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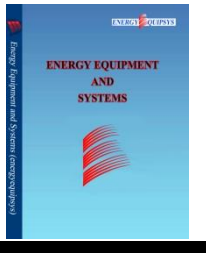

Techno-Econo-Environmental study on the use of domestic-scale wind turbines in Iran

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ABSTRACT

Existing fossil fuels do not meet the needs of modern societies and are almost coming to an end. Hence, governments can respond both to the needs of the people and the industry, by investing in the use of renewable energies. As well as saving fossil fuels, natural gas and even water. According to the research, renewable energy, especially wind energy, has been used in recent years and are able to satisfy some of the existing needs. The purpose of present study is to investigate the techno-econo-enviro use of domestic-scale wind turbines in Iran in order to select the optimal turbine according to the geographic location of each station in the country. At the present study, five types of wind turbines, including Generic 1kW, Generic 3kW, Generic 10kW, BWC XL 1.25kW and WES Tulipo 2.5kW have been used at all stations in the country to provide the most suitable type of turbine with the help of HOMER software and based on the geographic location of each station. The results showed that among all stations and types of wind turbines, the highest and lowest total net present cost (NPC) with 49131 $ and 11622 $ respectively are related to Zanjan and Alvand stations and Generic 1kW wind turbines. Also, the cost per kWh of produced wind electricity is 2.847 $ and 0.674 $ respectively at these stations. Also in the case of using hybrid wind-diesel system by Generic 1kW, Generic 3kW, BWC XL. 1.25kW, WES 2.5kW and Generic 10kW wind turbines at the all under study stations, annually generate a total of 246409, 213951, 212826, 122460 and 152030 Kg CO_2 respectievely. Another point is that at Alvand, Arak, Babolsar, Iranshahr, Kashan, Khoy and Orumieh Generic 1kW wind turbine, at Anzali, Hamedan, Ramsar and Torbate Heydarie BWC XL. 1.25kW wind turbine, and at the 91 remaining stations WES 2.5kW wind turbine are the most economically feasible options.

Keywords: Power Curve; Cost of Electricity; Diesel Fuel; CO_2 Emission; Total NPC.

1. Introduction

In the current century, the use of renewable energies, including wind, more than ever has been considered due to increased population and increased environmental pollution. The specific geographic location of Iran allows the use of clean energy and makes it economically viable. Wind energy is one of the most economical methods of producing renewable electricity and guarantees an important and significant part in terms of energy security. In our country, the use of this technology has been considered [1].

In the present study, at first the price of a common wind turbine in the domestic-scale was found, and then, by entering the cost of purchase, operating & maintenance, replacement and the lifetime of the wind turbines and the other inputs in the HOMER

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program, for each station in the provinces of Iran, an appropriate wind turbine is introduced. The turbines used in the software include Generic 1kW, Generic 3kW, Generic 10kW, BWC XL 1.25kW and WES Tulipo 2.5kW.

1.1. Benefits of using wind energy

Like other renewable energy sources, wind energy has higher benefits than other non-renewable energy sources. The main advantages include no need for fuel, thereby reducing the consumption of fossil fuels, free of wind energy, the ability to meet part of the demand for electrical energy, the decreased price of wind energy compared to fossil fuels, less current expenditure and capital expenditure of wind energy on the long-term, diversification of energy sources and the establishment of a sustainable energy system, lack of water requirements, the lack of land for installation, lack of environmental pollution compared to fossil fuels, increased reliability of power generation and job creation [2].

1.2. Wind energy in the world

The total capacity of all wind turbines installed worldwide by the end of 2017 has reached 539581 MW, of which 52573 MW were added in 2017. All of the turbines installed by the end of 2017 could cover more than 5% of global electricity demand. In 2017, Denmark has achieved a new world record by providing 43% of its energy needs. China, with a capacity of 19 GW more than 2016, has positioned itself as the leader of wind power with a capacity of 188 GW. From the leading markets, the United States (89 GW), Germany (56 GW), India (32.9 GW), Britain (17.9 GW), France (13.8 GW) and Brazil (12.8 GW) can be named. Overall growth of wind energy around the world, along with geographic diversity is the very encouraging. New regions of the world, such as Latin America and, recently, Africa, play an important role in this dynamic development. Obviously, many governments have realized that wind power has huge benefits to their societies, as they are inexpensive and available without emissions [3].

1.3. Wind energy in Iran

Iran is one of the leading countries in wind energy use in windmills, but the first modern and industrial application of wind power in Iran occurred in 1995 when two modern turbines with a capacity of 500 MW purchased and installed in the Gilan province. After that, government decided to develop wind energy in Iran. At present, the total power of wind power plants in Iran is 72.73 MW, which is far from an installation of 1690 MW by 2025. According to the Iran's 20-year vision plan, by the end of 2025, Iran should establish 90 MW wind farm annually. To achieve this goal, the Renewable Energy and Energy Efficiency Organization is trying to use the capacities of the private sector and foreign investors to build wind power plants. Annually a 1000 MW wind power plant must be built up to Iran does not fall behind from developing. The share of wind energy in the world is rising. In some countries, such as Germany, it has reached 24 %, while in Iran it is only 3.7% [4].

By the end of June 2018, 45% of renewable energy production supplied by wind energy which has the highest percentage of renewable energy use in Iran. Generally, the use of renewable energy in Iran from the beginning has produced 2153 million kWh of renewable electricity, no emissions of 1486 thousand tons of greenhouse gas, 611 million m^3 of natural gas savings and about 474 million liters of savings in water consumption.

In the province of Khorasan Razavi and Qazvin, the capacity of the installed wind farm is more than 10MW. In southern Khorasan province, a wind power plant with a capacity of 5 to 10 MW and in the north and center of Qazvin province and in the south-east of East Azarbaijan province is also a wind power plant with the same capacity. In Fig.1, the location of the existing power plants is shown [5]. In Fig.2, the Atlas of Iran's wind speed is shown at a height of 50 m [6]. It is clear from Fig.2 that there is a good consistency between the points where existing wind power plants and high potential areas.

1.4. Literature review

In 2018, Syarifah et al designed a hybrid power generation system for remote areas using HOMER software [7]. Its available renewable sources include wind, solar, and biomass, and the site was investigated by a hotel in Indonesia. The results showed that the total NPC was 759478 $, the price per kWh of produced electricity was 0.341$ and

