Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 160 (2019) 746–751

Energy Procedia

www.elsevier.com/locate/procedia

2nd International Conference on Energy and Power, ICEP2018, 13–15 December 2018, Sydney, Australia

Prospect of wind energy utilization in Saudi Arabia: A review

Hamed Allhibi, Harun Chowdhury*, Mohamed Zaid, Bavin Loganathan, Firoz Alam

School of Engineering, RMIT University, Melbourne, 3000, Australia

Abstract

In Saudi Arabia, the current production of electric power is mainly relying on crude oil which causes a high percentage of carbon dioxide emissions and no power is generated from any renewable sources. However, recently Saudi Government has announced a development plan 'The Saudi Vision 2030' where the target is 20% of the production of power from the renewable sources mainly from solar and wind. Like other countries e.g., China, India, US and UK that produce a significant amount of their electric power from renewable sources. Saudi Arabia has a vast land area where there is a plenty of prospect to install renewable power plants (solar and wind farm) to generate a significant amount of electric power to meet their 2030 target. This paper analyses past 10 years wind data in various location of Saudi Arabia to investigate the feasibility to generate power. This study also recommends the potential locations that are suitable for wind power generation including suggestions of the wind turbine specifications.

Keywords: Renewable energy; wind energy; wind turbine; Saudi Arabia; KSA; Saudi Vision 2030;

1. Introduction

There is a rapid increase of power generation worldwide utilizing the wind energy because of its higher efficiency in conversion process. For instance, in 2016, the amount of the wind energy was increased by 12% (50 GW) from 2015 [1]. The wind energy reached 469 GW of total energy in 2016 worldwide [2]. That makes 4% of the total energy

* Corresponding author. Tel.: +6199256103.
E-mail address: harun.chowdhury@rmit.edu.au

10.1016/j.egypro.2019.02.184

generated worldwide which is equivalent to that produced by Japan, the 5th largest energy producer in the world. In Europe, the share of wind energy production technology was 12% of all other energy sources. Recent data indicate that most of the Middle East countries except Iran and Israel accounted almost 0% of this renewable energy technology [3]. The production of energy from this renewable source in these countries has not been implemented for a variety of reasons. Firstly, the availability of oil in large quantities in these countries and secondly, the lack of information and investment on research in extracting energy from other renewable energy sources. However, Gulf Cooperation Council (GCC) member states: The United Arab Emirates, Bahrain, Saudi Arabia, Oman, Qatar and Kuwait have taken many measures to reduce their dependency on crude oil and planned to utilize other natural sources such as natural gas, wind and solar energy to produce electricity and reduce carbon emission despite of the rapid population and industrial growth in these countries. Fig. 1 shows the worldwide power generation from renewable energy share in percentage by region.

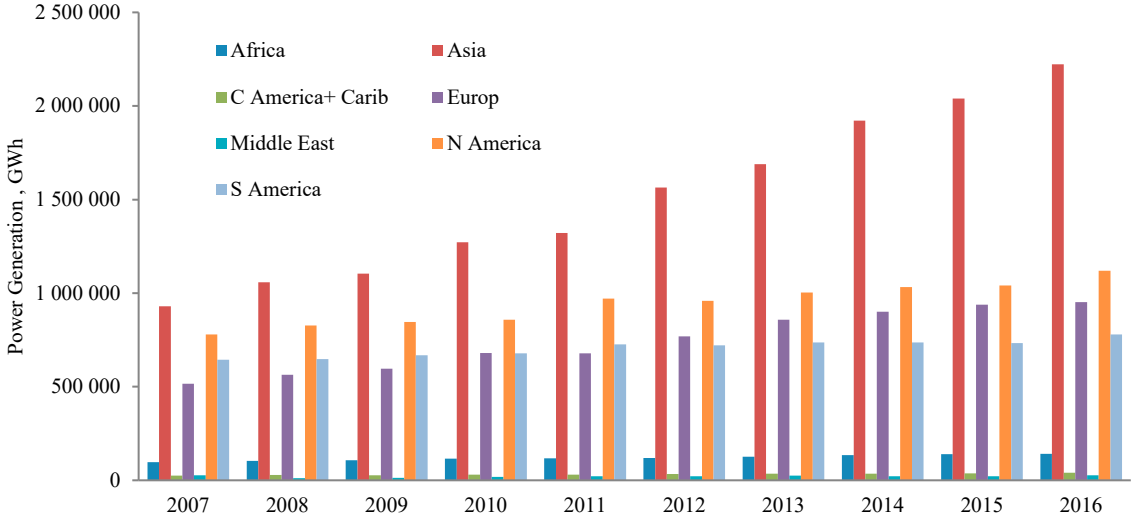

Fig. 1. Renewable energy power generation [19].

