Araştırma Makalesi / Research Article

Ürdün Haşemit Krallığı'nda yenilenebilir enerji

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Özet

Son yıllarda fosil yakıt kaynaklarının tükenmesi ve çevresel kaygılar nedeniyle, mevcut enerji üretiminde yenilenebilir enerji kaynaklarının payı giderek artmaktadır. Yenilenebilir enerji kaynakları arasında yer alan rüzgar ve güneş enerjileri temiz, sürdürülebilir ve çevre dostu enerji kaynakları olmaları nedeniyle öne çıkmaktadır. Rüzgar ve güneş enerjisi potansiyeli meteorolojik şartlara göre oldukça değişkenlik göstermektedir. Yıllık ortalama rüzgâr şiddeti, 2018'den 2020'ye kadar azalma eğilimi (%22) göstermektedir. Benzer şekilde rüzgâr enerjisi gücü (P) beş yılın son döneminde düşüş eğilimi (%50) göstermektedir. Yıllık ortalama rüzgâr şiddeti ve toplam rüzgâr enerjisi potansiyeli, Agaba'da Amman'dakinden neredeyse iki - üç kat daha fazladır. Sonuçlar, çalışma döneminde son iki yılda Akabe'de daha yüksek rüzgâr şiddeti ve rüzgâr enerjisi potansiyeli gözlendiğini göstermektedir. Rüzgar şiddetinin ve güneş radyasyonunun değişken ve zor kontrolü, güneş ve rüzgar enerjisi sistemlerinde güç kalitesi, üretim- tüketim dengesi ve güvenilirlik açısından bazı sorunlara neden olmaktadır. Bu nedenle rüzgar ve güneş enerjisi sistemlerinin kurulumu ve işletilmesi sırasında, sistemlerin kurulduğu bölgelerin rüzgar şiddeti ve güneş radyasyonu özelliklerinin bilinmesi ve tahmin edilmesi oldukça önemlidir, Ayrıca inceleme bölgesinde elektrik maliyetini düşürmek için yenilenebilir enerji çiftlikleri ve santrallerinin kurulabileceği en uygun yerlerin seçimi büyük önem taşımaktadır.

Anahtar Kelimeler: *Ürdün, Yenilenebilir Enerji, Güneş Enerjisi, Rüzgar Santralleri, Hava.*

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Renewable energy in the Hashemite Kingdom of Jordan

Abstract

Due to the depletion of fossil fuel resources and environmental concerns in recent years, the share of renewable energy resources in current energy production has been increasing. Wind and solar energies, which are among the renewable energy sources, stand out because they are clean, sustainable, and environmentally friendly energy sources. Wind and solar energy potential varies considerably according to meteorological conditions. Annual average wind speed shows a decreasing trend (22%) from 2018 to 2020. In similar way, wind energy power P also shows a decreasing trend (50%) at the same period during the last five year. Annual average wind speed and total wind energy potential are almost two - three times more in Aqaba than in Amman. Results show more wind speed and wind energy potential have been observed in Aqaba during the last two year at the study period. The variable and difficult control of wind speed and solar radiation cause some problems in terms of power quality, production consumption balance and reliability in solar and wind energy systems. Therefore, during the installation and operation of wind and solar energy systems, it is very important to know and predict the wind speed and solar radiation characteristics of the regions where the systems are installed. Definition of the best places to establish the renewable energy farms and power plants will reduce the cost of electricity at study areas in Jordan.

Keywords: *Jordan, Renewable Energy, Solar Energy, Wind Farms, Weather.*

Introduction

Today, a large portion of the worldwide energy needs are met from petroleum derivative sources. Around 25.2% of essential energy utilization is given from petroleum product sources, while the rest is gotten from environmentally friendly power sources (IEA, 2020). As needs be, one might say that only one quarter of the on-going energy utilization can be met from clean and friendly to the ecosystem sustainable power sources. Then again, petroleum product holds are diminishing step by step relying upon utilization and it is anticipated that they will run out sooner rather than later because of restricted saves. It is anticipated that demonstrated

non-renewable energy source stores will be totally exhausted following 70 years at current utilization rates, and conceivably considerably prior, given the rising interest patterns. Petroleum derivatives also negatively affect climatic conditions. Sustainable power sources gain significance as an option in contrast to fossil energy sources because of their predetermined number of stores and their hurtful consequences for the climate. It is anticipated that the portion of sustainable power sources in absolute energy creation will increment before very long. Among the sustainable power sources, wind and sun-oriented energy can be displayed as the main sources. Wind power for wind energy and sun-based radiation for sun-oriented energy are significant boundaries (Rahman et al, 2014).

