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Theoretical Study to Select Wind Turbines and Energy Production for the Entire Area in Iraq

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Abstract

The majority of electrical power generation systems in Iraq are gas turbine stations that cause many economic and environmental problems since they are based on fossil fuel sources. Renewable energy, specifically wind, can be a solution (besides solar energy) to produce clean energy. Throughout this work, specific wind turbines can be suggested within certain dimensions and hub heights to satisfy viable rated power for available wind density. Many regions in Iraq, especially eastern and western regions, seem promising locations for installing wind turbines for electricity generation. The results showed that these locations have a power density between 700-1200 kWh/m^2 annually at an elevation of 80 m as a critical height. The suggested horizontal axis turbine can offer rated power of up to 200 kW, reaching 350 kW in some locations, especially in Hay district and around. Other locations (southern and internal regions) can produce less power, and they are suitable for vertical axis turbines with rated power of 10-20 kW. However, some locations are not recommended for large-scale turbines due to the long time off-design period. Micro-turbines that produce 5 kW are suitable for the northern region of Iraq.

Keywords: Fossil fuel; Power; Renewable energy; Sustainability; Wind turbine

1. Introduction

Besides the pollutants that pollute the environment, fossil fuels are the primary source of greenhouse gases. The increasing carbon content in the atmosphere leads to so-called "global warming," which directly impacts the climate. This event is accompanied by many dangers to human beings and sustainable development [1], [2]. On the other hand, the increase in energy demand due to population growth and the fluctuation of oil prices motivate the use of alternative energy sources. Serious and direct thinking to use renewable energies becomes, therefore, inevitable. Solar and wind energies can generate electricity in huge capacities for different applications as they are clean and sustainable [3], [4]. Wind energy is one of the most abundant renewable energy resources on the earth and has been harnessed for centuries. Wind is the movement of air due to the change in atmospheric temperature by solar radiation that causes differences in atmospheric pressure [5]. Currently, wind energy is used in two main applications: electric generation and water pumping [6], [7].

Wind turbines transform the kinetic energy of the wind through movable parts into mechanical energy. However, some wind machines can be used to grind grain, such as the windmills. Some other machines can be used directly to pump water in remote areas. The smallest turbines are used for individual household applications, battery charging, or auxiliary power on sailing boats. Large wind turbines are sources of commercial electrical power in developed countries. While micro-turbines are used to produce power for small houses [8]-[10]. Wind turbines are classified according to the position of the axis of rotation into [11], [12]:

- Horizontal-axis wind Turbine (HAWT): In this type, the rotor's axis is parallel to the wind stream and the ground. The turbine usually has a large swept area and three blades.
- Vertical-axis wind Turbine (VAWT): In this type, the rotor's axis is perpendicular to the wind stream and the ground. The most common types are Darrieus and

Savonius. Some other types have mixed characteristics.

- A small turbine, called a micro-turbine, has an area of less than 6 m^2 and can be used for small applications. Fig. 1 shows more details about the types of wind turbines.

Figure 1. Common types of wind turbines.

The intention to use electrical power generated from wind has grown significantly in the last few decades due to the decrease in the cost of wind turbines [13]. Therefore, there is currently a variety of wind turbines in the market to meet different electrical energy demands and weather conditions, starting from power of 10 kW up to 10 MW [14], [15].

In the design, the length of the blades is the most significant factor that affects the harvesting of the electrical power in a wind turbine, where the rotor-swept area is essential because the rotor captures the wind energy. So, the larger the blades, the more energy it can produce. Although the calculation of wind power illustrates many essential features related to wind turbines, the best measure of wind turbine performance is annual energy output. Many parameters affect the efficiency of wind turbines, such as the wind speed and direction, height of the rotational axis and its diameter, geometry of blades, and gear characteristics. For example, the HAWT turbine is effective when the axis has a hub altitude of at least 40 m. Where there is an increase in the output power by double (100-120%) [16]-[18], in this case, the wind speed is usually between 8-14 m/s with mostly continuous flow. The generated power is generally more than 500 kW [19]. However, some parameters also influence the turbine's overall efficiency, such as wind power, volumetric contribution of wind, gearbox losses, and converter losses (losses due to the change of the mechanical power into electrical power in the generator). Manufacturers have found that the turbine efficiency may decrease by 5% after three years of operation [20].

Recently, Iraq has been looking for renewable sources as alternatives to fossil fuels for electricity generation. In 2019, the Ministry of Electricity (MoE) announced plans to build the country's first wind farm in the southern province of Najaf. This project, which is expected to generate 50 MW of electricity, is a significant step towards realizing the potential of wind energy in Iraq [21]. Hence, reviewing the available studies, analyzing the outcomes, and introducing the primary set of points related to wind energy in Iraq is important.