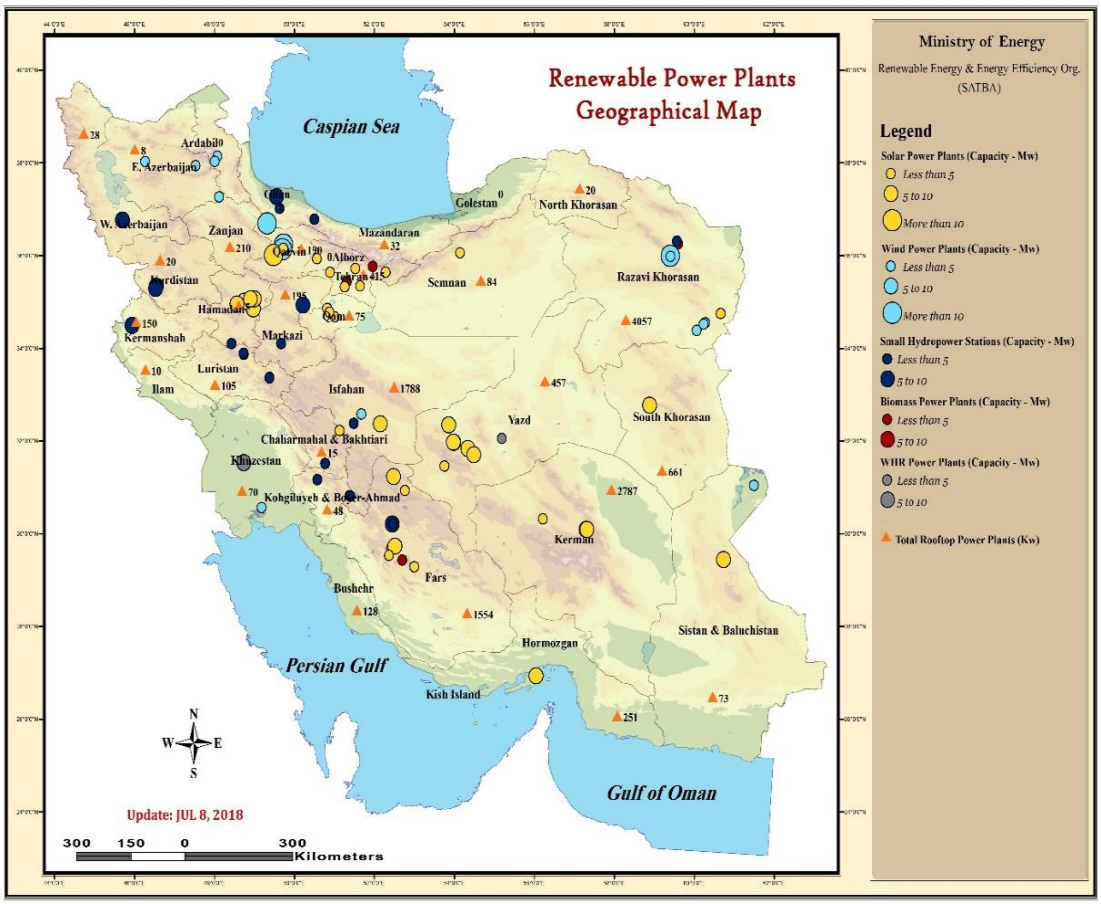

Fig.1. The geographic location of Iran's renewable power plants [5]

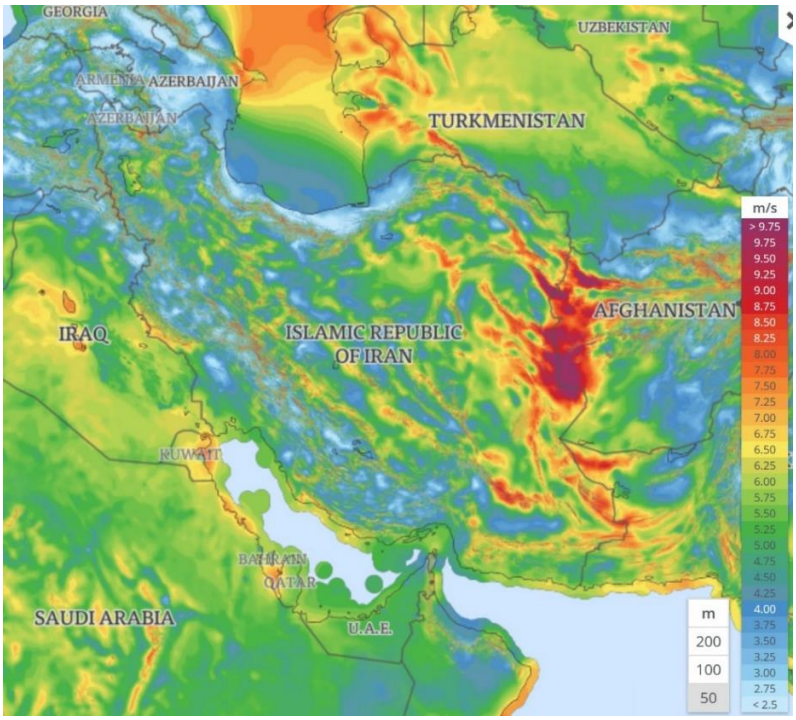

Fig.2. Atlas of Wind Energy in Iran [6]

the annual operating & maintenance cost was 2132 $. Of the total 1648385 kWh of annual electricity demand, 78.93% is supplied by solar cells, 15.19% by biomass generators and the rest by wind turbines. Also, about of 17.7% excess electricity was produced.

In 2017, Bulut et al. reviewed the technical-economic potential of renewable energy in order to meet the needs of a four-person family in Balikersir, Turkey [8]. The HOMER software was used and three different scenarios connected to the grid, including solar cell, wind turbine and hybrid solar cell-wind turbine were investigated. The parameters examined were the cost per kWh of electricity produced, the total investment cost and the amount of pollutants. The results of the research showed that although the price of hybrid systems is higher, the return on investment period is 5.79 years that is much less compared with solar and wind systems, which are 8.2 years and 19.35 years, respectively.

Usman and Gidado used a HOMER software in 2017 to investigate the use of a system of wind turbine and solar cell connected to grid for a rural health center in Nigeria [9]. The results showed that the connected to grid solar cell system with the battery was the most economical option that could supply 43% of the electricity demand. The economic system consists of a 2 kW solar cell, two 6FM200D batteries and a 1 kW converter. The total NPC of the entire system is 8901$, and the price per kWh of generated electricity is 0.096$, and the system avoids the release of 542.7 kg of CO_2 per year compared to the total electricity supply from the national grid.

Sirvastava and Giri, in 2016, investigated the energy supply of 11 kWh/day with a peak of 6.1 kW from a laboratory in Gorakhpur, India using HOMER software [10]. The system consisted of solar cells, wind turbines, diesel generators, converters and batteries, and was off-grid. The results of the research showed that the optimal system consists of 5 kW of solar cells, 4 kW of generators, 10 batteries of 6FM200D and 4.5 kW of converters, and annually eliminates 25472 kg of CO_2 emissions. Meanwhile, the price per kWh of electricity produced in this system was $ 0.262.

2. Introducing HOMER Software

HOMER software makes it easy to assess the design of grid-connected or grid-independent power generation systems in a variety of applications. When designing a power generation system, it encounters different configurations of the system, making it difficult to make decisions for choosing designs. What parameters are sensitive to system design and change the system variables? What number and size of each component of the system should be used? A large number of technology and repair options, and the cost of technology and access to energy resources make decision making more difficult. Homer's sensitivity optimization and optimization algorithms make it possible to evaluate all acceptable system configurations [11]. HOMER simulates the operation of a system by creating equilibrium equations for every 8760 hours of the year. HOMER calls for electrical and thermal demand at any hour to be provided by the system and calculates the energy flow to or from the components of the system. HOMER also decides for systems that include batteries or generators of power from fuel, at what times the startup of generators is economical, or when the batteries are recharged or discharged. Then decides what configuration is possible. Therefore, while this configuration provides electrical demand according to the user's requirements, it calculates the installation and utilization costs of the system during the life of the project. The software also calculates the cost of the system, including investment, Replacement, operating and maintenance, fuel and profits [11].

3. Used data

The most important input for software is the average power consumption per hour over a 12-month period of one year. These data that are read from the power meter are shown in Fig.3. The average power required for the residential house under study is 9.1 kWh/day with average and peak values of 0.379 kW and 1.77 kW respectively.

Due to the use of diesel generator for emergency situations in the system, the price of consumed diesel is other software inputs, which is considered in the present work at $ 0.07 per liter [12].

Another critical parameter that is important for software in prioritizing the use of wind turbines is the wind speed at the stations and the height of each station, as presented in Table 1. The software calculates the power generated by the wind turbine using the following equation:

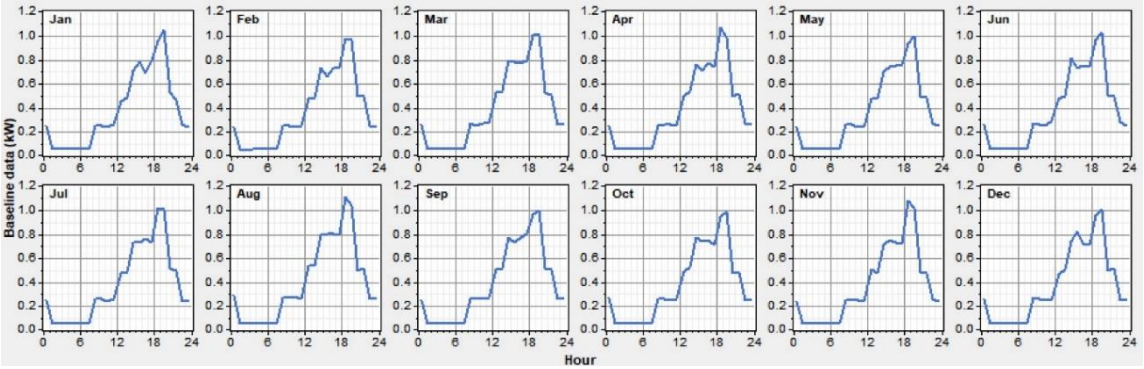

Fig.3. Average daily power consumption profile for 12 months

$$P_{WTG} = \frac{\rho}{\rho_0} \times P_{WTG,STP} \quad (1)$$

In the above equation, ρ is the actual air density, ρ_0 is the air density at standard temperature and pressure, P_{WTG} is the wind turbine output power, and $P_{WTG,STP}$ is the wind turbine output power of the power curve. In Eq.(1), the value of ρ is obtained from the following equation:

$$\frac{\rho}{\rho_0} = \left(1 - \frac{B\,z}{T_0}\right)^{\frac{g}{RB}} \times \left(\frac{T_0}{T_0 - B\,z}\right) \quad (2)$$

In the above relation, z is the height in meters, B is the rate of decrease and is equal to 0.0065 K/m, g is the gravity of the earth and is equal to 9.81 m/s^2 and t_0 is the standard temperature and equal to 288.16 K. In Figs. 4 to 8, the used wind turbine power curve is shown.