From 2011 to 2021, environment friendly, to the ecosystem power has created from 20% to 28% of politically persuasive country supply. Fossil power decreases in size from 68% to 62%, and nuclear from 12% to 10%. The degree of hydropower diminished from 16% to 15% even as power from daylight based and wind improved from 2% to 10%. Biomass and geothermal power created from 2% to 3%. There are 3,146 Gigawatts associated in a hundred 35 worldwide regions, even as 156 overall regions have legitimate standards dealing with the reasonable power region. In 2021, China addressed right around 1/2 of the general impact in feasible power.

Numerous nations round the field have previously got sustainable power contributing extra than 20% in their general power supply, with a couple creating north of 1/2 of their power from renewables. A couple of worldwide areas produce all their power the utilization of inexhaustible power. Public sustainable power markets are projected to continue to develop firmly with inside the 2020s. Studies have demonstrated that a worldwide progress to 100% sustainable power all through all areas - power, delivery, and desalination - is conceivable and financially practical. Sustainable power resources exist over enormous geological districts, in evaluation to petroleum derivatives, which can be engaged in a limited assortment of worldwide areas. Arrangement of sustainable renewable power execution advancement is bringing about sizable power security, environment friendly and financial benefits. In any case renewables are being destroyed through masses of billions of bucks of fossil gas gifts. In by and large broad evaluation concentrates on their serious areas of strength for is for renewables which consolidates solar and wind power. Nonetheless,

the Worldwide Energy Association communicated in 2021 that to achieve petroleum derivative products extra undertaking is expected to impact renewables and known concerning period to shoot through generally 12% every year to 2030.

Renewable energy is gotten from normal cycles that are recharged continually. In its different structures, it gets straightforwardly from the sun, or from development inside the earth. Remembered for the definition is energy produced from sunlight based, wind, hydropower from inexhaustible assets.

Solar Energy:

Solar energy and heat are harnessed through a variety of ever-evolving technologies, including solar heating, photovoltaic, concentrated solar power (CSP), concentrator photovoltaic (CPV), solar architecture, and artificial photosynthesis. The majority of new renewable energy is solar. Solar technologies are generally categorized as either passive solar or active solar based on the manner in which they capture, convert, and distribute solar energy. Designing spaces that naturally circulate air, selecting materials with favourable thermal mass or light dispersing properties, and orienting a building to the Sun are passive solar techniques. Solar thermal energy, produced by heating with solar collectors, and solar power produced by converting sunlight into electricity through photovoltaic (PV) or CSP are examples of active solar technologies.

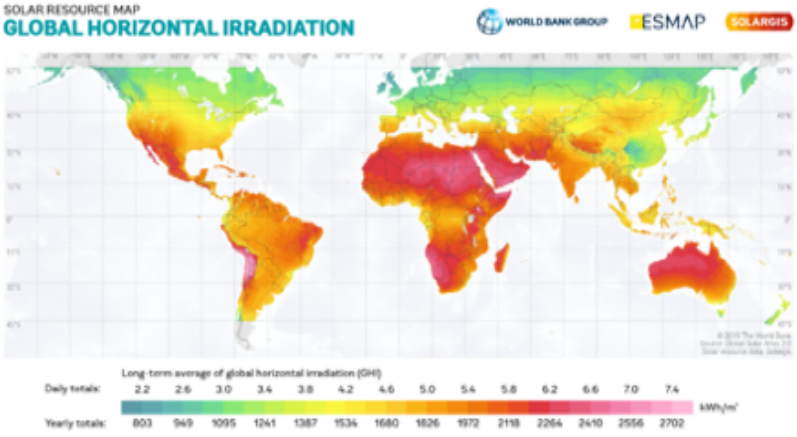

Figure 1. Global Horizontal Irradiation. URL-1

Figure 1 shows global variation of horizontal irradiation. Jordan has a favourable daily and annual total solar energy potential.

Wind energy :

Wind turbines can be driven via air flow. The evaluated force of contemporary utility-scale wind turbines increases from roughly 600 kW to 9 MW. Because the power created by the breeze is corresponding to the 3D shape of the breeze speed, the power delivered by a turbine will increment in relation to its greatest result. Seaward and high-elevation destinations, for instance, are ideal areas for wind farms. Wind-produced power met almost 4% of worldwide power interest in 2015, with almost 63 GW of new wind power limit introduced. Full burden long periods of wind turbines normally range from 16 to 57% yearly, yet they might be higher in especially good seaward locations. China had the second-biggest breeze energy limit expansion, trailed by Europe, the US, and Canada. In Denmark, wind energy met an overabundance, while Ireland, Portugal, and Spain each met almost 20%. Wind energy's drawn-out specialized potential is assessed to be multiple times the flow power interest or multiple times the on-going worldwide energy creation, accepting that all reasonable snags are overcome. This would require the establishment of wind turbines over huge regions, especially in seaward areas with more prominent breeze resources. Because the typical speed of seaward wind is 90% higher than that of land-based breeze, seaward assets can contribute fundamentally more energy than land-based turbines, (Ezhiljenekkha and MarsalineBeno, 2020; Dalabeh, 2017).

