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Renewable Energy Potential in Jordan

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Abstract

In Jordan the present demand for energy is high and is predicted to increase rapidly in the near future. Relying on fossil fuel to generate power puts constrains on the country economy due to fossil fuel soaring prices and as well as its negative impact on the environment. According to the previous fact there are governmental and public interests in using renewable energy technologies. In addition, the Jordanian government is promoting and investing heavily in renewable energy; such as wind, and solar power. Consequently this paper aims to assess the potential of renewable energy resources, in particular wind and solar energy in Jordan's biggest cities namely, Amman, Irbid, Maan, Aqaba, and Mafaq. Analysis is done by using the latest statistical state of Jordan's energy sectors, along with measured data and history of wind speed, solar irradiations, air temperature and relative humidity, for the selected sites. The article also will help to define a methodology to assess renewable energy availability and potential in Jordan such as solar and wind energy by developing local climatic data sets of Jordan's most geographical areas.

Keywords: Renewable energy, Solar Energy, Wind Energy, Climatic data.

INTRODUCTION

Jordan faces a high growth rate in population and urbanisation, this growth and urbanisation will increase the rate of energy consumption. As the population in Jordan continue to grow and the limited amount of fossil fuel begin to diminish, it may not be possible to provide the amount of energy demanded by Jordan by only using fossil fuel to convert energy. In addition Jordan is an oil importing country and, at the same time, Jordan is a country with very limited conventional energy resources e.g. natural gas. Relying on imported fossil fuel resources have contributed to Jordan having a very high level of greenhouse gas emissions (GHG) per capita [1]. According to [2] Jordan's total GHG is about 26 Mt of CO^2 which represents 0.06 % from 46,906 tons of the world total CO_2 emissions taking into account that, the annual GHG emissions is expected to rise to around 2.7% between the year 2016 and the year 2040. Currently a day's electricity generation produces 73% of GHG whilst the biggest portion of the remaining emission comes from waste, industrial process and agriculture as shown in Figure 1 [3]. It is worth mentioning here that, the country's rapid growth in population and successive arrivals of refugees over the last 10 years have increase electricity generation to a peak of 3.8 GW in the year of 2013 [4].

According to [5] nearly 96% of the country's electricity production is generated using imported fossil fuels e.g. oil and natural gas. In addition, many explosive attacks were carried out on the main gas feeder between Jordan and Egypt (Arab Gas Pipeline) from 2011-2014 which used to natural deliver gas to generate 88% of Jordan's needed energy production. With the pipeline no longer in use consequently the government has relied on alternating Egyptian gas by diesel and heavy fuel oil to operate power plants on extra cost of JD 4 billion in the year 2012. Figure 2 shows the country's energy mix production in the year 2015, the figure also shows the majority of the country's electricity generation is produced using oil which accounts for 51% followed by production using natural gas, oil shale, renewable energy and imported electricity which accounts for 21%, 11%, 7% and 2% respectively [6].

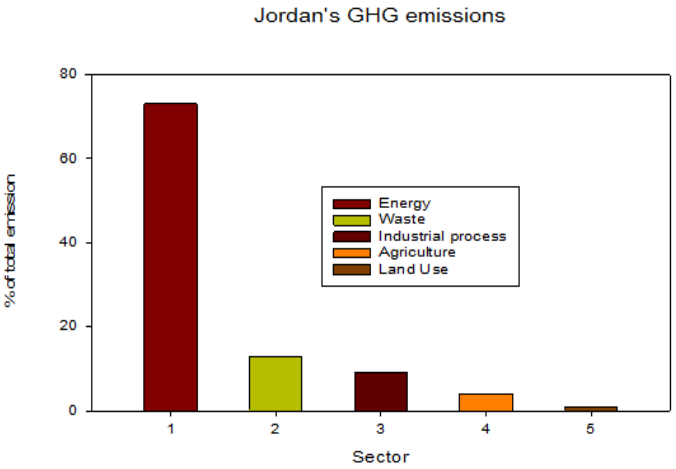

Figure 1: Jordan's total GHG by industry

Jordans most recent employment of renewable energy technologies, specifically wind and solar energy systems, is considered as one of the main measures that have been carried out by the government in order to endorse and encourage the utilization of renewable energy resources by public and private sector due to renewable energy expected economic and environmental benefits. The fact that, Jordan is one of the

globes best solar and wind resources, makes from the country as one of the leading market for solar and wind energy harvest. The population of Jordan are now encouraged and invited to take the lead of the rising renewable energy business due to its strong availability, grid access, governmental support, and the existence of legal services.