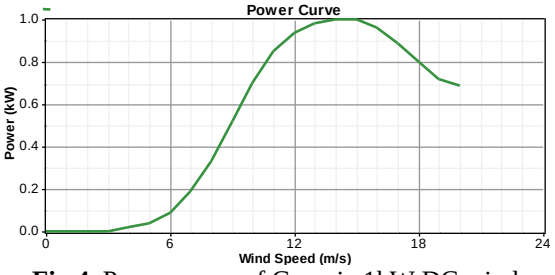

Fig.4. Power curve of Generic 1kW DC wind turbine

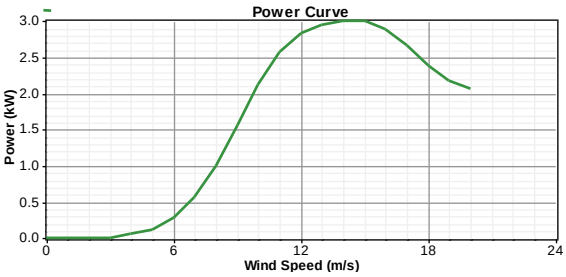

Fig.5. Power curve of Generic 3kW DC wind turbine

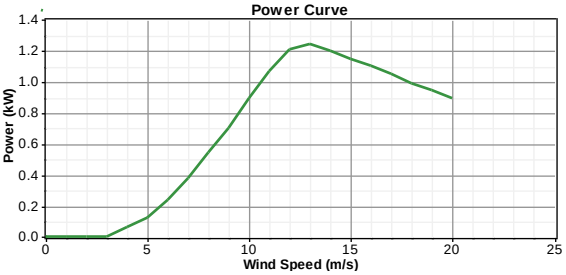

Fig.6. Power curve of BWC XL 1.25kW DC wind turbine.

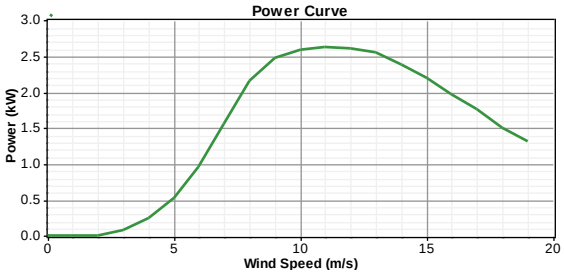

Fig.7. Power curve of WES Tulipo 2.5kW AC wind turbine.

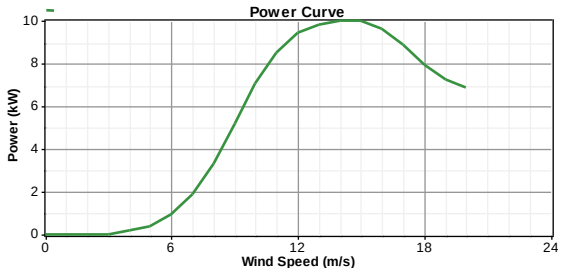

Fig.8. Power curve of Generic 10kW DC wind turbine.

The actual annual interest rate in the present work was 19% [13], the penalty for pollutants was not included, the lifetime of the project was 25 years, and the deployment strategy for the generator was cycle charging. For software analysis, the need for prices and other information on the equipment used is given in Table 2.

Table 1. Data required for simulation

Station	Longitude	Latitude	Height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ave
Abadan	48.3	30.4	6	2.1	2.8	3	3.3	3.4	4.5	4.4	3.6	3.3	2.2	2.2	2.1	3.1
Abadeh	52.7	31.2	1980	4.6	4.8	4.8	4.5	5	5.6	6.2	5.9	5.1	4.5	4.2	4.6	5
Ahar	47.1	38.5	1707	4.4	4.9	5.8	6.5	6.1	7.3	9.1	8.7	6.3	4.9	4.1	4.3	6
Ahvaz	48.7	31.3	22	2	2.2	2.4	2.7	2.8	3.5	3.6	3	2.4	1.8	1.9	1.9	2.5
Alvand	49.2	36.3	1422	4.2	4.8	5.7	6	5.8	6.2	6.9	6.7	5.3	4.6	3.9	4	5.3
Anzali	49.5	37.5	-26	2.3	2.2	2.1	2	1.8	2	1.8	1.9	2.2	2.1	2.2	2.5	2.1
Aq Qaleh	54.5	37	27	3.7	3.7	3.6	3.4	3.7	4	4.1	4	3.8	3.5	3.5	3.6	3.7
Arak	49.8	34.1	1708	0.7	1.4	1.8	2.1	1.9	1.9	1.8	1.5	1.4	1.3	0.9	0.7	1.4
Ardakan	54	32.3	1270	4.7	4.8	4.9	4.5	5.1	5.9	6.4	6.1	5.3	4.5	4.4	4.7	5.1
Ardestan	52.4	33.4	1441	4.5	4.7	4.6	4.3	4.9	6	6.8	6.4	5.3	4.5	4.3	4.6	5.1
Babol	52.7	36.5	527	3.7	3.8	3.7	3.5	3.8	4.1	4.5	4.4	4	3.7	3.6	3.7	3.9
Babolsar	52.7	36.7	-21	1.5	1.8	2.2	2.2	2.1	2.1	2	1.9	1.7	1.7	1.6	1.4	1.8
Bafq	55.4	31.6	1461	4.8	5	5.1	4.7	5.2	5.8	6.3	6.1	5.3	4.6	4.5	4.7	5.2
Baft	56.6	29.3	2405	4.6	5	5	4.7	5.1	5.3	6	5.8	5.2	4.4	4.2	4.5	5
Bam	58.4	29.1	713	4.5	4.8	4.9	4.6	5.1	5.6	6.2	6.1	5.6	4.7	4	4.4	5
Bandarabas	56.4	27.2	10	4.9	5.3	6.1	6.6	6.6	6.6	7.3	7.4	6.3	5.5	5	4.5	6
Bandae Genave	50.5	29.6	60	4	4.2	4.2	4	4.7	4.9	4.5	4.3	4.1	3.7	3.8	4.1	4.2
Bandar Lenge	54.9	26.6	107	4.5	5.1	4.9	4.9	5.4	5.2	4.9	4.8	4.5	4.2	3.9	4.5	4.7
Bandar Mahshahr	49.2	30.7	46	3.6	3.8	3.8	3.7	4.4	4.6	4.4	4.1	4	3.6	3.6	3.7	3.9
Birjand	59.2	32.9	1491	4	4.7	5.4	5.8	6.1	7.2	8.7	7.6	5.6	4.3	3.6	3.7	5.6
Bojnurd	57.3	37.5	1511	3.6	4.3	5	5.3	5.4	5.8	6.1	5.6	4.6	3.9	3.5	3.4	4.7
Borujen	51.3	32	24.4	4.1	4.3	4.3	4.2	4.6	5	5.3	5	4.6	4.1	3.9	4.2	4.5
Bukan	46.2	36.5	1780	3.9	4.4	5.4	5.9	5.5	6.2	7.4	7.1	5.3	4.3	3.5	3.7	5.2
Bushehr	50.8	28.9	0	4.6	5	4.9	4.7	5.4	5.6	4.8	4.7	4.4	4.1	4.3	4.7	4.8
Chabahar	60.6	25.3	6	2.6	2.9	3.1	3	2.7	3.3	3.8	3.5	2.8	2.1	2.1	2.3	2.9
Chalus	51.4	36.7	1332	4	4.2	4.5	4.5	4.5	4.9	5.3	5.2	4.5	4.1	3.7	3.8	4.4
Darab	54.5	28.8	1372	4.4	4.7	4.6	4.5	4.9	4.9	5.1	4.9	4.6	4	3.9	4.3	4.6
Dargaz	59.1	37.5	483	3.9	3.9	4	4	4.1	4.5	4.8	4.7	4.3	4	3.9	3.8	4.2
Dehloran	47.3	32.7	334	3.8	3.9	3.9	4.3	4.8	5.2	4.7	4.7	4.7	4.4	4.1	3.9	4.4
Dezful	48.5	32.4	503	3.6	3.8	4	4.3	4.7	4.9	4.6	4.5	4.5	4.2	3.8	3.7	4.2
Dir	51.9	27.8	7	4.6	5	4.8	4.6	5.2	5.3	4.7	4.6	4.3	4	4.1	4.5	4.7
Do Gonbadan	50.8	30.4	746	3.8	3.9	3.9	3.8	4.5	4.7	4.5	4.3	4.1	3.7	3.7	3.9	4.1
Do Rud	49.1	32.5	2224	3.6	4.2	5	5.3	5.3	5.4	5.4	5.2	4.5	4.2	3.6	3.6	4.6
Esfahan	51.7	32.5	1850	4.2	4.4	4.5	4.5	4.8	5.4	5.8	5.85	4.8	4.3	4	4.2	4.7
Firuzabad	52.6	28.9	997	4.2	4.5	4.4	4.2	4.8	4.8	4.6	4.4	4.2	3.8	3.8	4.1	4.3