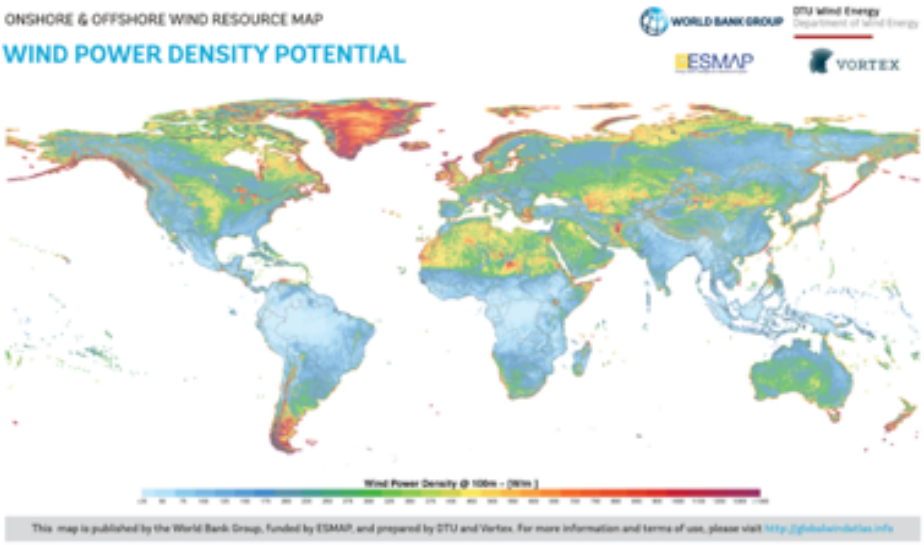

Figure 2. Wind Power Potential URL-2

Figure2 shows global variation of wind power potential. Jordan has moderate wind power potential at global frame.

Hydropower:

For certain, even a moderate ocean swell or stream of water that moves gradually can convey a lot of energy because of how water is by and large on different events denser than air. Water has the main change capacity of any innocuous to the biological system power source, at around 90%, and it can make power in different ways.

Huge hydroelectric dams and storage facilities, which are as of now famous in emerging countries, similar to China's Three Gorges Dam (2003) and Brazil's and Paraguay's Itapúa Dam (1984), have normally given hydroelectric power.

Hydroelectric power underpinnings of up to 50 MW regularly make up little hydro systems. On more unpretentious streams or as a low-influence improvement for more prominent ones, they are an enormous piece of the time used. Past what 45,000 little hydroelectricity establishments can be found in China, which is the world's most prominent hydroelectricity

maker. Run-of-the-stream hydroelectricity plants use Stream Energy without building a huge stock. Typically, the water is passed along the stream valley's side on through channels, lines, or segments until it appears at a level over the valley floor, where it can fall through a penstock to control a turbine. However, many run-of-the-stream hydro power plants are limited scale hydro or Pico hydro plants, a run-of-stream plant can in any case make a lot of power, a lot of like with the Essential Joseph Dam on the Columbia Stream in the US.

In 2010, the Asia-Pacific region made 32% of the world's hydropower. Of the imperatively 50 nations by level of power conveyed by limitless sources, 46 are basically hydroelectric. There are right now three hydroelectricity stations more noteworthy than 10 GW: The Three Holes Dam in China, the Itapúa Dam across the line among Brazil and Paraguay, and the Guri Dam in Venezuela. A ton of hydropower is flexible, so it supplements wind and sun controlled. Two sorts of hydropower that have potential for the future are wave power, which gets the energy of sea surface waves, and streaming power, which changes over the energy of tides. Streaming power from the Waterway of Fundy, which is home to the most raised streaming stream on the planet, is saddled in a presentation project show to the Sea Legitimate Power Affiliation and related with the cross section on the Maine coast. Using the temperature contrast between additional blasting surface waters and cooler critical waters, sea nuclear power change is at this point unfruitful, [URL-3and 4]

Renewable Energy in Jordan:

The Hashemite Realm of Jordan is one of the energy importing countries, which expands the proportion of imported energy to Gross domestic product and prompts extraordinary strain on the harmony between instalments and the consistent requirement for unfamiliar monetary standards to back the acquisition of the Realm's energy needs (Baniyounes, 2017). It requires the quest for elective wellsprings of customary energy, and sustainable power is one of the main elective sources accessible in the Realm, and since systems are sufficiently adaptable to stay up with improvements and occasions, the sustainable power technique has been changed to target 20% of the all-out energy blend in 2020, and the methodology zeroed in on creating ways of taking advantage of different environmentally friendly power sources, including solar and wind energy, nuclear power, ground

energy, hydropower and some other normal sources fully intent on adding to an expansion in the extent of sustainable power from the all-out energy blend, which would prompt a decrease in the oil charge, enhancement of fuel sources, and ecological security to accomplish reasonable turn of events (Alrwashdeh, 2022).