Recently, there have been a significant number of research activities that have highlighted the renewable energy potential in Jordan that are worth noting such as [1] who has evaluated solar energy potential in Jordan based on academic resources only. [7] has reviewed energy usage demand in various Middle East countries including Jordan. [8] has develop model to evaluate the size factor and project the production costs of wind energy in different locations within Jordan. [9] have highlighted a technical evaluation of wind energy potential for few locations within Jordan by utilizing statistical assessment in order to clarify wind energy specification relying on real time measured wind data. [10] has evaluated wind energy harvesting in five cities in Jordan. Unfortunately, other than as already noted none of the previous researches were relied on more than one meteorological data system and using different simulation engines in order to assess the potential of installing renewable energy means such as solar energy and wind energy in a country where conventional energy resources are very limited such as Jordan.

Consequently, this research study presents a simulation investigation of the potential of installing renewable energy harvesting techniques mainly; solar and wind energy in the country's main cities namely; Amman, Irbid, Zarqa, Ma'an, and Mafrak. The simulation outputs and results are analysed in terms of solar irradiance intensity, wind speed, air temperature, earth temperature and relative humidity. The meteorological data has been gathered from local meteorological stations (The applied Science Private University), RETScreen software and department of Energy's (DOE) Building Technologies (EnergyPlus).

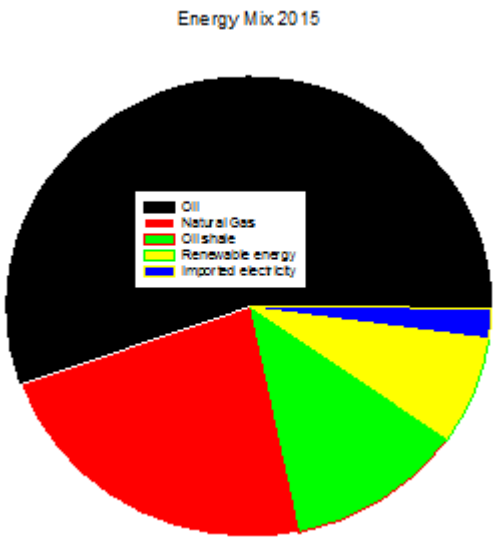

Figure 2: Jordanian energy mix 2015

Renewable energy in Jordan

Jordan remains one of the fastest developing countries in the middle east. Based on reports by the Jordanian department of Stastics [11]

Jordan remains one of the fastest developing country in the Middle East region. Based on what reported by the Jordanian department of statistics [11], the current country's current total population sets around 9,864,336 .This rapid rise in population and demand on infrastructure has made Jordan one of the most energy demaning countries in the region. As a consequence of the high demand for energy there is a higher level demand for energy there is a higher level of GHG emissions compared to the regions neighbouring countries.

Jordan is currently challenging itself to minimise the growth of GHG emissions by entering into more economic, liable, environmentally friendly and cost effective energy resources.

The combination of Jordan's location and climate give it potential to become one of the best renewable energy generators in the word. The importance of using more renewable energy systems would have a great impact on reducing Jordan's GHG emissions, based on the fact that the most of Jordan's GHG emissions are due to the demand of electricity generation. Jordan is rich with renewable energy resources. According to [12] in the future, Jordan will be able to generate 100% of the country's electricity demand by using renewable energy resources thus saving the treasury around $12 billion a year. In addition, Jordan's wind and solar energy availability could deliver up to 50 times more than the country's expected electric energy demand by the year 2050 [13].