Table 1. Continued

Station	Longitude	Latitude	Height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ave
Ghamsar	52.3	35.2	1835	3.7	3.8	3.8	3.6	4	4.6	5	4.8	4.2	3.7	3.6	3.8	4.1
Gonabad	58.7	34.4	1195	4	4.2	4.3	4.1	4.6	5.4	5.9	5.7	5	4.2	3.9	4	4.6
Gonbad Ghabus	55.2	37.3	545	3.5	3.7	3.8	3.7	4	4.3	4.4	4.2	3.9	3.5	3.4	3.5	3.8
Gorgan	54.5	36.8	1368	3.6	3.7	3.6	3.4	3.8	4.1	4.4	4.2	3.9	3.5	3.5	3.6	3.8
Hamedan	48.5	34.9	1749	1.5	2.4	3	3.1	2.5	1.9	1.9	1.7	1.6	1.9	1.5	1.4	2
Ilam	46.4	34.9	1749	3.5	3.7	3.8	4	4.3	4.6	4.4	4.3	4.2	4	3.7	3.6	4
Iranshahr	60.7	27.2	591	1	1.4	1.8	2.1	1.9	2.1	2.5	2	1.5	1.1	0.9	0.9	1.6
Jahrom	53.6	28.7	1207	4.3	4.6	4.5	4.4	4.9	4.8	4.8	4.7	4.4	3.9	3.9	4.2	4.4
Jask	57.5	25.8	24	3.8	4.2	4	4.1	4.5	4.5	4.4	4.4	4.3	3.7	3.3	3.7	4.1
Jiroft	57.7	28.7	1251	4.1	4.6	4.5	4.3	4.8	5	5.4	5.4	5	4.2	3.7	4.1	4.6
Kamyaran	46.9	34.8	1568	3.5	3.7	4	4.2	4.4	4.8	5	4.9	4.4	4	3.6	3.5	4.2
Kangan	52.1	27.8	278	4.2	4.6	4.4	4.3	4.7	4.7	4.4	4.3	4	3.7	3.7	4.1	4.3
Karaj	51	35.8	1328	3.9	4.5	5.5	5.9	5.7	6.1	6.6	6.3	5	4.3	3.6	3.7	5.1
Kashan	51.5	34	982	0.1	0.4	0.5	0.8	0.8	0.7	0.8	0.6	0.4	0.3	0.2	0.1	0.5
Kashmar	58.5	35.2	1441	4.1	4.2	4.2	4	4.3	4.9	4.6	4.4	4.1	3.7	3.8	4.1	4.2
Kazerun	51.7	29.6	884	4	4.3	4.3	4	4.7	4.9	4.6	4.4	4.1	3.7	3.8	4.1	4.2
Kerman	57	30.3	1754	2.2	3.1	3.3	3.2	3.1	2.9	3.3	3	2.4	1.9	1.8	1.8	2.7
Kermanshah	47.1	34.3	1322	4.1	4.8	6.1	6.1	5.2	5	4.9	4.9	4.5	4.3	3.4	3.9	4.8
Khalkhal	48.5	37.6	1572	4.8	5.2	5.9	6.4	6.1	6.9	8.2	8.1	6.3	5.2	4.3	4.5	6
Khash	61.2	28.2	1366	4.3	4.8	4.8	4.8	5.3	5.6	5.1	4.8	5.1	5.2	4.2	4.3	4.9
Khomeyn	50.1	33.6	2129	3.9	4.5	5.2	5.5	5.5	5.8	6	5.7	4.8	4.3	3.7	3.8	4.9
Khormuj	51.4	28.7	312	4.6	5	4.8	4.6	5.3	5.4	4.9	4.8	4.5	4.1	4.2	4.6	4.7
Khoramabad	51.4	33.5	1810	3.5	3.8	4.2	4.5	4.7	4.9	4.8	4.6	4.3	4	3.6	3.5	4.2
Khoy	45	38.6	1103	0.8	1.4	1.8	1.7	1.3	1.4	1.1	1	1	1	0.8	0.7	1.2
Kuhdasht	47.6	33.5	1306	3.4	3.4	3.4	3.7	4.1	4.3	4.1	4.1	4	3.9	3.6	3.5	3.8
Langrud	50.2	37.2	-11	5.2	5.3	5.3	5.1	5	5.2	5.7	5.9	5.5	5.2	4.8	5	5.3
Lar	54.3	27.7	842	4.2	4.6	4.4	4.4	4.9	4.8	4.7	4.6	4.3	3.9	3.7	4.2	4.4
Mahabad	45.7	36.8	1608	3.8	4.3	5.1	5.4	5.1	5.7	6.9	6.7	5	4.2	3.4	3.6	4.9
Maragheh	46.2	37.4	1915	4	4.4	5.1	5.6	5.4	6.3	7.8	7.5	5.6	4.4	3.7	3.8	5.3
Marand	45.8	38.4	1406	3.8	3.9	4	4	4.1	4.6	5.6	5.5	4.5	4.1	3.7	3.7	4.3
Marivan	46.2	35.5	1828	3.7	4.2	5.1	5.4	5.2	5.7	6.5	6.2	4.9	4.2	3.4	3.6	4.8
Mashhad	59.6	36.3	999	2.3	3.1	4.1	4.1	4.1	4.7	5	4.4	3.5	2.8	2	1.9	3.5
Masjed Soleyman	49.3	32	406	3.5	3.6	3.6	3.8	4.3	4.4	4.2	4	4	3.8	3.6	3.6	3.9