The Hashemite Realm of Jordan has had a reasonable wealth in sustainable power sources (sustainable power is energy produced from boundless regular sources, including solar energy, wind energy, hydro energy and bioenergy), particularly sun oriented energy, with its high typical direct sun powered radiation potential, because of the event of The Realm is in the supposed sunlight based belt nations, which are the regions situated between scopes 25 north and 25 south, and different logical examinations have shown that the quantity of days in which the sun gleams on the Realm is 316 days out of every year and a normal of 8 hours out of each day. Concerning wind energy, it is viewed as one of the most outstanding wellsprings of energy Sustainable power age in the Realm, as numerous locales in the Realm are described by a breeze speed running between 7-8.5m/s, which is a reasonable speed for building stations that exploit wind energy to create electric power (Abu-Rumman et al., 2020)

Renewable energy projects in Jordan:

The Realm of Jordan is grouped among the energy importing in nations, and that implies extraordinary strain on the state spending plan and a steady requirement for unfamiliar monetary standards. This required the Hashemite Realm to consider elective energy arrangements, and these arrangements are driven by sustainable power sources, because of the realm's wealth in it, particularly sunlight based and wind energy in view of the area of Geological realm (URL-5 and 6).

The Realm of Jordan is situated in the sun-oriented belt district, which causes it to get a high measure of sun powered energy, as the quantity of radiant days in the Realm is 316 days out of each year, at a pace of 8 hours of the day. Wind speed because of the sea breeze arrives up to 7 - 8.5 m/s.

The Hashemite Realm has begun carrying out these means on the ground beginning around 2012, by giving various guidelines and regulations; the first is Sustainable power and Energy Defence Regulation No. 13 as a sta-

ge to support the pattern toward this path. This regulation opens the entryway for interest in it, in collaboration with numerous organizations and specific focuses to work on this area and execute various among the tasks and the consenting to of numerous arrangements to lay out future undertakings, the most conspicuous ventures carried out by the Realm of Jordan are listed below:

Tafila Wind Farm: The principal environmentally friendly power project from the confidential area in Jordan situated in Tafileh Governorate, southeast of the Dead Ocean, and meets the energy needs of 80,000 homes.

Baynunah Sun oriented Power Plant: The biggest solar energy project in Jordan in East Amman, and produces yearly energy covering 160,000 homes, adding to diminishing the emanation of 360 thousand tons of carbon gas every year. The venture is attempted by the UAE organization Masdar in association with the Jordanian government, and this plant alone covers around 3% of Jordan's energy utilization.

Ma'an Wind Energy Undertaking: A sustainable power project claimed by the Jordanian Government with Kuwaiti supporting with a limit of 200 Gigawatts of clean power each hour yearly.

The significance of sustainable power projects for Jordan: The Realm of Jordan is progressively dependent on sustainable power sources as one of the elective answers for the financial and ecological issues it experiences. It resorts to executing numerous environmentally friendly power tasks and consenting to arrangements for future undertakings. Jordan has likewise really started to take advantage of solar energy for neighbourhood purposes, which is to cover the day to day need of energy for homes to bring it into the business and modern areas (Molina and Mercado, 2011; Abu-Hameed and Bressler, 2019).

These undertakings give new position open doors to Jordanian youth and add to diminishing the joblessness rate in Jordan because of keeping unfamiliar trade. It is shipped off import oil and its subordinates in the state depository and putting them in projects that add to lessening joblessness, (Jaber et. al. 2015; Jaber 2012).

Renewable energy sources in Jordan: There are various supportable power sources in Jordan, fundamentally solar and wind energy on account of the land region of the Domain, despite biomass and waste.

Solar energy: The Hashemite Domain is portrayed by solar radiation (5-7 kilowatts/m2 each day) and splendid seasons of north of 3000 hours consistently, especially in the southern and central districts. It makes revenue in it useful to the extent that making electrical energy based on solar radiation (Olabi and Abdelkkareem, 2022).

Wind energy: It implies the engine energy conveyed by the breeze. It moves in view of differentiations in temperature and strain. Jordan is depicted by unambiguous districts in the north, concentration and south of the Domain, which are immediately missed breezes of up to 8m/s. It settles on the decision to place assets into it and exploit its breezes in Electric power age are an ideal decision (Alkhalidi et al, 2022; Al-Mhairat and Al-Quraan, 2022).