According to that, several works have presented their work showing the importance of wind energy and the feasibility of wind turbines in Iraqi climatic conditions. Several review studies [22]-[26] have presented a general overview of the importance of wind energy in Iraq with some examples of the current applications or available data. Some experimental studies have focused on various configurations for wind turbines, such as the horizontal axis [27]-[35], the vertical axis [36]-[38], and small or micro-turbines [39]-[42]. The ideas in these studies may have some developed suggestions or the ability to satisfy a range of powers for specific applications. Reviewing the available literature shows that the works have presented reasonable data and results for different cases and certain regions in Iraq. More details about the reviewed works can be found in Table 1.These investigations were limited to a particular area and did not cover the entire country. Also, they have yet to consider the compatibility of the turbine with the wind features. Therefore, the objective of this work is to analyze the statistical data of wind obtained from different locations and calculate actual power output. The novelty is related to (1) covering the entire area of Iraq, (2) specifying a suitable type of turbine for a certain location and assigning its dimensions and productive height, and (3) determining the optimum sites for wind energy harvesting.

2. Methodology

2.1. Data Collecting

In this work, several locations in Iraq have been selected based on the availability of meteorological stations, which provide weather data, especially wind characteristics. The obtained data represent the average values of mean wind speeds recorded during the last decade (daily, monthly, and annually) based upon measured data at an elevation of 10 meters above the ground [43]-[47].

The collected data include the annual average speed and major direction of wind that satisfies continuous flow, as shown in Fig. 2 and Fig. 3. Therefore, the city can be characterized by the main direction of wind. For example, Baghdad is defined by (NW, N) because wind passing through it is mostly northwest-direction (44%) or north-direction (24%), as shown in Fig. 4 [44]. If that ratio is equal to or greater than 50%, the location is denoted by one major direction, as (W) for Kut. The data also distributed the wind characteristics for all months of the year and overall selected locations in the country, as shown in Table 2.

Table 1. Details of previous works related to the use of wind energy in Iraq.

Ref.	Description	Type of work	Type of turbine	Main findings
[27]	Predicting wind energy using an application tool in the Kurdistan region (North)	Theoretical	HAWT	The work proposed the location of 132 KV turbines
[28]	Evaluating the potential of wind energy in Basra (south)	Theoretical	HAWT	It was concluded that the location is suitable for a large-scale turbine with a power output of up to 400 kW
[29]	Evaluating the availability of wind power for many sites in the southern region	Theoretical	HAWT	The power density is more than 200 W/m^2 at a height between 60-100 m
[30]	Providing the number of hours that wind is effective in Wasit province (East)	Theoretical	HAWT	It is recommended to serve 850 kW turbine works at an elevation of 50 m
[31]	Using software to analyze the capacity factor of wind energy in south-eastern regions	Theoretical	HAWT	The output power can reach up to 500 kW at 65 m height
[32]	Selecting the best location of the wind turbines for some places, mainly in the south	Theoretical	HAWT	The best sites were the south-eastern parts
[33]	Selecting the best location of the turbines in Nineveh province (North)	Theoretical	HAWT	The power density is between 50-120 W/m^2 at 50 m height
[34]	Introducing design parameters to operate wind turbine in Baghdad (Center)	Theoretical	HAWT	The output power can reach up to 800 kW at 60 m height
[35]	Using software to analyze the exergy maps for wind energy harvesting	Theoretical	HAWT	An output power of 100 kW average is acceptable
[36]	Evaluating the wind power for sites in the north	Theoretical	VAWT	It can be used with low-output power
[37]	Analyzing VAWT productivity in Baghdad	Theoretical	VAWT	It can be used with a very low output power
[38]	Manufacturing a VAWT turbine in Tikrit for water-lifting purposes	Experimental	VAWT	It can be used with a very low output power
[39]	Analyzing a small turbine for lighting the highway roads in general	Experimental	Small	A power of 200 W can be produced
[40]	Manufacturing a tiny turbine in Tikrit for house-holding	Experimental	Small	A power of 20 W can be produced
[41]	Manufacturing a small turbine in Tikrit for house-holding	Experimental	Small	A power of 300 W can be produced
[42]	Testing a small turbine in Basra for house-holding	Experimental	Small	A power of 1300 W can be produced

2.2. Calculation of Power

The harvested wind power can be calculated by equation (1) [49]:

$$P = \frac{1}{2} Cp\, \rho\, V^3\, A \tag{1}$$

Where;

Cp is the power coefficient
ρ is the air density (kg/m^3)
V is the wind speed (m/s)
A is the effective area of airflow (m^2)

A wind turbine's theoretical coefficient of power is 16/27 [50]. However, this value cannot be achieved due to the energy losses by mechanical and electrical transmissions. The highest actual power coefficient ranges between 0.4 and 0.5 [51]. By fixing this value at 0.4 (in case of high losses), the maximum power output will be by equation (2):

$$P = 0.24\, V^3\, A \tag{2}$$

The calculation of wind power is based on instant wind speed during the on-design period, but the best measure of wind turbine performance is based on the annual energy output (in kWh/m2.year), also denoted commonly as power density. The later can be calculated as equation (3) [52], [53]:

$$P_d = 2.1\, V^3 \tag{3}$$

2.3. Assumptions

Some assumptions are required based on the turbine type under consideration to satisfy reliable power calculation and suitable turbine selection. For the HAWT turbine, assume:

- The target of power in the current work is 100 kW for a small-scale HAWT turbine (low power) and 200 kW for a large-scale turbine (high power).
- Cut-in wind speed is 4 m/s [54], [55].