Table 1. Continued

Station	Longitude	Latitude	Height	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ave
Miyaneh	47.7	37.3	1690	4.1	4.6	5.8	6.6	6.2	7.3	9.1	8.7	6.2	4.6	3.6	3.8	5.9
Minab	57.1	27.2	559	3.9	4.4	4.3	4.2	4.7	4.8	4.9	4.9	4.7	4	3.5	3.9	4.3
Naein	53.1	32.9	1422	4.7	4.8	4.9	4.6	5	5.9	6.5	6.2	5.3	4.6	4.4	4.7	5.1
Neyriz	54.3	29.2	1893	4.6	5	5	4.7	5.2	5.2	5.6	5.3	4./8	4.3	4.2	4.6	4.9
Neyshabur	58.8	36.2	1536	4	4.2	4.2	4.1	4.4	4.8	5.1	4.9	4.5	4	3.9	4	4.4
Orumieh	45.1	37.5	1316	1.4	1.8	2.3	2.4	2.2	2.1	1.9	1.9	1.9	1.7	1.6	1.5	1.9
Parsabad	47.9	39.7	327	4.9	5.4	5.9	6.2	5.8	6.5	7.9	7.7	6	5.2	5	5.2	6
Qaen	59.2	33.7	1660	4.1	4.4	4.5	4.2	4.9	5.8	6.7	6.6	5.6	4.5	3.9	4.1	4.9
Qom	51	34.7	1546	3.9	4.7	5.7	6	5.9	6.2	6.5	6.2	5	4.4	3.7	3.8	5.2
Ramsar	50.7	36.9	-20	1.8	1.9	2.1	2.1	1.9	2.1	2.1	1.9	2	1.9	1.8	1.9	2
Ravar	56.8	31.3	1604	4.6	4.8	5	4.6	5.1	5.7	6.3	6.1	5.3	4.4	4.3	4.5	5.1
Sabzevar	57.7	36.2	973	1.9	2.7	2.9	3.3	3.9	4	4.6	3.7	3.5	2.8	2.3	2	3.1
Sanandaj	47	35.3	1899	3.7	4.2	5.1	5.6	5.3	5.7	6.4	6.2	4.9	4.2	3.5	3.6	4.9
Saravan	62.6	27.4	1148	4.1	4.6	4.5	4.6	5.1	5.2	4.5	4.2	4.5	4.8	3.9	4.1	4.5
Sari	53.1	36.6	822	3.7	3.7	3.6	3.4	3.8	4.1	4.4	4.3	4	3.6	3.5	3.6	3.8
Semnan	53.4	35.6	1451	3.7	3.8	3.8	3.6	4	4.6	4.9	4.7	4.2	3.74	3.6	3.7	4
Sepidan	52	30.3	2323	4.2	4.5	4.5	4.1	4.8	5.1	5.3	5	4.5	4	3.9	4.3	4.5
Shahrebabak	55.2	30.1	1824	4.9	5.2	5.3	4.9	5.3	5.6	6.3	6	5.2	4.6	4.5	4.8	5.2
Shahekurd	50.9	32.3	2430	3.7	3.9	4.2	4.4	4.6	4.9	5	4.7	4.3	4	3.6	3.7	4.2
Shahrud	55	36.4	1345	3.8	4.3	5.4	5.5	5.5	6.3	6.7	6.2	4.8	3.8	3.5	3.4	4.9
Shiraz	52.5	29.5	1418	3.8	4.9	6	5.9	6.2	5.6	5.2	4.9	4.5	4.1	3.5	3.5	4.8
Sirjan	55.7	29.5	1881	4.7	5.1	5.1	4.8	5.2	5.3	5.9	5.6	5.1	4.4	4.3	4.6	5
Tabas	56.9	33.6	961	4.1	4.3	4.5	4.2	4.8	5.63	5.9	5.6	4.9	4.2	3.9	4.1	4.7
Tabriz	46.3	38.1	1361	4.2	4.6	5.8	6.7	6.3	7.7	9.7	9.3	6.5	4.7	3.7	3.9	6.1
Takab	47.1	36.4	1936	4	4.6	5.8	6.4	6	6.7	7.9	7.5	5.6	4.4	3.5	3.7	5.5
Taybad	60.8	34.7	937	4.2	4.4	4.4	4.1	4.7	5.8	6.6	6.5	5.6	4.6	4.1	4.3	4.9
Tehran	51.3	35.7	1191	3.5	5	6.4	7.1	7.2	6.7	5.5	4.9	4.7	4.7	3.9	3.5	5.3
Torbare Jam	60.6	35.2	1242	4.3	4.3	4.3	4	4.4	5.2	5.7	5.6	5	4.4	4.2	4.3	4.6
Torbate Heydarie	59.2	35.3	1451	0.8	1.3	1.7	2	2.6	3.3	3.8	3.3	2	1.6	1.2	0.8	2
Yasuj	51.7	30.8	1940	4	4.2	4.2	4	4.6	4.9	4.9	4.6	4.3	3.8	3.8	4.1	4.3
Yazd	54.4	31.9	1230	4.4	5.1	6	6.6	6.6	6.1	6.4	5.7	4.4	3.8	3.3	3.9	5.2
Zabol	61.5	31	510	4.2	4.6	4.6	4.5	5.3	6.3	6.8	6.4	6.1	5.2	4.2	4.3	5.2
Zahedan	60.9	29.5	1370	3.4	4.1	4.5	4.1	3.3	3.5	3.6	3.1	2.6	2.2	2.1	3	3.3
Zanjan	48.5	36.7	1663	2.7	3	3.1	3.1	2.8	3	3.2	3	2.7	2.4	2.5	2.5	2.8

Table 2. List of prices and equipment information.

Equipment's	Capital cost ($)	Replacement cost ($)	Operating & Maintenance ($)	Lifetime	Descriptions
Generic 1kW [8]	2000$	2000$	20$	20 years	
Generic 3kW [9]	9000$	8000$	15$	20 years	
BWC XL 1kW [10]	2307$	1845$	10$	20 years	Hub height: 25 m
WES Tulipo 2.5kW [14]	5000$	4000$	50$	15 years	
Generic 10kW [7]	6118$	6118$	35$	19 years	
Converter [15]	8000$	1000$	100$	15 years	Efficiency: 90%
Surrette 6CS25P [15]	1200$	1100$	50$	9645 kWh	Nominal: 6V, 1156Ah
Generator [15]	3500$	3000$	20$	10000 h	Minimum load ratio: 30%

As the main economic output, the software delivers a list of categorized systems based on the total NPC. The total NPC represents all costs that are imposed on the system throughout the life of the project (including installation, replacement, fuel, electricity purchase from the network and penalties from emission of pollutants) minus the revenues system (including revenue from sales of electricity to the network or proceeds from the sale of emergency equipment). The total NPC is calculated as follows [16]:

$$NPC = \frac{C_{ann,total}}{CRF(i, R_{proj})} \quad (3)$$

In the above equation, $C_{ann,total}$ is total annual cost, CRF is the cost return factor, i is the real interest rate, and Rproj is the lifetime of the project. All costs and revenues are valued at a fixed interest rate throughout the year. In this assessment, for the purpose of influencing inflation in calculations, the real interest rate resulting from inflation is calculated and the effect of the interest rate change on net final cost is applied.

The cost return factor, which indicates the return on capital during N years, is calculated as follows [16]:

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (4)$$

Software is able to compute the real annual interest rate through the following equation [16]:

$$i = \frac{i' - f}{1+f} \quad (5)$$

Also, the cost per kWh of energy during the lifetime of the project is obtained by software from the following equation [16]:

$$COE = \frac{C_{ann,total}}{E_{Load\ Served}} \quad (6)$$

In the above equation, $E_{Load\ Served}$ is the real electric load by a hybrid system with a kWh/y unit and in dollar terms.

4. Results

The results of Table 3 show the best use of the five turbines examined at each station from about 1056 possible states. Table 3 shows that the highest and lowest total NPC for all stations and all types of wind turbines with a value of $ 49131 and $ 11622, respectively, are related to Zanjan and Alvand stations and Generic 1kW wind turbines respectively. Also, at the stations mentioned, the cost per kWh of generated wind power is $ 2.847 and $ 0.674 respectively. According to the results, Kashan stations with 4007 kg/y and Karaj and Bandar Lengeh with zero kg/y have respectively the highest and lowest CO_2 emissions, respectively, corresponding to zero percent wind power generation and 100% wind power generation at the stations listed.

For all stations and types of wind turbines examined, the average total NPC, the average cost per kWh of generated wind

power, the average amount of annual CO_2 emissions and the average generated wind power are 20168.4$, 1.71$, 1858.2 $, and 61% respectively. Meanwhile, for Generic 1kW, Generic 3kW, BWC XL 1.25kW, WES 2.5kW, and Generic 10kW wind turbines, the average total NPC for all stations examined is 20849.2 $, 25388.1 $, 18690 $, 16523.2 $, and 19391.6 $. In order to supply electricity from all types of wind turbines examined, the most economical option for all stations is WES 2.5kW, and the Generic 3kW wind turbine is the most economical option due to the highest average total NPC. If Generic 1kW, Generic 3kW, BWC XL 1.25kW, WES 2.5kW and Generic 10kW wind turbines at the stations examined, annually generated 246409 kg, 213951 kg, 212826 kg, 122460 kg and 152030 kg of CO_2 emissions. The most compatible environmental wind turbine, WES 2.5kW, and the most malleable environmental wind turbine, are Generic 1kW.

