers to use electric power by removing tariffs on electric power generated by wind. Current renewable energy markets face limitations. These limitations include lack of access to an affordable electricity network, higher initial cost than conventional energy sources, lack of awareness about the scale of available resources, the speed of development in renewable technologies, and the potential economic benefits of renewable energy [92, 93, 94].

11.2. Adoption of government's supportive policies

By studying the environmental benefits of wind energy, governments can develop policies to support this clean and environmentally-friendly industry. Given the environmental pollution caused by the use of fossil fuels and the associated diseases, governments should provide special support for this industry. Otherwise, large sums should be spent to promote the health and well-being of communities. Unfortunately, in many countries, energy policies focus on the use of common sources of energy such as fossil fuels. Recently, however, some developed countries have imposed taxes on polluting industries. This will make renewable technologies more competitive than conventional sources of energy production. Due to the size of initial investment and high risk at the outset, cooperation with financial institutions is essential, which may include partnerships with investors such as the World Bank, investment banks, development banks, and commercial banks [83, 94].

Iran is rich in oil and natural gas reserves and the income from fossil fuels dominates the economy and affects the country's energy policy. In 2010, Iran adopted a new strategy by shifting towards diversifying its energy sector by eliminating energy subsidies. The new strategy helps to free up over 60 billion USD of public funds, some of which can be invested in the renewables sector. In addition, the Iranian government has a clear vision of developing the country's wind energy industry to become a wind energy hub in the Middle East.

So far, there is no clear policy for wind energy in Iran, but the Iranian ministry of energy has made considerable efforts for developing a legal frame work. A new law aims for 20 GW of thermal power capacity and floating the two major wind farms in the country (Manjil and Binalood) on the stock market. The Foreign Investment Promotion and Protection Act, protecting investors against political risks, covers all foreign investments in Iran. However, international sanctions against Iran have negatively impacted the development of the renewable energy sector due to prohibition of any technical or financial foreign investments [89, 90, 93].

12. RECOMMENDATIONS

The presence of 120-day winds and scarcity of water resources encouraged people to make efficient use of windmills (As-bads) in Iran. As-bads are historical examples of the potential of wind energy to improve local livelihoods and prevent migration [94].

This study offers specific suggestions for overcoming the many limitations of developing wind power plants. In order to accelerate the use of wind energy, a positive approach and a strong political strategy at all levels are needed. Policies to promote the deployment of wind energy technologies are divided into four categories: financial incentives (tax credit), government investment (loans, feed-in tariffs, research and development), regulatory arrangements (determining the share of renewable energy in the country's energy basket, tender offers, guaranteed purchase tariffs), and access policies (bidding policy) [39, 85].

12.1. Tax credit

In this method, an investor receives an annual income-tax credit. Credit is calculated on the basis of the amount of investment in the project or the amount of energy generated during a year. This tool will enable investors to reduce part of their financial obligations. Tax credit has been factored into the state budget in many EU countries including Belgium, France, Italy and the Netherlands and is very sensitive to political conditions [73]. In EU countries, there are several direct and indirect taxes such as income tax, asset tax, company tax, and value-added tax to promote the use of renewable energy [85, 99].

12.2. Low-interest loans

In developing countries such as Iran, low-interest loans are essential for the purchase of wind energy systems. Many financial institutions provide low-interest loans to their customers to buy wind energy systems. In developing countries, low-interest loans should be provided to motivate residents to install wind energy systems [85, 73].

12.3. Feed-in tariffs

In developing countries, the government must specify tariffs on purchasing electricity from suppliers of wind energy. A feed-in tariff is the primary policy mechanism for supporting the development of renewable energies in industrialized countries such as Germany, Italy, France, Japan, China, and the United States [71, 73]. In Iran, the guaranteed-purchase tariff rates are 0.11-0.13 US dollars per KWh [86].