- Usually, the rated wind speed is more than 9 m/s to operate a large-scale turbine (H-HAWT) in its maximum power [55], [56], or more than 6 m/s to produce viable energy for a small-scale turbine (L-HAWT) [54].
- The minimum swept area should be no less than 1000 m^2 for low power generation and around 2000 m^2 for high power generation [34],[57], [58].
- Regarding the tower height, the wind speed at the selected locations is considered a gentle class according to the Beaufort scale. Therefore, a minimum tower height of 60 m for small-scale turbines and more than 80 m for large-scale or high-power production are advised [34], [57], [59].
- Wind speed-elevation profile is based on the modified 1/7 power law. Where it has been found that this exponent is not precise for some locations in Iraq [60]. For example, the index is 0.29 for the eastern region due to the presence of hills and mountains and 0.24 for the western region due to the considerable desert area.
- The turbine is limited to the continuous flow of wind in its direction [61].

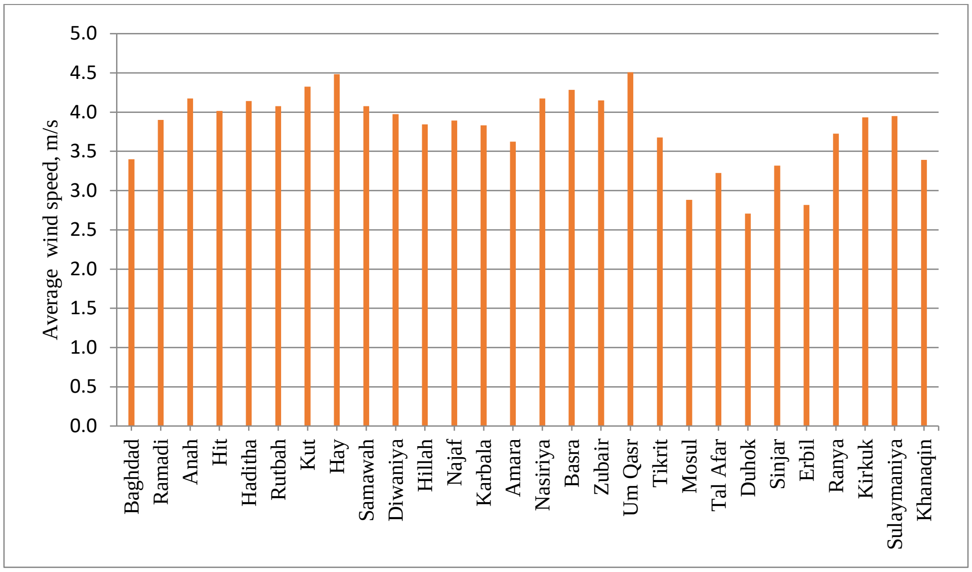

Figure 2. Average wind speed over many locations in Iraq [43]-[47].

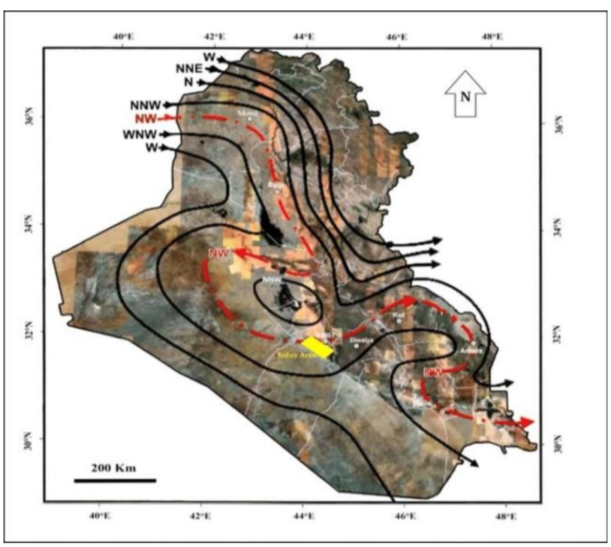

Figure 3. Wind direction over Iraq [48].

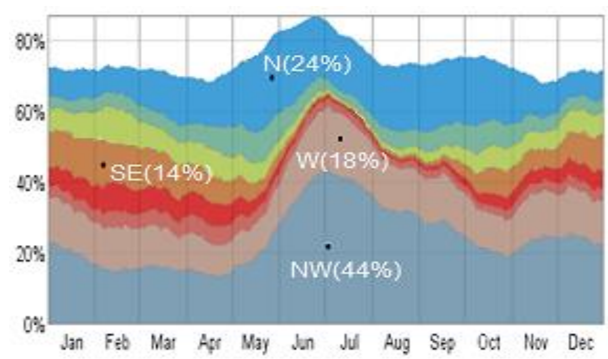

Figure 4. Variations of wind speed direction in Baghdad [44].

Table 2. Details of Mean wind speed in (m/s) for many locations in Iraq [43]-[47].