Table 3. Results

Station	Turbine type	Total NPC ($)	COE ($/kWh)	CO_2 (kg)	Electrical (%)
Abadeh	1	17457	1.046	1885	58
	2	21591	1.294	1641	70
	3	15653	0.938	1916	51
	4	13717	0.822	663	91
	5	16200	0.971	975	93
Abadan	1	24332	1.458	2808	23
	2	32895	1.971	2713	24
	3	21697	1.300	2257	46
	4	18333	1.099	1872	59
	5	20798	1.247	2209	58
Ahar	1	16076	0.932	1503	73
	2	20039	1.161	1244	83
	3	14262	0.827	1548	65
	4	12849	0.745	404	96
	5	15375	0.891	725	97
Ahvaz	1	28547	1.654	3567	3
	2	34953	2.026	3586	10
	3	27872	1.615	3036	16
	4	20890	1.211	2511	37
	5	28405	1.646	2476	52
Alvand	1	11622	0.674	893	95
	2	47971	2.780	822	85
	3	15192	0.880	1780	58
	4	13311	0.771	553	93
	5	15946	0.924	893	95
Anzali	1	29129	1.688	3955	1
	2	35767	2.073	3832	4
	3	28963	1.678	3842	4
	4	29927	1.734	3216	18
	5	31793	1.842	3478	13
Aq Qaleh	1	24800	1.438	2094	60
	2	20500	1.685	2069	45
	3	20578	1.193	1719	55
	4	16322	0.946	1327	77
	5	18924	1.097	1677	79
Arak	1	29210	1.693	4003	0
	2	36272	2.102	3992	0
	3	29423	1.705	3991	0
	4	32137	1.862	3865	3

	5	33362	1.933	3953	1
Ardakan	1	17546	1.017	1865	61
	2	21603	1.252	1615	74
	3	15574	0.903	1868	55
	4	13571	0.786	619	92
	5	16172	0.937	950	94
Ardestan	1	17724	1.027	1913	60
	2	21692	1.257	1655	72
	3	15781	0.915	1922	53
	4	13765	0.798	671	92
	5	16321	0.946	933	94
Babol	1	21987	1.274	2286	47
	2	28862	1.673	1941	49
	3	18820	1.091	1869	56
	4	16002	0.927	1253	79
	5	19478	1.129	1231	84
Babolsar	1	29175	1.691	3980	1
	2	36064	2.090	3919	2
	3	29204	1.692	3918	2
	4	30855	1.788	3234	12
	5	32391	1.877	3420	7
Bafq	1	17121	0.992	2345	39
	2	21437	1.242	1577	74
	3	15462	0.896	1843	56
	4	13488	0.782	595	93
	5	16072	0.931	923	94
Baft	1	18131	1.051	2030	55
	2	22115	1.282	1775	68
	3	16229	0.941	2051	49
	4	14341	0.831	822	89
	5	16898	0.979	1135	92
Bam	1	17199	0.997	2362	39
	2	21601	1.252	1620	74
	3	15448	0.895	1845	56
	4	13576	0.787	622	93
	5	16139	0.935	950	94
Bandarabas	1	15265	0.885	1847	57
	2	19720	1.143	1139	87
	3	13709	0.794	1378	72
	4	12716	0.737	362	97
	5	15166	0.879	684	97
Bandae Genave	1	20083	1.164	2146	45
	2	23312	1.351	2085	58
	3	17241	0.999	1695	66
	4	15080	0.874	1014	86
	5	17658	1.023	1353	88
Bandar Lenge	1	18062	1.047	2015	58
	2	21913	1.270	1741	70
	3	41931	2.430	0	100
	4	14042	0.814	757	91
	5	16783	0.973	1115	93
Bandar Mahshahr	1	21671	1.256	2197	50
	2	27107	1.571	1881	53
	3	18058	1.047	1894	59

	4	15672	0.908	1174	82
	5	18312	1.061	1526	84
Birjand	1	16844	0.976	2250	43
	2	20978	1.216	1485	78
	3	15021	0.871	1741	60
	4	13238	0.767	527	94
	5	15906	0.922	876	95
Bojnurd	1	18395	1.066	2636	30
	2	22478	1.303	1877	65
	3	16559	0.960	1525	71
	4	14401	0.835	838	88
	5	16954	0.983	1160	91
Borujen	1	21089	1.222	1774	59
	2	26230	1.520	1590	61
	3	17421	1.010	1734	64
	4	15072	0.873	1025	84
	5	17611	1.021	1341	88
Bukan	1	17388	1.008	2402	38
	2	21423	1.242	1615	73
	3	15745	0.912	1915	54
	4	13763	0.798	658	92
	5	16312	0.945	986	94
Bushehr	1	18042	1.046	1997	59
	2	21785	1.263	1708	71
	3	16041	0.930	1381	77
	4	13860	0.803	723	91
	5	16742	0.970	1101	93
Chabahar	1	28518	1.653	3769	5
	2	33973	1.969	3048	16
	3	22923	1.329	2531	37
	4	19479	1.129	2140	50
	5	25326	1.468	2198	47
Chalus	1	18949	1.098	2254	46
	2	22884	1.326	1985	60
	3	17165	0.995	1649	67
	4	14745	0.854	917	87
	5	17392	1.008	1259	89
Darab	1	18596	1.078	2142	52
	2	22489	1.304	1874	65
	3	16540	0.959	1520	71
	4	14471	0.839	866	88
	5	17071	0.989	1194	91
Dargaz	1	22375	1.297	1752	58
	2	23497	1.362	2140	55
	3	17537	1.017	1766	63
	4	12443	0.721	1070	84
	5	17865	1.035	1406	86
Dehloran	1	20789	1.205	1680	64
	2	23628	1.369	1688	64
	3	16886	0.979	2211	44
	4	14722	0.853	936	87
	5	17392	1.008	1282	89
Dezful	1	19460	1.128	2369	44
	2	24037	1.393	1824	59

	3	17246	1.000	2308	41
	4	15087	0.874	1027	85
	5	17781	1.031	1379	87
Dir	1	18417	1.068	2092	55
	2	22221	1.288	1813	68
	3	16244	0.942	2046	50
	4	14130	0.819	788	90
	5	16986	0.984	1166	92
Do Gonbadan	1	20349	1.179	2913	20
	2	23271	1.349	2137	52
	3	17933	1.040	1860	60
	4	15480	0.897	1130	82
	5	18139	1.051	1476	85
Do Rud	1	20020	1.160	1962	61
	2	22871	1.325	1970	61
	3	16932	0.981	2229	42
	4	14842	0.860	938	86
	5	17479	1.013	1273	89
Esfahan	1	18228	1.056	2627	29
	2	22453	1.301	1865	64
	3	16551	0.959	2133	45
	4	14224	0.824	801	89
	5	16920	0.981	1142	91
Firuzabad	1	20403	1.183	2062	58
	2	23223	1.346	2065	58
	3	17271	1.001	1700	65
	4	15029	0.871	1009	85
	5	17587	1.019	1338	88
Ghamsar	1	21149	1.226	2278	47
	2	23997	1.391	2285	47
	3	18337	1.063	1950	56
	4	15998	0.927	1221	79
	5	18565	1.076	1553	82
Gonabad	1	18480	1.071	2140	51
	2	22564	1.308	1893	64
	3	16861	0.977	1569	70
	4	14344	0.831	831	88
	5	17042	0.988	1178	91
Gonbad Ghabus	1	22115	1.282	2326	45
	2	30590	1.773	2315	45
	3	18473	1.071	2007	55
	4	16151	0.936	1290	78
	5	18697	1.084	1628	80
Gorgan	1	23851	1.383	2211	50
	2	31055	1.800	2450	41
	3	19531	1.132	2723	27
	4	16540	0.959	1387	75
	5	22194	1.286	1144	82
Hamedan	1	29125	1.688	3963	1
	2	35847	2.077	3863	3
	3	29059	1.684	3876	3
	4	30463	1.766	3111	15
	5	32108	1.861	3584	10
Ilam	1	21213	1.230	2278	49