Wind power technology is expected to rise rapidly in many countries in future including KSA. Recently in Saudi Arabia, research and development initiatives have been taken by several government funded projects aimed to reduce the consumption of crude oil and thereby controlling CO_2 emissions. There are several studies [2-5] and experiments are ongoing in solar and nuclear power to generate electricity. The Saudi Vision 2030 is focusing mainly on renewable energy including wind energy. Its target is to reach 20% of its internal power generation from solar and wind by 2030 [6].

2. Current power generation scenario in KSA

Currently in KSA, electricity is generated by Saudi Electricity Company (SEC) and Saline Water Conversion Corporation (SWCC) mainly from diesel and natural gas [7]. SEC generate 79 GW of electricity with a rate of 36% efficiency and SWCC provides 12% of the total electricity in KSA. The National Electricity Transmission Company, a company owned by the Saudi Electricity Company, is responsible for the transfer of electrical power from the generation plants to the distribution networks, operation and maintenance of the electricity transmission system from 110 kV to 380 kV. The company has approximately 77,181 km power transmission line for high voltage and low voltage. It also has 3059 transformers and 990 stations for high voltage and low voltage [8].

In 2001, Saudi Arabia, Bahrain, UAE, Qatar, Kuwait and Oman agreed to establish a Gulf Cooperation Council (GCC) and developed an interconnecting power station. In 2009, the Commission started its functions with four member states before the rest of the countries were organized in 2014. In 2017, GCC dealt with a total of 142 cases of loss of generation or loads over 100 MW and maintained for the ninth year in a row for the continuity of security of

power networks by up to 100% [9]. Fig. 2 shows the electricity production and the unit price of electricity (Riyals/kwh) in Saudi Arabia between 2012 and 2017. Over that period, the lowest point of production was observed in 2013 with the total production of electricity generation at around 203 GWh, while the peak point was on the following year in 2014 at approximately 219 GWh. From 2014 till 2017, there was a steady decrease in the production of electricity in Saudi Arabia, which was due to high electricity price rate as indicated in Fig. 2.

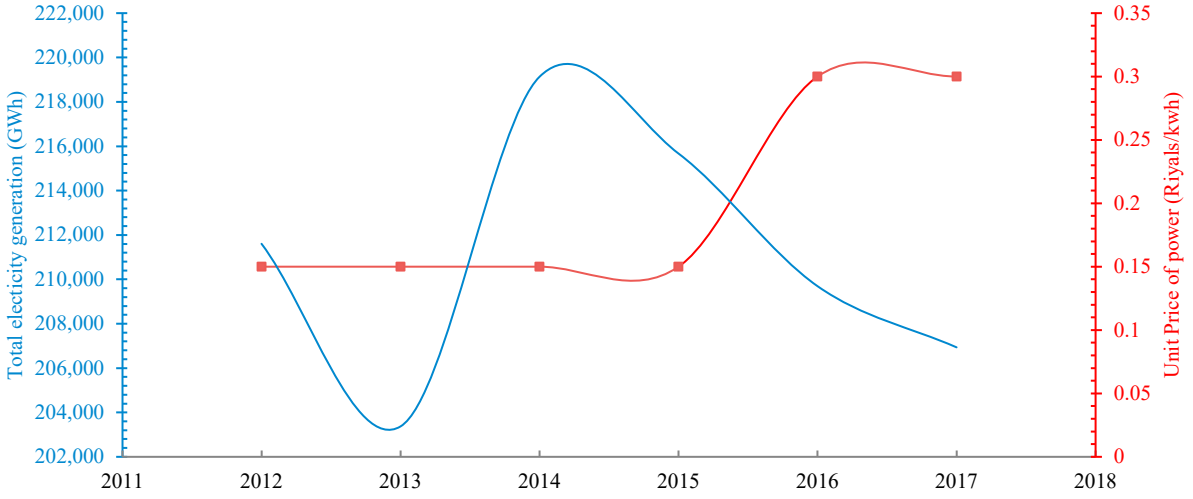

Fig. 2. Electricity production and change of unit price of power in Saudi Arabia, adapted from [8-9].