It.	City /Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Wind Dir.
1	Baghdad	2.8	3.2	3.4	3.6	3.8	4	3.9	3.9	3.3	3.1	2.9	2.9	3.40	NW, N
2	Ramadi	3.5	3.6	3.8	3.8	4.5	5.1	4.7	4.2	3.8	3.4	3.2	3.2	3.90	NW, W
3	Anah	3.4	3.8	4	4.2	4.4	5.5	5.8	5	4	3.4	3.3	3.3	4.18	W
4	Hit	3.4	3.6	3.8	3.9	4.2	5.3	5.5	4.8	3.9	3.4	3.2	3.2	4.02	W
5	Haditha	3.4	3.7	3.9	4.1	4.3	5.5	5.8	5	4	3.4	3.3	3.3	4.14	W
6	Rutbah	4	4.3	4.4	4.3	4.2	4.6	4.7	4	3.5	3.5	3.6	3.8	4.08	W
7	Kut	3.5	3.8	3.9	3.9	4.4	5.8	5.8	5.3	4.6	3.8	3.6	3.5	4.33	W
8	Hay	3.9	4.1	4.2	4.5	5.1	5.5	5.3	5.2	4.4	3.9	3.8	3.9	4.48	W
9	Samawah	3.5	3.7	3.8	3.9	4.3	5.3	5.1	4.5	4.1	3.8	3.5	3.4	4.08	W
10	Diwaniya	3.4	3.6	3.8	3.8	4.3	4.6	4.9	4.8	4.1	3.6	3.4	3.4	3.98	NW, W
11	Hillah	3.3	3.4	3.6	3.7	4	5	5	4.5	3.8	3.4	3.2	3.2	3.84	NW, N
12	Najaf	3.3	3.4	3.6	4.1	4.4	5.1	4.9	4.4	3.7	3.3	3.2	3.3	3.89	NW
13	Karbala	3.3	3.4	3.6	3.7	4.2	4.9	5.1	4.4	3.7	3.3	3.2	3.2	3.83	NW
14	Amara	4	4.2	4.1	3.9	3.4	3.3	3.1	3.1	3.5	3.4	3.7	3.8	3.63	NW, N
15	Nasiriya	3.6	3.8	4	4	4.4	5.1	5.2	4.8	4.3	3.7	3.6	3.6	4.18	W
16	Basra	3.7	4	4.1	4.1	4.4	5.5	5.3	5.3	4.2	3.6	3.6	3.6	4.28	NW, N
17	Zubair	3.8	4.1	4.1	4	4.8	5.4	4.9	4.2	3.6	3.6	3.6	3.7	4.15	NW, W
18	Umm Qasr	4	4.2	4.4	4.5	5	5.5	5.3	5.2	4.2	4.1	3.8	3.9	4.51	NW, W
19	Tikrit	3	3.1	3.4	3.6	3.9	4.7	4.9	4.4	3.8	3.3	3	3	3.68	N, NW
20	Mosul	2.4	2.6	2.7	2.8	3	3.4	3.5	3.2	3.1	2.8	2.6	2.5	2.88	NW
21	Tal Afar	2.7	2.9	3	3.1	3.4	4.2	3.8	3.6	3.3	3.1	2.9	2.7	3.23	NW
22	Duhok	2.4	2.6	2.6	2.8	3	3.2	3.2	3.1	2	2.7	2.5	2.4	2.71	N
23	Sinjar	2.9	3	3.1	3.3	3.6	4.1	4	3.8	3.4	3	2.8	2.8	3.32	N, NW
24	Erbil	2.5	2.6	3	2.7	2.9	3.1	3.2	3.1	2.9	2.7	2.6	2.5	2.82	N, NW
25	Ranya	3.2	3.4	3.6	3.9	4	4.3	4	3.8	3.7	3.9	3.6	3.3	3.73	N
26	Kirkuk	3.9	3.7	3.5	3.7	4	4.5	4.3	4.3	4	3.9	3.8	3.6	3.93	N, NE
27	Sulaymaniya	3.5	3.7	3.8	4	4.2	4.3	4.5	4.8	4.1	3.6	3.5	3.4	3.95	N, NE
28	Khannaqin	3	3.1	3.3	3.4	3.5	3.9	3.9	3.8	3.5	3.3	3	3	3.39	NW, N

Now, for the VAWT turbine, the following assumptions have been considered:

- Target of power is 20 kW.
- Minimum wind speed is 3.5 m/s for Darrieus turbine and 3 m/s for Savonius type [61], [62].
- The minimum effective area is 500 m^2 for Darrieus turbine and 300 m^2 for Savonius type [63]-[65].
- The turbine is operative for any wind direction (omni-directional) [61], [62].
- A minimum tower height of 20 m is recommended for feasible power production [63]-[65].

Note that for micro-turbines, assume unlimited operation conditions.

3. Results

Generally, the mean wind speed in Iraq is between 3 – 5 m/s for the standard elevation (10 m), which is considered a low wind velocity [49]. This range can be more significant for higher elevations. Moreover, at any given wind elevation, wind speed values are higher in summer and lower in winter. This point is advantageous for generating more power and overcoming peak loads in summer due to cooling load. However, the values of wind speed fall within the level of low-energy production for the application of electricity generation [5]-[8].