	2	24075	1.396	2278	49
	3	19318	1.120	1604	71
	4	15740	0.912	1189	80
	5	18364	1.064	1535	83
Iranshahr	1	28987	1.680	3702	0
	2	36199	2.098	3964	1
	3	29344	1.701	3963	1
	4	31666	1.835	3724	6
	5	33021	1.914	3856	3
Jahrom	1	19470	1.129	2784	26
	2	23013	1.334	2002	61
	3	17005	0.986	1635	68
	4	14875	0.862	962	86
	5	17469	1.012	1295	89
Jask	1	22206	1.287	1982	64
	2	25340	1.469	1807	57
	3	17710	1.027	1805	63
	4	15386	0.892	1096	84
	5	18076	1.048	1458	86
Jiroft	1	19518	1.131	2413	39
	2	25583	1.483	1889	53
	3	17546	1.017	1790	61
	4	15410	0.893	1116	82
	5	17897	1.037	1427	85
Kamyaran	1	20853	1.208	2187	52
	2	23676	1.372	2191	52
	3	17767	1.030	1828	60
	4	15597	0.904	1123	82
	5	18102	1.049	1450	85
Kangan	1	19665	1.140	2836	25
	2	23266	1.349	2068	59
	3	18499	1.072	1396	78
	4	15012	0.870	998	86
	5	17641	1.022	1344	88
Karaj	1	17784	1.031	1922	60
	2	21556	1.249	1638	73
	3	15739	0.912	1912	54
	4	13776	0.798	664	92
	5	41207	2.388	0	100
Kashan	1	29195	1.692	4007	0
	2	36296	2.103	4007	0
	3	29447	1.706	4007	0
	4	32586	1.888	4007	0
	5	33519	1.942	4007	0
Kashmar	1	20284	1.176	2033	59
	2	23264	1.349	2056	59
	3	17286	1.002	1692	66
	4	15010	0.870	1002	85
	5	17507	1.015	1319	88
Kazerun	1	21234	1.231	1825	58
	2	23428	1.358	2114	56
	3	17441	1.011	1744	64
	4	15220	0.882	1054	84
	5	17695	1.026	1371	87

Kerman	1	28859	1.672	3865	3
	2	34696	2.011	3274	10
	3	28272	1.638	3637	8
	4	24225	1.404	1942	60
	5	23869	1.383	2663	32
Kermanshah	1	19461	1.128	1815	67
	2	22272	1.291	1817	67
	3	16263	0.942	2064	48
	4	14194	0.823	785	90
	5	16922	0.981	1133	92
Khalkhal	1	15973	0.926	1466	74
	2	19997	1.159	1223	84
	3	14100	0.817	1506	66
	4	12865	0.746	405	96
	5	15340	0.889	715	97
Khash	1	19425	1.126	1561	71
	2	22051	1.278	1754	69
	3	16155	0.936	1414	75
	4	14096	0.817	773	90
	5	16796	0.973	1115	92
Khomeyn	1	18283	1.060	2066	54
	2	22149	1.284	1793	67
	3	16351	0.948	2076	48
	4	14311	0.829	806	89
	5	16834	0.976	1119	92
Khormuj	1	18092	1.049	2023	57
	2	23797	1.379	1285	74
	3	16170	0.937	1414	75
	4	14008	0.812	755	91
	5	16776	0.972	1117	93
Khoramabad	1	19201	1.113	2878	21
	2	26812	1.554	1786	54
	3	17815	1.032	1833	60
	4	15581	0.903	1117	82
	5	18136	1.051	1448	85
Khoy	1	29035	1.683	3717	0
	2	36279	2.102	4001	0
	3	29430	1.706	4001	0
	4	32412	1.878	3950	1
	5	33300	1.931	3698	0
Kuhdasht	1	22423	1.300	2418	41
	2	30892	1.790	2089	44
	3	18884	1.095	2104	51
	4	16498	0.956	1371	75
	5	19348	1.121	1520	79
Langrud	1	16828	0.975	1692	69
	2	20881	1.210	1453	79
	3	14784	0.857	1673	63
	4	13300	0.771	559	94
	5	15976	0.926	905	96
Lar	1	19133	1.109	2281	47
	2	25970	1.505	1508	65
	3	17076	0.990	1650	67
	4	14868	0.862	966	86

	5	17619	1.021	1323	89
Mahabad	1	17919	1.039	2531	34
	2	22193	1.286	1782	69
	3	16220	0.940	2036	50
	4	14079	0.816	748	90
	5	16606	0.962	1066	93
Maragheh	1	17356	1.006	2389	38
	2	21416	1.241	1599	74
	3	15642	0.906	1889	55
	4	13611	0.789	621	92
	5	16194	0.938	947	94
Marand	1	18938	1.098	2806	24
	2	23236	1.347	2090	56
	3	17328	1.004	2335	39
	4	15217	0.882	1033	84
	5	17810	1.032	1372	87
Marivan	1	19497	1.130	1823	67
	2	22328	1.294	1828	67
	3	16466	0.954	1486	72
	4	14259	0.826	799	89
	5	16823	0.975	1119	92
Mashhad	1	23080	1.383	2685	24
	2	31669	1.898	2329	35
	3	20399	1.222	2110	44
	4	17067	1.023	1563	69
	5	19581	1.173	1890	71
Masjed Soleyman	1	23709	1.374	2387	35
	2	26076	1.511	2049	48
	3	19543	1.133	1659	70
	4	15964	0.925	1240	80
	5	18504	1.073	1578	82
Miyaneh	1	16341	0.947	2126	47
	2	20446	1.185	1356	81
	3	14637	0.848	1639	63
	4	13134	0.761	488	95
	5	15676	0.908	812	96
Minab	1	20184	1.170	2013	60
	2	23046	1.336	2023	60
	3	17135	0.993	1662	67
	4	14893	0.863	976	86
	5	17474	1.013	1313	89
Naein	1	17224	0.998	2368	38
	2	21590	1.251	1612	74
	3	15607	0.904	1874	55
	4	13588	0.787	622	92
	5	16156	0.936	947	94
Neyriz	1	18565	1.076	1929	55
	2	22115	1.282	1779	68
	3	16310	0.946	2061	49
	4	14213	0.824	802	89
	5	16870	0.978	1135	92
Neyshabur	1	19872	1.152	2475	38
	2	23698	1.373	2191	51
	3	17717	1.027	1813	60

	4	15353	0.890	1085	82
	5	17941	1.040	1418	84
Orumieh	1	29191	1.692	3982	1
	2	36058	2.090	3916	2
	3	29220	1.693	3919	2
	4	30863	1.789	3508	11
	5	32554	1.887	3711	7
Parsabad	1	15447	0.895	1894	55
	2	19810	1.148	1163	86
	3	13793	0.799	1410	71
	4	12696	0.736	360	97
	5	15221	0.882	693	97
Qaen	1	17958	1.041	2535	34
	2	21988	1.274	1744	69
	3	16223	0.940	1411	74
	4	14006	0.812	723	91
	5	16578	0.961	1051	93
Qom	1	17593	1.020	2426	37
	2	21516	1.247	1626	73
	3	15684	0.909	1902	54
	4	13725	0.795	655	92
	5	16307	0.945	987	94
Ramsar	1	29207	1.693	3978	1
	2	35969	2.084	3888	3
	3	29141	1.689	3892	3
	4	30491	1.768	3119	14
	5	32322	1.873	3631	9
Ravar	1	17438	1.011	2424	36
	2	21812	1.264	1670	72
	3	15782	0.915	1926	53
	4	13655	0.791	648	92
	5	16256	0.942	977	94
Sabzevar	1	27949	1.620	3384	8
	2	33374	1.934	3125	22
	3	20727	1.201	2595	33
	4	18835	1.092	1966	57
	5	21142	1.225	2274	57
Sanandaj	1	18362	1.064	2082	54
	2	22338	1.295	1824	67
	3	16417	0.951	1475	72
	4	14261	0.826	797	89
	5	16774	0.972	1107	92
Saravan	1	19317	1.120	2144	49
	2	22898	1.328	1969	62
	3	16837	0.976	1590	69
	4	14624	0.848	911	87
	5	17226	0.998	1244	90
Sari	1	21656	1.256	2397	44
	2	24460	1.418	2400	44
	3	18627	1.080	2044	53
	4	16293	0.944	1326	77
	5	18888	1.095	1669	79
Semnan	1	21108	1.223	2265	48
	2	23936	1.387	2270	48