According to [14] Jordan's total GHG represented 7 % of the country's total energy generation by the end of the year 2015. The renewable energy contribution to the country total energy mix as shown in Figure 3 is divided into: wind energy, solar energy and biomass which represent 65%, 32% and 3% respectively using 15 renewable energy power-station which was installed by the end of year 2015, reaching the total-installed capacity up to 500 MW. Moreover the government of Jordan is planning to raise renewable energy contribution to 10% of total energy mix by the year 2020 taking into account that includes installing 30-50MW using biomass energy generation.

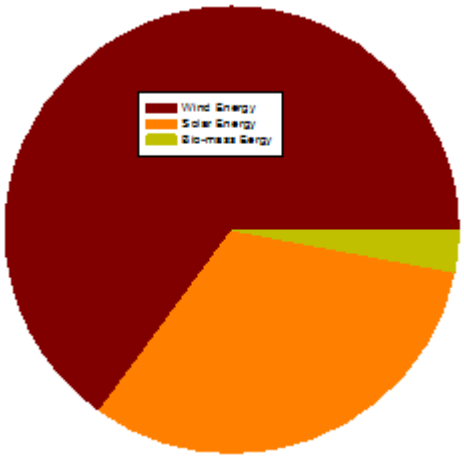

Figure 3: Jordan's renewable energy share

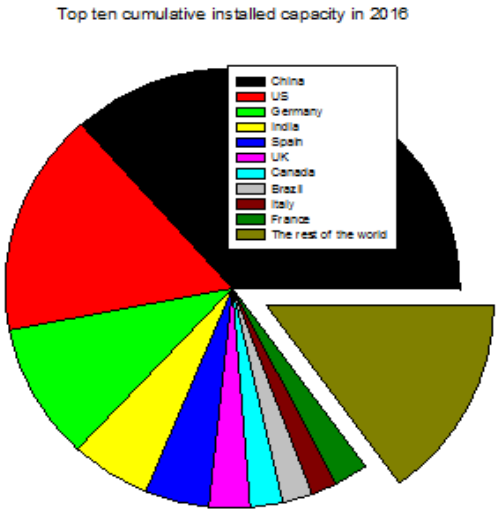

Figure 5: Top 10 accumulative installed capacity

Wind energy in Jordan

Wind energy is not a new technology it has been used by Mankind for more than 3000 years to drive water supply pumps and to grind crops and grains in mills [12].Presently, wind energy is considered as one of the most significant and growing renewable and sustainable energy resource in producing electricity. By the end of the year 2016, the global total electricity production using wind energy reached was about 487 GW recording an 11% increase in comparison with the year 2015 as shown in Figure 4 [15]. In addition the figure shows that, the total recorded global accumulative electricity generation using wind energy for the year 2014, 2013, 2012, 2011 and 2010 which was 370 GW, 319 GW, 283 GW, 238 GW and 198 GW respectively. The biggest installed accumulative capacity of wind energy was noted to be in China followed by the United States of America, Germany, India and Spain at 34.7 %, 16.9 %, 10.3 %, 5.9% and 4.7% respectively while the accumulative installation in the rest of the world was noted to be 15.5% as shown in Figure 5.