Biomass energy: This energy is limited to animal waste areas of strength for and in the city. Concerning plant waste, it is poor due to confined vegetation cover and nonattendance of storm in the Domain. The Domain places assets into regular waste as a wellspring of energy, for example, it has changed over the old Rusayfa waste dump into a biogas creation plant to convey electrical energy from it.

The main purpose of the paper is to compare wind energy potential at two study areas (Amman and Aqaba). Sea breezes play an important role on daily, monthly, and annual wind speed and energy potential variation. Global variations of energy potential are also discussed at the following parts.

Methodology

The Best İnvestment Destinations İn Jordan For Wind Farms

In this part of the study, we will calculate the potential of wind energy in the most important two favourable areas for investment in Jordan. It may be an expected destination for investment companies specialized in the field of generating electricity from wind energy.

Wind speeds were used in the most important and main two climatic stations distributed in Jordan to calculate the rising wind energy potential monthly, yearly and for last five years, which is in the following formula: [URL-7 and 8]

$$P=0.5\ \rho\ v3 \quad (1)$$

were.
P = Wind Power (W/m^2)
ρ = Air Density (Constant = 1.29 Kg/m^3)
v3= Wind Speed (m/s)

Amman

Amman	2018	2019	2020	2021	2022	Monthly AVG	Power (KW)
Jan	3.333	3.667	3.472	2.222	2.500	3.039	18.101
Feb	2.361	3.306	3.222	1.667	2.611	2.633	11.778
Mar	3.194	3.139	3.556	2.889	3.389	3.233	21.803
Apr	2.917	3.139	2.972	2.639	2.472	2.828	14.585
May	3.444	2.944	3.167	2.694	3.250	3.100	19.215
Jun	4.083	3.556	3.694	3.056	3.139	3.506	27.786
Jul	4.444	3.972	3.194	3.500	3.306	3.683	32.232
Aug	3.944	3.722	3.306	2.833	2.778	3.317	23.532
Sep	2.806	2.639	1.583	2.528	2.306	2.372	8.610
Oct	2.722	2.167	1.306	1.694	1.694	1.917	4.542
Nov	2.111	1.917	1.500	1.333	1.694	1.711	3.231
Dec	3.111	2.806	1.694	2.306	1.333	2.250	7.347
Annual AVG Speed	**3.206**	**3.081**	**2.722**	**2.447**	**2.539**		
Annual Power	**21.255**	**18.864**	**13.012**	**9.448**	**10.562**		
5 Years Average (m/s)				**2.799**			
POWER For 5 Years Average				**14.145**			
Note: All Wind Speed Data in (m/s)							

Table 1 shows monthly variation of wind speed power in Amman. Annual average wind speed shows a decreasing trend (22%) from 2018 to 2020. In

similar way, wind energy power P also shows a decreasing trend (50%) at the same period in five years.