	3	17888	1.037	2487	33
	4	15887	0.921	1197	80
	5	18449	1.069	1533	82
Sepidan	1	20931	1.213	1721	61
	2	23094	1.339	2027	59
	3	17257	1.000	1695	65
	4	15039	0.872	1009	85
	5	17512	1.015	1316	88
Shahrebabak	1	17447	1.012	1854	62
	2	21484	1.245	1607	74
	3	15575	0.903	1877	55
	4	13725	0.795	673	92
	5	16357	0.948	1006	94
Shahre-kord	1	23234	1.392	2240	36
	2	26891	1.612	1818	51
	3	17594	1.054	2421	33
	4	15693	0.940	1154	80
	5	18067	1.083	1451	83
Shahrud	1	17858	1.035	2509	35
	2	21984	1.274	1752	70
	3	16117	0.934	2010	51
	4	14017	0.812	734	91
	5	16649	0.965	1073	93
Shiraz	1	18367	1.064	2077	55
	2	22133	1.283	1791	68
	3	16296	0.944	2057	49
	4	14174	0.821	781	90
	5	16714	0.969	1106	92
Sirjan	1	17973	1.042	1979	58
	2	21814	1.265	1705	70
	3	16108	0.934	2001	51
	4	13926	0.807	736	90
	5	16621	0.963	1075	93
Tabas	1	18351	1.064	2090	53
	2	22394	1.298	1838	66
	3	16279	0.943	2065	48
	4	14115	0.818	772	90
	5	16954	0.983	1142	92
Tabriz	1	16115	0.934	1514	74
	2	20171	1.169	1279	83
	3	14250	0.826	1541	66
	4	12899	0.748	422	96
	5	15542	0.901	762	97
Takab	1	16984	0.984	2286	42
	2	21007	1.218	1501	77
	3	15249	0.884	1791	58
	4	13403	0.777	570	93
	5	16053	0.930	913	95
Taybad	1	17759	1.030	2481	36
	2	21826	1.265	1694	71
	3	15929	0.923	1957	53
	4	13837	0.802	678	92
	5	16426	0.952	1011	93
Tehran	1	17199	0.997	2341	40

	2	21237	1.231	1570	75
	3	15369	0.891	1832	57
	4	13582	0.787	631	92
	5	16192	0.938	967	94
Torbate Jam	1	18211	1.055	2618	30
	2	22528	1.306	1872	65
	3	16488	0.956	2116	46
	4	14296	0.828	811	89
	5	16846	0.976	1136	91
Torbate Heydarie	1	29140	1.689	3962	1
	2	35797	2.074	3848	3
	3	28991	1.680	3855	3
	4	30031	1.740	3276	16
	5	31637	1.833	3231	11
Yasuj	1	22473	1.302	1874	56
	2	25292	1.466	1787	56
	3	17700	1.026	1807	61
	4	15416	0.894	1106	82
	5	17879	1.036	1414	86
Yazd	1	17382	1.007	1850	63
	2	22890	1.327	1599	75
	3	15375	0.891	1841	56
	4	13633	0.790	641	92
	5	16221	0.940	970	94
Zabol	1	17291	1.002	1798	65
	2	21273	1.233	1543	77
	3	15221	0.882	1779	59
	4	13488	0.782	598	93
	5	16080	0.932	930	95
Zahedan	1	28024	1.624	3627	8
	2	32869	1.905	2706	26
	3	21643	1.254	2213	49
	4	18241	1.057	1824	61
	5	21589	1.251	1927	62
Zanjan	1	49131	2.847	3501	5
	2	34533	2.001	3447	13
	3	27819	1.612	3259	11
	4	23422	1.358	1726	68
	5	27575	1.599	2038	63
1-Generic 1kW	2-Generic 3kW	3-BWC XL. 1.25kW	4-WES Tulipo 2.5 kW	5-Generic 10kW	

Three stations suitable for the use of Generic 1kW wind turbines are prioritized, Alvand with the total NPC of 11622 $, Bandarabas with total NPC of 15265 $ and Parsabad with total NPC of 15447 $. With regard to this wind turbine, Zanjan, Arak and Ramsar stations are the most unsuitable stations, respectively, with total NPC of 49131$, 29210$ and 29207 $ respectively.

Three stations suitable for the use of the Generic 3kW wind turbine, respectively, are Bandarabas with the total NPC of 19720 $, Parsabad with the total NPC of 19810 $, and Khalkhal with the total NPC of 19997 $. With regard to this wind turbine, the Alvand, Kashan and Khoy stations, respectively, with the total NPC of 47971$, 36296 $ and 36279 $ respectively, are the most unsuitable stations.

The three stations suitable for using the BWC XL.1.25kW turbine, according to the priority, are Bandarabas with the total NPC of 13709 $, Parsabad with the total NPC of 13793 $ and the Khalkhal with the total NPC of 14100 $. With regard to this wind turbine, the stations of Bandar Lengeh, Kashan and Khoy, respectively, with the total NPC of 41931 $, 29447 $ and 29430 $ respectively, are the most unsuitable stations.

Three stations suitable for the use of WES 2.5kW wind turbine, respectively, are Dargaz with the total NPC of 12443 $, Parsabad with the total NPC of 12696 $, and Bandarabas with the total NPC of 12716 $. With regard to this wind turbine, the Kashan, Khoy and Arak stations, respectively, with the total NPC of 32586 $, 32412 $ and 32137 $ are the most unsuitable stations.

The three stations suitable for using Generic 10kW wind turbines, as a matter of priority, include Bandarabas with total NPC of 15166 $, Parsabad with the total NPC of 15221 $ and Khalkhal with total NPC of 15340 $. With regard to this wind turbine, the Karaj, Kashan and Arak stations, respectively, with the total NPC of 41207 $, 33519 $ and 33362 $, are the most unsuitable stations.

From the results of Table 3, it is obvious that Generic 3kW and Generic10kW wind turbines are not in the first priority economic point at any stations. At Alvand, Arak, Babolsar, Iranshahr, Kashan, Khoy and Orumieh stations Generic 1kW wind turbine is the most economical option. At Anzali, Hamedan, Ramsar and Torbate Heydarie stations, the BWC XL 1.25kW wind turbine is the most economical option and for the remaining 91 stations, the WES 2.5 kW wind turbine is the most economically feasible option. One of the important reasons for the low cost of using a WES 2.5kW wind turbine is that this type of wind turbine, in contrast to the other four wind turbines, has AC power and the cost of the electrical converter to convert the current DC to AC decreases.

According to the results of Table 3, Khoy, Kashan and Arak stations use almost zero percent of wind turbines, which indicates their very weak potential in this area, therefore it is recommended that in these places, there is no investment in the field of using wind turbine.

5. Conclusion

Increasing the share of renewable energy in electric power generation is one of the medium and long term strategic policies of many countries in the world. The expansion of wind farms in many countries requires direct and indirect government support. These supports are tax exemptions, financial and customs facilities, purchases of electricity at preferential prices and location assignments. In Iran, considering the private costs of wind and fossil power plants, the development of wind power plants for electricity production is not yet fully economical, but it is becoming economically. But if the social costs of fossil fuels containing negative impacts are compared, the cost of production in wind turbines, will be less than fossil fuels, and its electricity can be used as a sustainable energy for sustainable socio-economic development of the country. The use of wind energy in Iran, in addition to construction and development, has created new occupations, and finally, the localization of wind energy technology will increase the economy of the country [17, 18]. Considering the issues raised in the present work, the technical-economic-environmental study on wind speed data at 10 m altitude of 102 stations in Iran was carried out using HOMER software. Five domestic-scale wind turbines have been used for power supply feasibility studies. Major results are as follows:

- The highest and lowest total NPC for generic 1kW wind turbine with a value of 49131$ and 11622$ respectively are related to Zanjan and Alvand stations.
- The highest and lowest total NPC for generic 3kW wind turbine with a value of 47971$ and 19720$ respectively are related to Alvand and Bandarabas stations.
- The highest and lowest total NPC for the BWC XL 1.25kW wind turbine with values of 41931 $ and 13709 $ respectively are related to Bandar Lengeh and Bandarabas stations.
- The highest and lowest total NPC for WES 2.5kW wind turbine with a value of 32586 $ and 12443 $ respectively are relate to Kashan and Dargaz stations.
- The highest and lowest total NPC for generic 10kW wind turbine with values of 41207 $ and 15166 $ respectively are related to stations in Karaj and Bandarabas.
- Since WES 2.5kW wind turbine is the most economical and the most environmentally friendly wind turbine, this wind turbine is recommended for use in Iran.
- According to the results, it can be stated that the stations of Bandarabas, Parsabad and Khalkhal are recommended for the use of a variety of wind turbines, since approximately the amount of production price per kW of wind power in them is less than the other stations This is possible due to its good wind potential.
- According to the results, it can be stated that Kashan, Arak and Khoy stations are not

suitable for use with a variety of wind turbines, because the cost per kilowatt hour of wind power produced in them is higher than other stations.

Since the present work is the continuation of the authors work [19-24], the authors hope that the results of this work can play an important role in the development of the country and increase the level of comfort of the Iranian people.

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