The scenario of presenting the results has focused on the locations that produce high power density and rated power based on their wind features and turbines. The results have been divided into three groups according to the similarity in the wind characteristics and the potential for wind energy. Also, the work presents the productivity of different turbines: small-scale (L-HAWT), large-scale (H-HAWT), Savonius (S-VAWT), Darrieus (D-VAWT), and micro-turbine. The results presented the power at three different heights: 20, 60, and 80 m.

The first group (A) has the lowest wind speed (less than three m/s) in Mosul, Duhok, and Erbil locations. For these locations, the annual power density is too small (less than 50 kWh/m^2), as shown in Fig. 5. Therefore, HAWT and VAWT turbines are both not feasible to use even at high elevations [6], [53]. Small or micro-turbines can supply rated power up to 5 kW if installed in these locations, as shown in Fig. 6.

The second group (B) has relatively medium wind speed (3 – 4 m/s) in the locations: Baghdad, Ramadi, Diwaniya, Hillah, Najaf, Karbala, Amara, Tikrit, Tal Afar, Sinjar, Ranya, Kirkuk, Sulaymaniya and Khanaqin. In these locations, micro-turbines can be useful in producing more than 5 kW of power. In the case of using VAWT or HAWT turbines, these locations have different responses according to wind features, type of turbine used, and elevation, as follows:

- VAWT turbine at 20 m height: In this case, the power density ranges from 90-270 kWh/m^2 annually, as shown in Fig. 7. Due to the limitation in wind characteristics and corresponding power output, some locations do not apply to VAWT turbines, such as Baghdad, Ramadi, Hillah, Karbala, Amara, Tikrit, Tal Afar, Sinjar and Ranya. These sites have rated power less than 10 kW, as shown in Fig. 8. Other locations (Diwaniya, Najaf, Kirkuk, Sulaymaniya, and Khanaqin) are applicable with rated power up to 1 kW. Note that some locations are limited to Savonius types due to the low wind speed or the lake of continuous wind period.

- HAWT turbine at 60 m height: In this case, the power density ranges from 160-460 kWh/m^2 annually, as shown in Fig. 9. In general, most of these locations are not applicable for L-HAWT turbine (swept area of 1000 m^2) due to the limitation in wind characteristics and power output (less than 50 kW), except for Najaf and Khanaqin, where the power may rise to 60 kW, as shown in Fig. 10.
- HAWT turbine at 80 m height: In this case, the power density ranges from 200-600 kWh/m^2 annually, as shown in Fig. 11. Even with a swept area of 2000 m^2 (H-HAWT), these locations can not satisfy the target rated power for large-scale (200 kW). However, some of the locations can satisfy encourageable rated power (more than 100 kW), such as Ramadi, Diwaniya, Hillah, Najaf, Karbala, Kirkuk, Sulaymaniya and Khanaqin (Shown in Fig. 12). Note that specific locations (Ramadi, Diwaniya and Hillah) are not recommended for HAWT turbine due to the extremely change in the direction of wind or long time for still air, which may cause high off-design period.

The third group (C) has relatively high wind speed (more than 4 m/s) in Anah, Hit, Haditha, Rutbah, Kut, Hay, Samawa, Nasiriya, Basra, Zubair, and Umm Qasr. These locations have different behaviors according to the features of wind and turbines used, as follows:

- VAWT turbine at 20 m height: In this case, the power density ranges from 290-540 kWh/m^2 annually, as shown in Fig. 13. Generally, these locations are applicable to VAWT turbines. They have shown rated power between 18-30 kW, as shown in Fig. 14. Note that some locations are limited to Savonius types due to the lake of continuous wind period.
- HAWT turbine at 60 m height: In this case, the power density ranges from 500-930 kWh/m^2 annually, as shown in Fig. 15. A few locations (Kut, Hay, and Umm Qasr) are applicable for the L-HAWT turbine at this elevation using a swept area of 1000 m^2. They can offer a rated power of more than 100 kW, as shown in Fig. 16. Other locations produce between 60-80 kW.
- HAWT turbine at 80 m height: In this case, the power density ranges from 700-1200 kWh/m^2 annually, as shown in Fig. 17. The mentioned density can be considered within the promised level. Therefore, for the swept area of 2000 m^2 (H-HAWT), all locations in this group (except Hit) can satisfy the target of rated power (200 kW). It is noticed that the suggested HAWT in Hay can offer a rated power of up to 350 kW (Shown in Fig. 18).
- However, some locations (Basra, Zubair, and Umm Qasr) may not be recommended for HAWT turbines due to the extreme change in the wind direction or the long time for still air, which may cause a high off-design period.

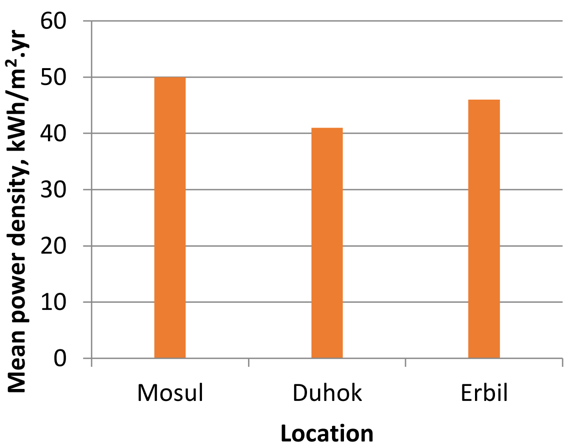

Figure 5. Annual power density in the locations of Group (A) at 20 m.