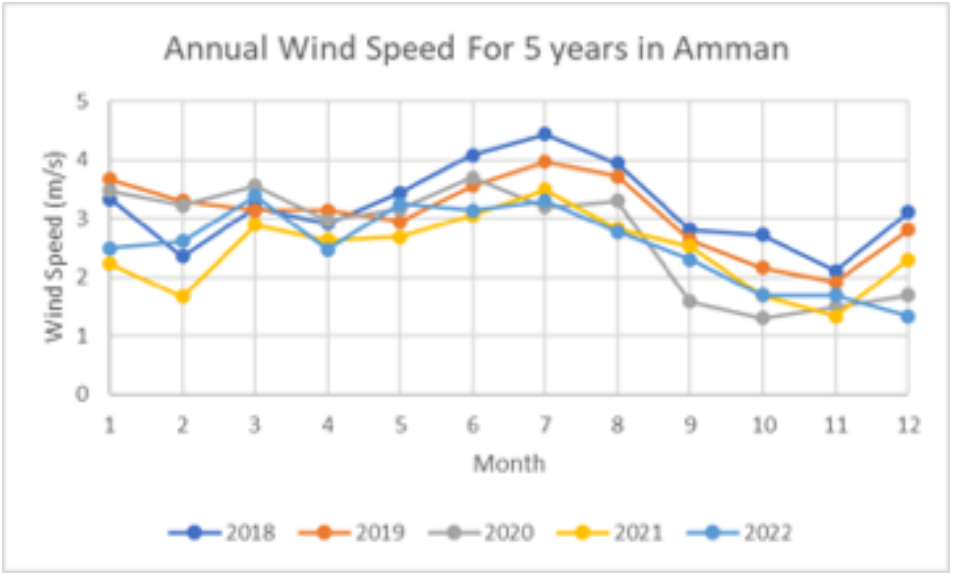

Figure 3: *Annual Wind Speed for last five years in Amman.*

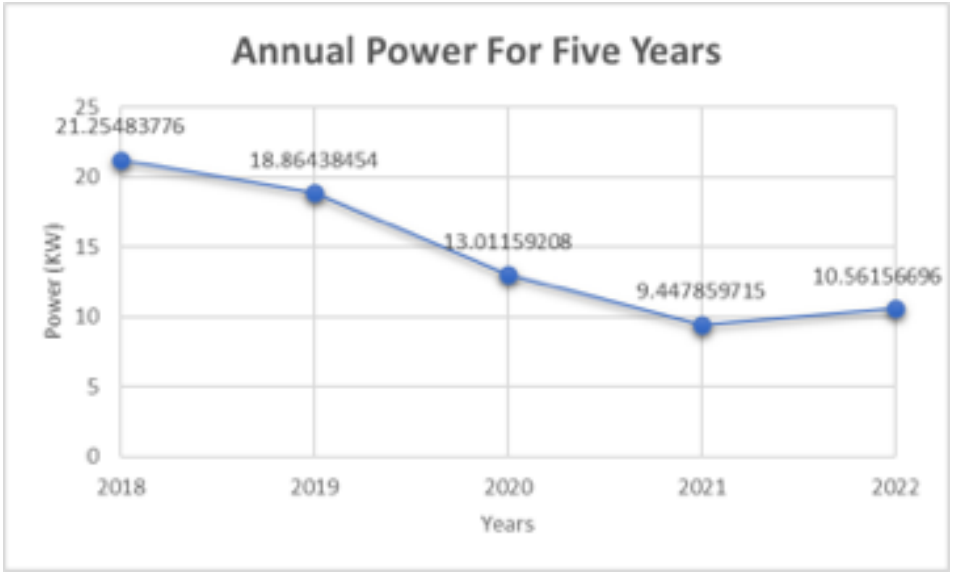

Figure 4: *Annual Power for Last Five Years in Amman.*

Figures 3 and 4 show annual wind speed and wind power from 2018 and 2022. Wind power is almost 50% less than the initial part of the study period in Amman.

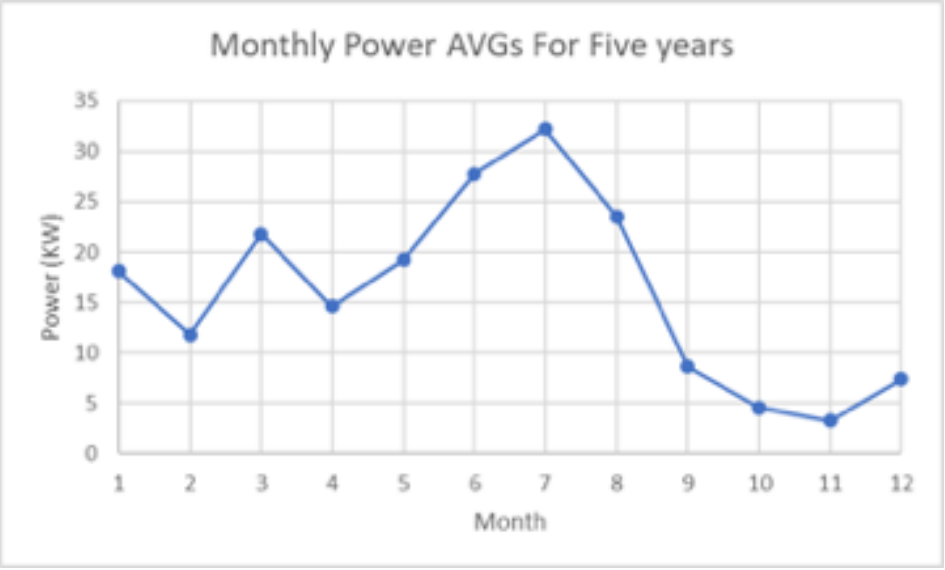

Figure 5: *Monthly Power AVGs for Last Five years in Amman.*

After Figure 5, higher wind speed and power have been recorded in summer period. This variation is associated with land-sea-air interactions.