3. Wind energy in Saudi Arabia

Wind energy can be an attractive technology of alternative energy sources for KSA. The wind map of Saudi Arabia marks that the kingdom is identified by the presence of two major areas which are the Arabian Gulf and the red sea coastline zones. As shown in the Renewable Resource Atlas, the annual average wind speeds in most areas of KSA is between 6.0 and 8.0 m/s. However, these statistics do not include a wind power potential analysis reflecting the wind speed distributions over time. Higher wind speeds occur in the northeast, the central and near the mountains in the western regions. King Abdullah City for Atomic and Renewable Energy (KACARE) established ten monitoring stations: in Hafar Al Batin, Sharurah, two sites in Yanbu, two sites in Riyadh, Aljof, Traif and Jeddah.

Fig. 3 shows the Saudi Arabia wind speed map. In the same time KACARE plans to install a complete wind monitoring network consisting of 40 monitoring masts around the country. Moreover, Atlas will provide the data as they are installed and refine the current data. KSA has enough wind energy potential with average wind speed 7.5-8 m/s in east coast reign and 7-7.5 m/s on the western coast. The central reign has average wind speed 5-6.5 m/s [10].

Fig. 4 shows the average wind speeds of different sites located 100 m above the sea-level during of entire year in 2016. These selected sites are located all over the entire kingdom represent north, south, east, west and the middle regions of Saudi Arabia. Both Riyadh, the capital (i.e. the largest city in Saudi Arabia), and Jeddah, the second largest, have the lowest average of wind speed which might be due to the natural landscape. Yanbu has the highest average wind speed. In the same time, Turaif, Sharurah and Hafar Al Batin are rural areas and have considerable average wind speed.

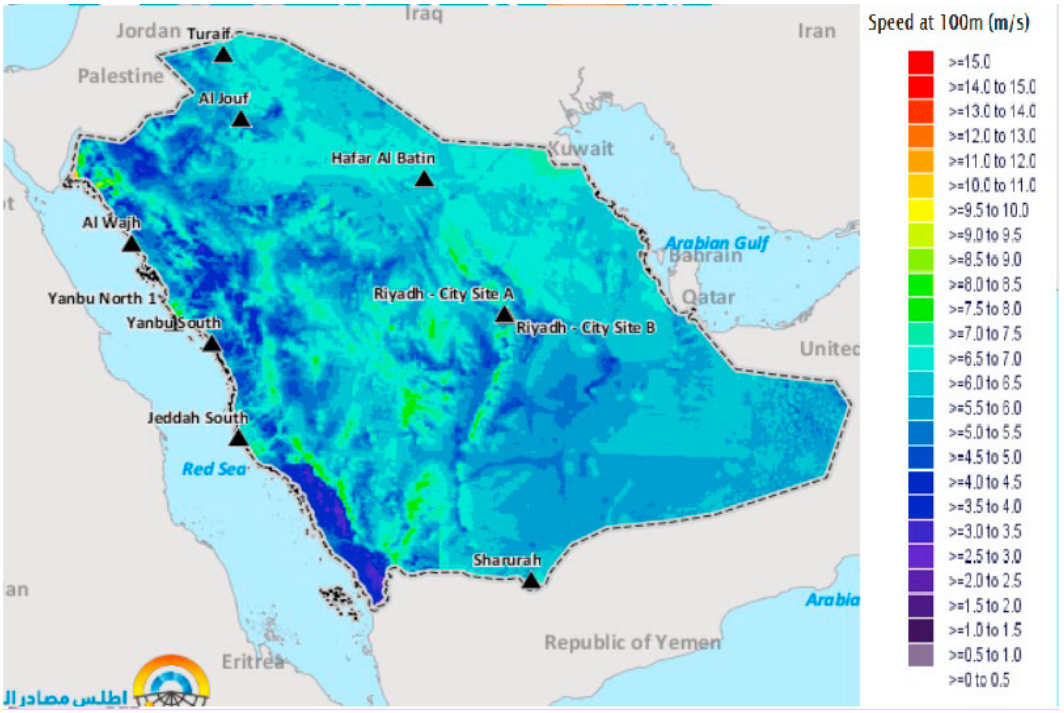

Fig. 3. Saudi Arabia airspeed around the country, adapted from [10].