12.4. Research and development

Skilled labor is one of the most important factors in the development of wind energy technology. Skilled labor is needed at all stages, from research to the installation of wind energy systems. For this purpose, educational institutions and training programs should provide education for specific groups such as planners, managers, and engineers [75]. Training programs on the installation and maintenance of wind technology are very important. To address this issue, locals are trained and skilled workers are employed to install and maintain wind energy systems. As research and development increases the efficiency of renewable energies and reduces production costs, developing countries need to allocate more funding to renewable energy research [80, 85].

12.5. Determining the share of renewable energy in the country's energy basket

This is a form of mandatory and predetermined development, in which a certain share of production is allocated to renewable energies within a specific timeframe. This share can be reflected in the National Energy Strategy of Iran, macro policies in development plans, and the proposed comprehensive renewable energy law.

12.6. Tender offers

Among the most important benefits of bidding are the discovery of real prices, reduction of electricity generation cost and, as a result, creation of a competitive space. At the same time, the price and capacity required for installation are controlled [79].

12.7. Guaranteed purchase

In this method, the purchase of electricity generated using renewable resources is guaranteed according to pre-set tariffs over a specified period of time. The tariff can be different for different plants according to plant size, and policymakers can adjust tariffs as technology develops. This method is an important policy tool for attracting private investors in the field of renewable energy and, consequently, increasing production.

12.8. Bidding policy for wind energy development

Tender offers are a popular policy tool. In 2015, more than 60 countries used this method to develop their renewable energy industry [85]. Turkey used bidding for construction of 2000 MW turbines in 2016, which will be operational in 2020. The United States has held tenders in five steps for the construction of 1,419 MW of renewable energy plants in 2011-2015. The goal is the reduction of prices in the bidding process. The policy ensures the average price per MWh $90 in the first tender and $80 in the third [94, 95].

13. CONCLUSIONS

Economic growth and its urgent need for energy show the necessity of optimal energy use. Wind energy is a new and renewable source of electricity with an increasing growth trend. In recent years, the use of this energy has begun in Iran, especially in Manjil, but little has been done in other parts of the country. Economic development will be possible if sufficient wind energy is available in a timely manner.

Among countries, Iran has a special place with its diverse energy resources. Nevertheless, energy consumption in the country is much higher than other developing countries and has led to environmental problems, which have alarmed economic planners. It should also be noted that the security of the country's energy supply increases with the diversification of its energy basket, which itself promotes national security. However, diversification of the energy sector requires accurate knowledge of the country's potential for different sources of energy and analysis of the effects of diversification. Some basic issues that should be considered in the design of a large energy sector include the ability to meet the needs of the economy, energy security, characteristics and potentials of the region, resources utilization technology, sustainability, and environmental issues.

In areas with low wind potential, hybrid systems have recently become common. For example, the advantage of a photovoltaic-wind-diesel system is that when wind speed is appropriate at times, energy production is carried out by wind turbines and the solar photovoltaic system is used when solar energy is preferred to wind power. When neither of the desired sources (wind and solar) has good potential, the diesel system can be used. Of course, the use of diesel systems alone can pollute the environment, but their use in a hybrid system releases less pollutants.

With a population of 80 million, the annual energy consumption of Iran will increase by about 7 %. According to expert estimates, the needed generation capacity will be about 90 GW by 2020. Currently, almost three-quarters of Iran's electricity is generated by gas-fired power plants and the rest is supplied using hydroelectric or diesel turbines.

Given that power generation using wind turbines is economical, it is recommended to install wind turbines in suitable locations. In addition, as one of the crises facing the world is environmental pollution and given that electricity generation by wind turbines lowers social costs, clean energies are recommended for electricity generation. The wind energy industry offers long-term advantages; therefore, it is advised to develop and expand the infrastructure needed for the development of wind turbines and wind power plants. Providing energy services can solve several social needs in developing countries, especially Iran, since Iran is subject to major changes in energy systems and their sustainable use.

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