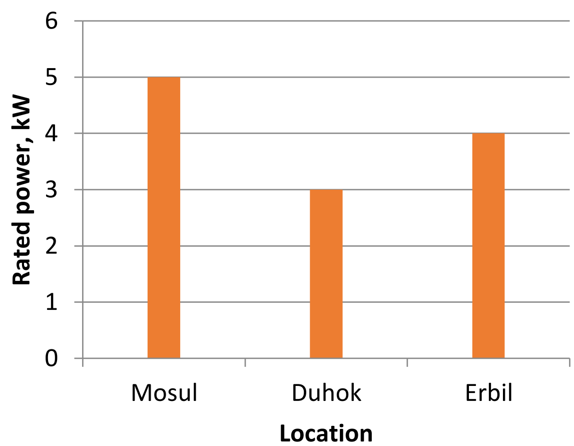

Figure 6. Rated power in the locations of Group (A) using micro-turbine at 20 m.

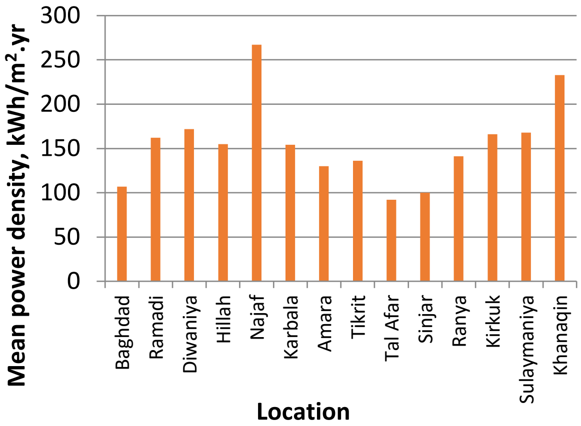

Figure 7. Annual power density in the locations of Group (B) at 20 m.

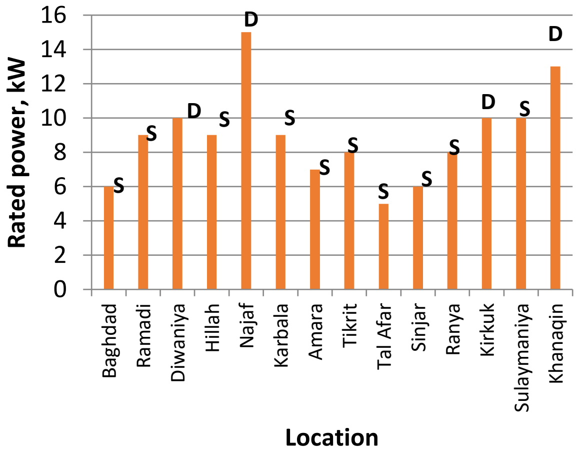

Figure 8. Rated power in the locations of Group (B) at 20 m using VAWT turbine (S for Savonius and D for Darrieus).

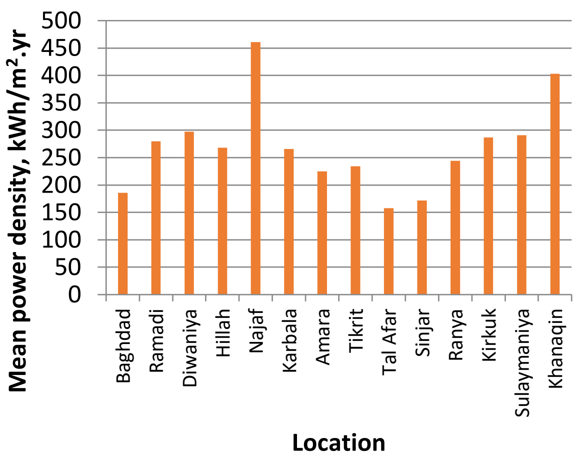

Figure 9. Annual power density in the locations of Group (B) at 60 m.

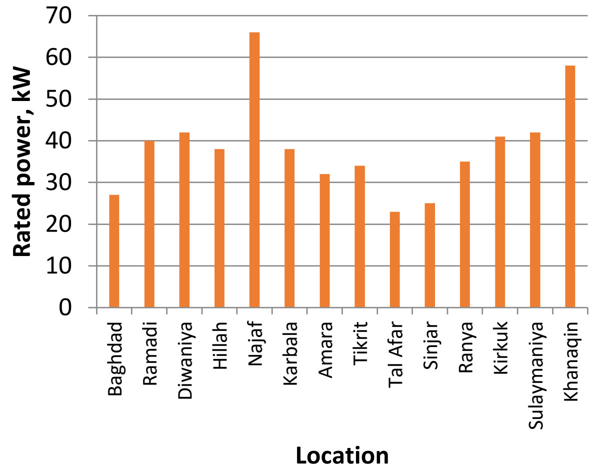

Figure 10. Rated power in the locations of Group (B) at 60 m using L-HAWT turbine.