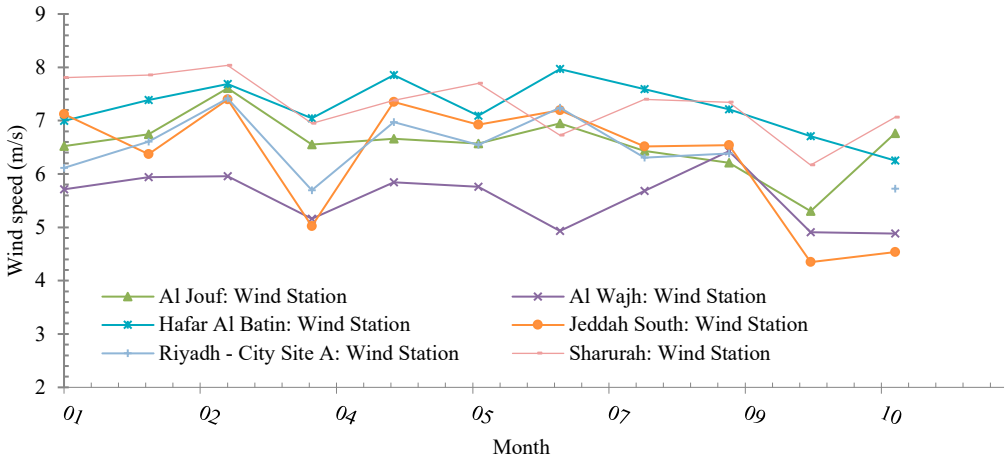

Fig. 4. Monthly average wind speed in different locations of Saudi Arabia in 2016, adapted from [10].

4. Selection of wind turbines for power generation in Saudi Arabia

Large wind turbine is required to convert the wind energy into electricity in a commercial scale. Currently, there are two leading wind turbine manufacturers: Vestas and Goldwind. They have installed a significant number of turbines worldwide for commercial wind power generation [11, 12]. Table 1 represents the specifications of two commercial wind turbine models.

Table 1. Comparison of two wind turbines with their specifications.

Type	Vestas V136	Goldwind 3.0MW(S)
Capacity	4-4.2 MW	3-3.4MW
Temperature	-20 +45	-30 +50
Frequency	50/60 Hz	50/60 Hz
Hub High	91.5 m	100m
wind speed	6-9 m/s	5.5-8.5 m/s
Price	$1.1 million/ MW	$1.01 million /MW
Annual Energy Production	18 GWh	-
Design Lifetime	25 Years	25 Years

Selection of a proper wind turbine depends on the availability of wind energy as well as the characteristics of wind speed in those sites. According to the available wind speed data for different sites in KSA, Vestas wind turbine is a suitable and sustainable solution to invest and produce electricity in Yanbu where the average wind speed is over 8 m/s. However, more research need to be done before installing wind farm for large scale power generation. A socioeconomic study also must be performed before implementing the project on site.

5. Discussion

Most of the countries in the world including KSA rely severely on coal, oil and natural gas which is the main cause of CO_2 emissions and global warming. However, in 2015, the representatives of more than 100 countries met to sign the Paris convention to limit carbon dioxide and naphtha emissions [13-14]. Their goal is to control and limit the global temperature not more than 2 °C per year. KSA is one of the important countries in this treaty for several reasons. Firstly, KSA is the largest crude oil exporter that exports more than 8 million barrels of crude oil daily [15] and consumes more than 3.4 million barrels of crude oil per a day [16]. In addition, in 2014, KSA generated around 494.82 million ton of CO_2 emission [17]. Consequently, that makes KSA to be in the 11th rank in the world of CO_2 emission. On the other hand, Saudi's electricity consumption is expected to grow twice by 2023 [18]. Therefore, in KSA, CO_2 emissions will be increased significantly because of future development and industrialization. For example, in 1990, CO_2 emissions were 208 million metric tons while in 2010, CO_2 emissions were 468.7 million metric tons. One of the solutions to reduce CO_2 emissions is to use renewable energy utilization for electric power generation.

KSA utilize more than 3 million barrels per day of domestic oil consumption to provide more than 55 GW of energy [1]. Therefore, KSA is the largest consumer of petroleum in the Middle East and the 6th in the world [2]. In addition, KSA is the first country in the world using crude oil for generating power. Because of the increasing use of crude oil to generate power for domestic consumption, KSA may become an oil importer by 2038 [19]. KSA has recently announced a national development plan ‘the Saudi Vision 2030’ to utilise the natural resources to produce energy. Producing 20% of the total energy from natural sources is one of the vision goals to reduce the reliance of crude oil. The Saudi Vision 2030 is monitored profoundly to fulfil its target through the investment projects to support scientific research or partnering with several advanced countries in renewable energy field.