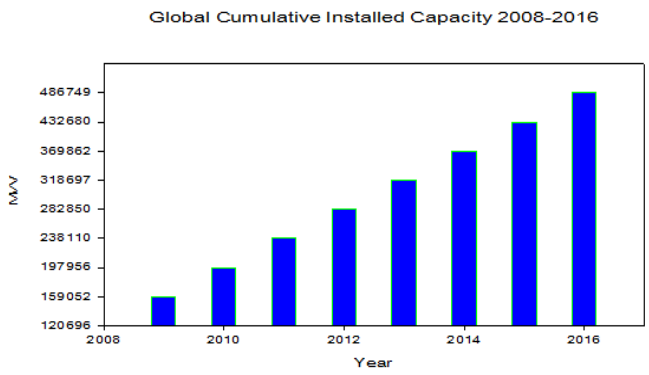

Figure 4: The biggest installed accumulative capacity of wind energy

In the Middle East and North Africa regions, wind energy gained some significant progress, reaching 3489 MW of electricity generation by the end of 2015 [16]. The Jordanian wind energy share is currently limited despite the fact that, according to the wind atlas, the annual average wind speed is rangs from 4-6.5 m/s in selected parts of Jordan. Currently, the present Jordanian wind energy generating capacity is around 119 MW delivered by three electricity generation stations namely: Al Ibrahimya which generates nearly 320 kW, Hofa wind farm which generate 1.125 MW and most importantly Altafila wind farm which generates 117 MW.As a consequences of Oil and fossil sore prices, the Jordanian wind energy market will gain momentum in the near future due to the fact that, many locations within the kingdom are with average wind speeds above 10 or even 12 m/s at 50 m elevation which is considered below the average height of a newly constructed wind turbines. Thus with more than $ 90 billion in revenue of wind energy business by the end of the year 2012 still wind energy cannot compete with thermally fired power plants using fossil fuel such as coal, oil, and etc. [17, 18].

Solar energy in Jordan

The main advantage of solar electricity generation especially in hot climate countries like Jordan is that, electricity generation occurs mostly at peak load demand. Jordan is characterized by having abundant solar energy resources which can cover t most of the country's electricity demand. In addition, Jordan location is regarded as one of the sun-belt states where the most of its area is exposed to a very high solar irradiance. In Jordan, solar energy harvest has substantial opportunity to generate electricity due to the sunny climate, the availability of huge desert and minimum fraction of overcast and rain. At the present there are nearly 15% of domestic buildings that

are provided with solar thermal systems. Jordan government has key tactics to increase the usage of solar energy. According to the government Energy Master Plan, 30 % of domestic buildings are projected to use solar thermal systems by the end of year 2020 [19].

Additionally, various projects with a gross production of 400 MW were assigned in the city of Ma'an, Aqaba and Almafrak [20]. The first governmental solar project to be installed was the Shams Ma'an Solar PV power plant with capacity of 52.5 MW. According to [5], the Shams Ma'an Solar PV power plant delivered a very low tariff of six US cents per kWh which considered as one of the cheapest ever installed worldwide and is nearly tied with the world record tariff of US cents 5.89 per kWh [21].

The first private sector solar PV project to be installed was the Applied Science Private University (ASU) project at a capacity of 250 kW in the year 2013 which covers 25 % of the university's electricity demand as shown in Figure 6. In the year 2015 the Al Azraq solar energy plant was installed at capacity of 5.17 MW. The announced future governmental and private sector solar PV plants installation plans are the Almafraq solar PV plant, Al-Quweira solar PV plant at a capacity of 200 MW and 100 MW respectively.

Figure 6: Sample of Applied Science Private University solar energy plant, Amman, Jordan, a (CPV)

JORDAN'S WEATHER DATA ANALYSIS AND DISCUSSION

In this research, data was collected from Applied Science Private University local meteorological station, Ret screen software and Metenorm software for the city of Amman, Irbid, Ma'an, Aqaba, and Mafraq. Applied Science Private University's local meteorological station was established in the year 2015 in order to provide local and international researchers with accurate climatic information and as well as to help with local weather forecasting for nearby Amman locations such as the area of Shafa Badran as shown in Figure 7. Ret Screen is an energy assessment tool that was developed by the Canadian ministry of natural recourses, the current version of the software has the ability to evaluate and assess energy projects economic, environment and risk aspects for various renewable energy resources [22]. Data is gathered from the ASU metrological station and Retscreen software and utilized in this paper to evaluate renewable energy potential for the selected Jordanian cities. Solar and wind energy obtainability relies on two key climate factors, these factors are the selected cities wind velocity and solar intensity (irradiance).

Figure 7: Applied Science Private University weather station

RESULTS AND DISCUSSIONS

Jordan total area is around 96000 km^2, with 3 different climatic zones: Jordan valley, Mountains and the Badia (desert) which covers 75% of the country's total area. Jordan is renowned for its sunny climate. The average sunny days are around 310 days of sunshine a year. Summer in Jordan is from June to September and the winter is from December to April. During the summer season the average mean air temperature ranges from 23 C ° -33.2 C° whereas in the winter mean air temperature ranges from 7.5 C° -17.5 C° as shown in Figure 8. Aqaba city recorded the maximum air temperature of 33.2 for the month of July.