Aqaba

Aqaba	2018	2019	2020	2021	2022	Monthly AVG	Power (KW)
Jan	2.889	2.750	2.389	2.889	3.083	2.800	14.159
Feb	3.528	3.306	2.611	3.667	3.972	3.417	25.726
Mar	4.528	3.833	3.722	4.556	4.861	4.300	51.282
Apr	4.222	4.556	5.194	5.306	5.028	4.861	74.091
May	4.083	5.417	5.444	4.889	4.917	4.950	78.230
Jun	5.389	5.111	5.278	6.083	4.889	5.350	98.769
Jul	4.611	5.111	5.333	5.389	4.889	5.067	83.893
Aug	5.417	4.472	4.389	5.222	5.111	4.922	76.921
Sep	5.861	5.722	5.139	6.111	4.833	5.533	109.275
Oct	4.556	4.139	4.500	5.528	4.000	4.544	60.534
Nov	3.278	3.250	2.917	3.806	3.389	3.328	23.770
Dec	2.694	2.000	3.139	3.000	3.028	2.772	13.742
Annual AVG Speed	**4.255**	**4.139**	**4.171**	**4.704**	**4.333**		
Annual Power	**49.676**	**45.731**	**46.814**	**67.124**	**52.484**		
5 Years Average (m/s)				**4.320**			
POWER For 5 years Average (KW)				**52.014**			
Note : All Wind Speed Data in (m/s)							

Table 2: *The last five years monthly wind speed and power and their averages for Aqaba. URL -8 Figure 6: Annual Wind Speed for last Five years in Aqaba.*

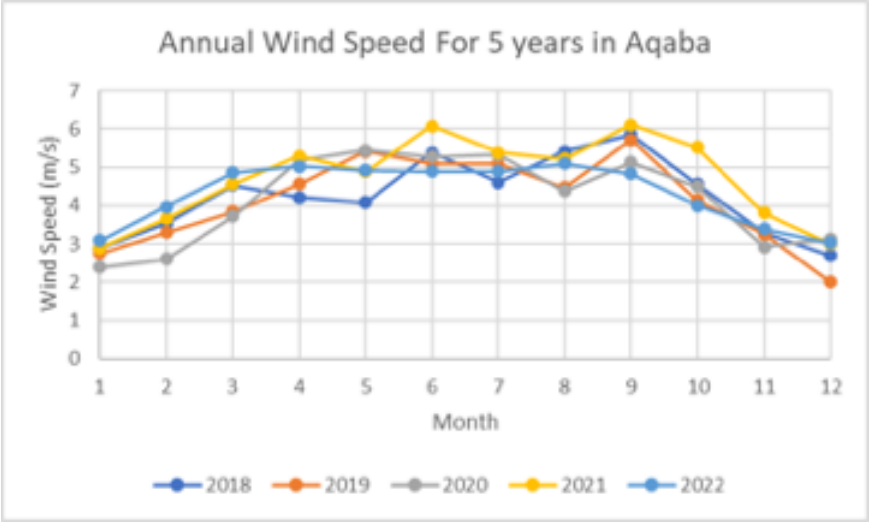

Figure 6: *Annual Wind Speed for last Five years in Aqaba.*

Table 2 and 6 show wind speed and potential has maximum values at five-year period in all months. Annual average wind speed and total wind energy potential are almost two - three times more in Aqaba than in Amman respectively.