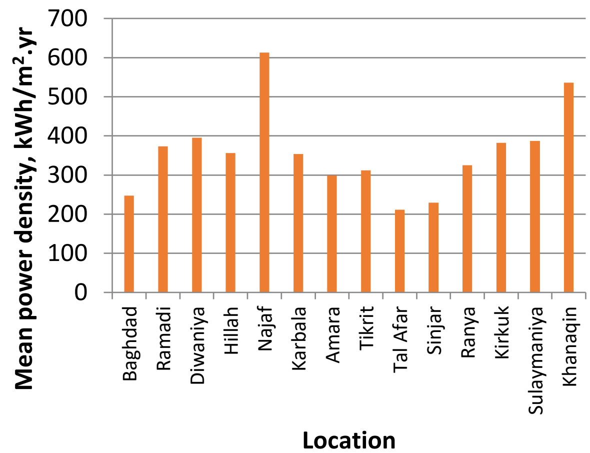

Figure 11. Annual power density in the locations of Group (B) at 80 m.

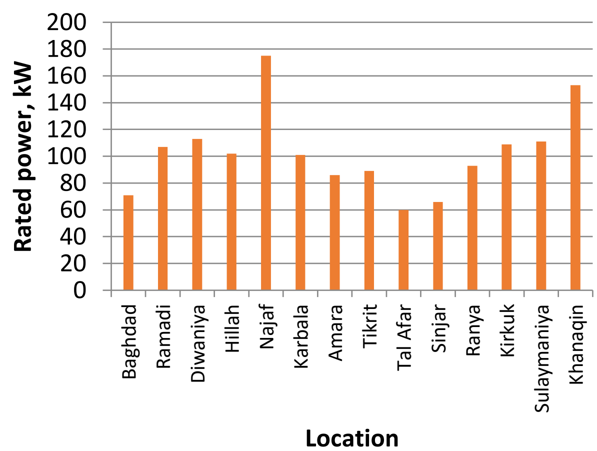

Figure 12. Rated power in the locations of Group (B) at 80 m using H-HAWT turbine.

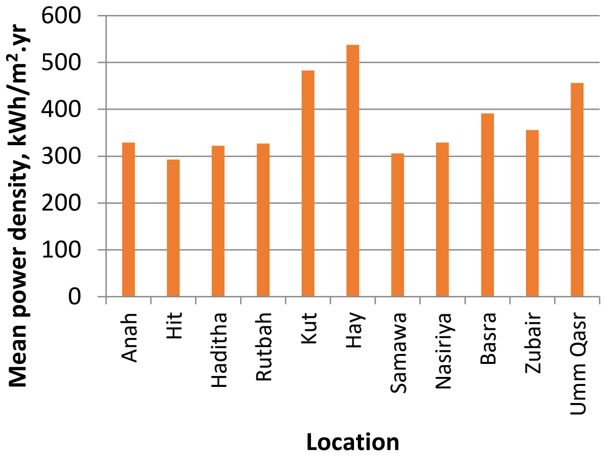

Figure 13. Annual power density in the locations of Group (C) at 20 m.

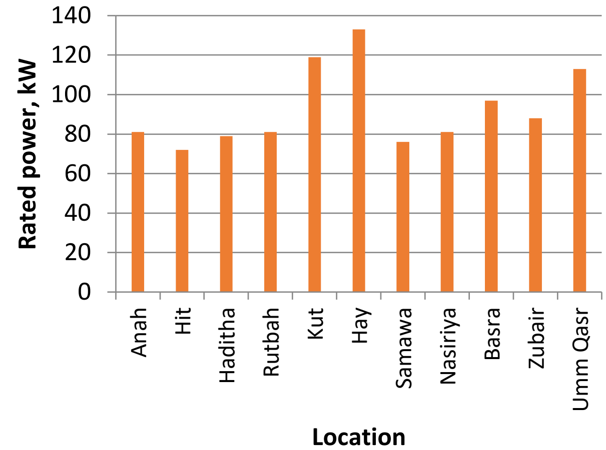

Figure 16. Rated power in the locations of Group (C) at 60 m using L-HAWT turbine.

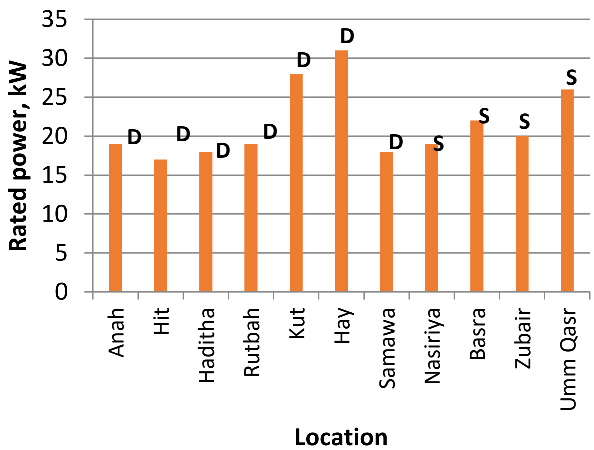

Figure 14. Rated power in the locations of Group (C) at 20 m using VAWT turbine (S for Savonius and D for Darrieus).

Figure 17. Annual power density in the locations of Group (C) at 80 m.