6. Conclusions and recommendations

Although the Kingdom of Saudi Arabia is heavily dependent on fossil fuels, it has the potential to utilize renewable energy sources specially the wind energy for electricity generation. Several locations of the kingdom are suitable for wind power generation in large scale. The Saudi governments can take initiative to install several wind firms in the potential sites by some pilot projects to further investigate the feasibility of wind power generation. Thus, the kingdom will be able to reach its target 20% power generation from renewable energy sources mentioned in the Saudi Vision 2030.

References

[1] British Petroleum 2017. BP Statistical Review of World Energy June 2017. Available at: http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-worldenergy.html. Accessed August 24, 2017.

[2] International Atomic Energy Agency (2018). *IAEA Annual Report for 2017*. [online] Available at: https://www.iaea.org/opic/annual- report-2017 [Accessed 2018].

[3] Gulfcooperationcouncilinterconnectionauthority(2018). *AnnualReportof2017*. [online]Availableat:http://www.gccia.com.sa/Data/Downloads/Reports/FILE_22.pdf [Accessed 2018].

[4] Irena.org. (2018). International Renewable Energy Agency (IRENA). [online] Available at: https://www.irena.org [Accessed 2 Dec. 2018]

[5] Alshammari, Y. and Sarathy, S. (2017). Achieving 80% greenhouse gas reduction target in Saudi Arabia under low and medium oil prices. *Energy Policy*, 101, pp.502-511.

[6] Saudi Arabia's Vision 2030. National Transformation Program 2020, 2016.Viewed 11 August 2016,< http://vision2030.gov.sa/en/ntp>

[7] Al Garni, H., Kassem, A., Awasthi, A., Komljenovic, D. and Al-Haddad, K. (2016). A multicriteria decision making approach for evaluating renewable power generation sources in Saudi Arabia. *Sustainable Energy Technologies and Assessments*, 16, pp.137-150.

[8] Saudi Electricity Company (2018). *Annual Report 2017*. [online] Available at: https://www.se.com.sa/ar-sa/Lists/List5/Attachments/21/AnnualReport2017.pdf [Accessed 2018].

[9] Alarabiya.net. (2018). Electricity cost in Saudi Arabia. [online] Available at: https://www.alarabiya.net [Accessed 13 Dec. 2017].

[10] Rratlas.energy.gov.sa. (2018). Saudi Arabia Renewable Resource Atlas. [online] Available at: https://rratlas.energy.gov.sa [Accessed 30 Nov. 2018].

[11] Goldwind Australia. (2018). - Goldwind Australia. [online] Available at: http://www.goldwindaustralia.com [Accessed 30 Nov. 2018].

[12] www.vestas.com, V. (2018). Vestas - wind turbine solutions and services. [online] Vestas.com. Available at: https://www.vestas.com/ [Accessed 30 Nov. 2018].

[13] Alrikabi, N. (2014). Renewable Energy Types. *Journal of Clean Energy Technologies*, pp.61-64.

[14] Sathaye, J. and Meyers, S. (2011). *Greenhouse gas mitigation assessment*. Dordrecht: Springer.

[15] Rambo, K., Warsinger, D., Shanbhogue, S., V, J. and Ghoniem, A. (2017). Water-Energy Nexus in Saudi Arabia. *Energy Procedia*, 105, pp.3837-3843.

[16] Baseer, M., Meyer, J., Rehman, S. and Alam, M. (2017). Wind power characteristics of seven data collection sites in Jubail, Saudi Arabia using Weibull parameters. *Renewable Energy*, 102, pp.35-49.

[17] Ramli, M., Twaha, S. and Al-Hamouz, Z. (2017). Analyzing the potential and progress of distributed generation applications in Saudi Arabia: The case of solar and wind resources. *Renewable and Sustainable Energy Reviews*, 70, pp.287-297.

[18] Al-Abbadi, N. (2005). Wind energy resource assessment for five locations in Saudi Arabia. *Renewable Energy*, 30(10), pp.1489-1499.

[19] Shaahid, S., Al-Hadhrami, L. and Rahman, M. (2014). Potential of Establishment of Wind Farms in Western Province of Saudi Arabia. *Energy Procedia*, 52, pp.497-505.