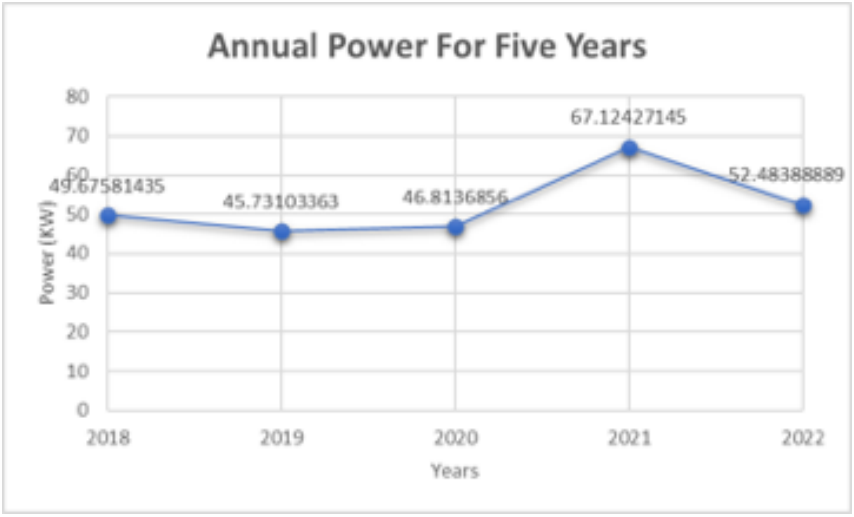

Figure 7: *Annual Power for Last Five Years in Aqaba.*

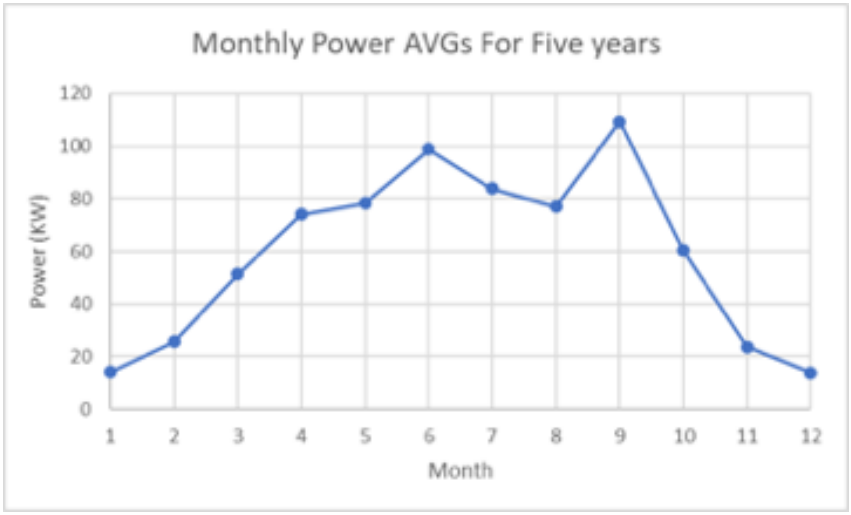

Figure 8: *Monthly Power AVGs for Last Five years in Aqaba.*

Figure 7 and Figure 8 show monthly and annual wind power variations in Aqaba at last five years. During the last two year at the study period, more wind energy potential has been observed in Aqaba.

Results

Jordan is a country that imports raw materials for the production of electric power. It is necessary to work on increasing the use of renewable energy in energy production, (Juaidi et. Al., 2022). Wind and solar energy are the most important renewable energy resources in Jordan. It is very good, helping to produce energy in Jordan using the two energies, wind energy and solar energy. In this paper, monthly variations of wind speed and wind energy potential at two study areas have been resented in Jordan. It is clear that Jordan is a suitable location for energy production through renewable energy. There are a very good number of measurements of wind speed and solar radiation in the Kingdom. Therefore, renewable energy farms will help to provide job opportunities for a huge number of engineers and technicians in various specialties and fields. It will raise the rate of local production and attract investment companies specialized in the field of renewable energy. It would benefit from selling energy to the state and citizens at a cost less than Energy production using fossil fuels of all kinds and with a small profit margin due to the low production cost, and despite the high constituent cost of energy farms, they give economic benefits in the long term. They are classified as one of the best projects with high income and a high profit margin in the long term. The providing energy with fairly good fees is considered a very good support with the low income of workers for investors in other fields to invest in Jordan. They carry out a huge production and industrial revolution that will give Jordan the necessary position in the region. They make it rise to a higher level, so we cannot forget the role of renewable energy in raising investment, income, providing job opportunities, and reducing the costs of producing electric energy by traditional methods.

On the other hand, since the city of Aqaba in particular is the main Sea Port for Jordan, some areas in the sea can be exploited to install solar farms in it or install wind turbines. Because they are available in excellent numbers inside the Red Sea this project will be pioneering in the Middle East. There are also large areas available in The Wadi Rum and Maan deserts near Aqaba can also be used to produce energy through solar panels and sell it to neighbouring villages.

As a conclusion, two study areas have a similar wind energy potential with Southern Italy and western part of Iberian Peninsula (URL-2)

Discussion

According to given data and charts above we find that Aqaba will be the best place to establish wind farms we found that highest Power of wind there, in comparison with Amman. It is determined that the lowest wind potential power in Aqaba in the last five years was in 2019 with 45.7 KW which is already higher than wind potential power in Amman. On the other hand, The Aqaba Monetary Extraordinary District, located within the verifiable city of Aqaba. It is described as a core area consisting of the aggregation point of three land masses and the intersection of four countries. It extends along the Jordanian coast on the Red Ocean, with an area of 375 km2 in the far south of the Hashemite Kingdom of Jordan with Sea front of 27 km, long of Modern waterfront. Aqaba, with a population of nearly 200,000 individuals, it is described as having access to the harmonized framework and social and administrative superstructure necessary for a thriving city and a high-level conservation improvement society.

The Aqaba Special Economic Zone Authority provides the necessary facilities for investment companies and others to make huge investments, which must include the field of renewable energy, both wind and solar energy, due to their availability in distinct numbers in the city of Aqaba, is economically and energetically a strategic location to work on producing Electricity in a clean way to preserve the environment. Also, Aqaba is one the best tourist destination, that's why commercially if we established wind farms there it will be a very good idea to bring Arab and foreign tourists which also can Support the economic situation in Jordan for next years.

For future work, decreasing trend of wind speed and wind energy potential at Amman will be analysed. Another study would be related wit future prediction of wind speed and energy potential by using advanced machine learning models.

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