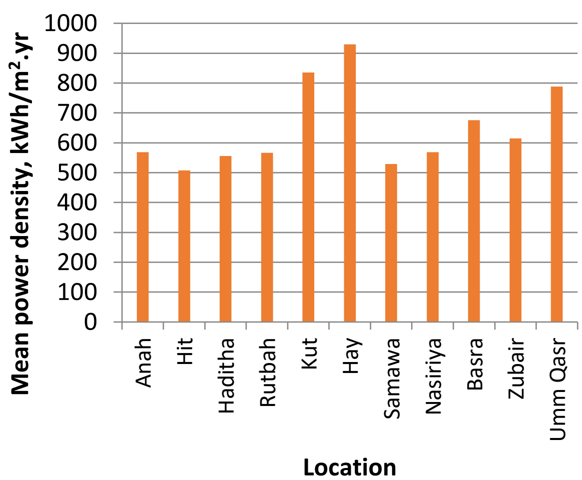

Figure 15. Annual power density in the locations of Group (C) at 60 m.

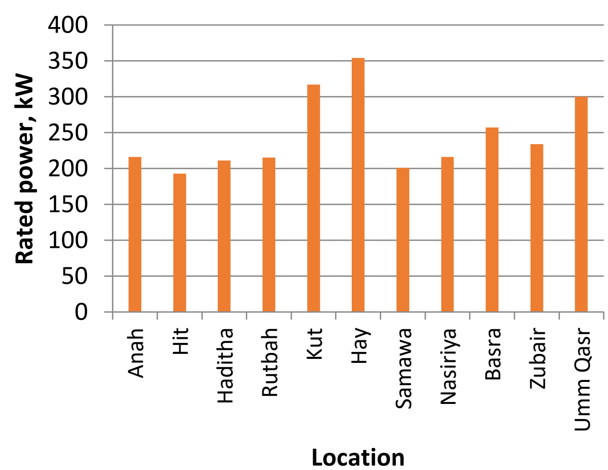

Figure 18. Rated power in the locations of Group (C) at 80 m using H-HAWT turbine.

For validation purposes, an analyzing comparison has been made to see the convergence of the current results with those mentioned by some reliable studies, taking into account the variations in their conditions, as shown in Table 3. In general, the results of the studies are compatible with the current results. Note that some studies show higher expectations for the produced power due to the variations in the wind features and turbine characteristics. However, many methods can be applied to the wind turbine to maximize the power [66], [67].

When measuring the power output of a wind turbine on site, several parameters are usually taken into account. The turbine capacity factor is one of them. The capacity factor defines the actual power of the plant at any given time [68]. In the current work, the locations have been selected based on the availability of data from meteorological stations. The obtained data represent the average values of mean wind speeds recorded during the last decade. Also, they can be characterized by the direction of wind and its ratio of variation.

Moreover, the turbine's coefficient of power is considered in terms of the energy losses caused by mechanical and electrical transmissions. All these factors impose reliable power values. Furthermore, following a standard for measuring the performance of wind turbines by developing a method for distributed turbines can be a good way to assign wind turbines suitable for medium and low wind locations [69].

Table 3. The extent to which the current work agrees with some reliable works.

[Ref.]	Type of turbine	Notes
[27]-[35]	HAWT	Most of the studies show compatible results for the output power. Some studies [27], [29], [30], [34] have shown higher power due to the assumptions of higher wind characteristics and higher turbine efficiency. Besides, some of them assumed turbines with larger scales and high elevations.
[36]-[38]	VAWT	The results are compatible.
[39]-[42]	Small or micro	The results are compatible.

4. Conclusions

This work has focused on wind energy as a green source and renewable energy for electricity generation in Iraq. The work analyzed the statistical data of wind speed obtained from different locations to achieve the optimum sites and suitable types of wind turbines according to the characteristics of wind in each location. The work has concluded that the western region of Iraq (especially those locations on the parting line between the desert and the alluvial plain) is the most promising site for installing feasible wind farms in the countryside to generate electricity. Due to the continuous wind flow, eastern regions of Iraq, which are enclosed between hills and mountains, are promising locations. The results have shown that these locations can offer annual power density ranges from 700-1200 kWh/m^2 annually. Based on that, HAWT's suggestion can offer rated power between 100-350 kW. Some locations (Basra, Zubair, and Umm Qasr) are not recommended for HAWT turbines due to the extreme change in the direction of wind. The VAWT type with 10-20 kW of power is suitable for some locations with low wind speeds, such as Baghdad, Amara, Tikrit, Sinjar, and Ranya. The lowest wind speed locations (Mosul, Duhok, and Erbil) are suitable for installing micro-turbines. Note that critical design parameters require a minimum tower height of 80 m and a minimum swept area of 2000 m^2 to ensure the production of feasible power. However, it is advised that wind power plants using hybrid systems be enhanced for future scope.

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Abbreviations

HAWT	Horizontal axis wind turbine
VAWT	Vertical axis wind turbine

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Saib A. Hamid and Sabah J. Aljanabi: Collecting the data and finding the problem statement.
Tawfeeq W. Mohammed: Determining the objectives and results analysis.
Harith H. Al-Moameri and Wisam K. Hussam: Collecting the data.

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