Figure 8 shows the countries average mean earth temperature, Irbid city has the maximum average mean earth temperature of 34.2 C°. The minimum average mean earth temperature during summer occurs in Ma'an and Mafraq recording 30.2 Cº and 30.3 Cº respectively. Furthermore, throughout the winter season, the minimum average mean earth temperature was observed in Mafraq recording 8.8 Cº, followed by Ma'an and Irbid recording 11.1 C° and 11.3 C° respectively.

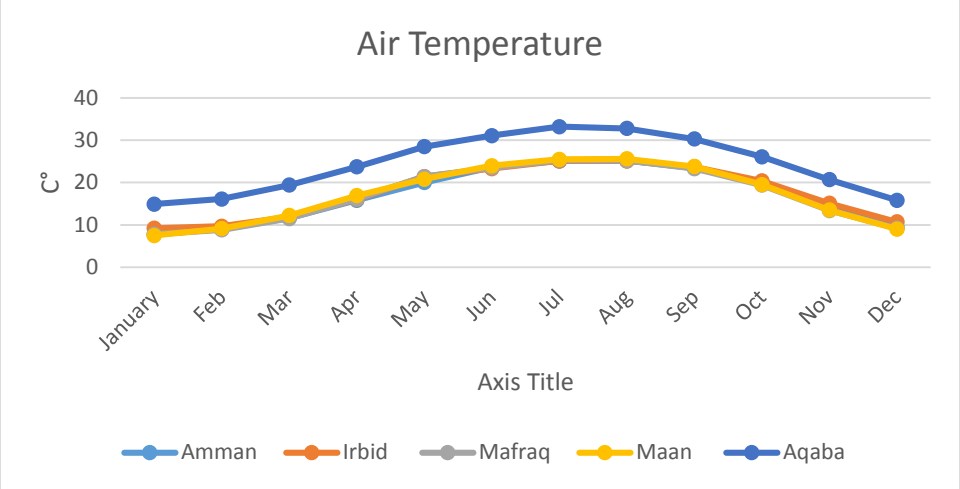

Figure 8: Air temperature of selected cities

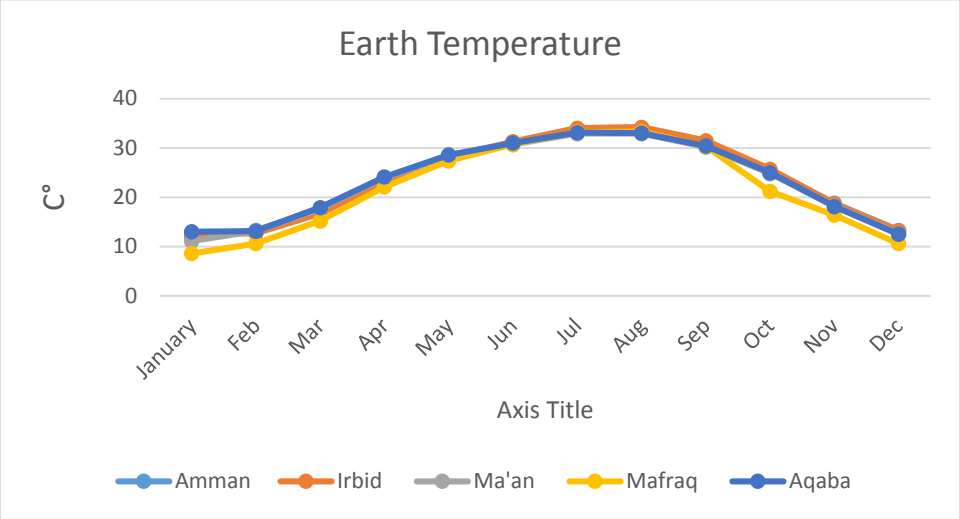

Figure 9: Earth temperature of selected cities

Jordan's climate is characterized by its dryness and low humidity. Figure 10 shows the country average relative humidity for the research's selected city. The maximum relative humidity was observed to be in Amman at 74 % in the month of January followed by Irbid city in the same month at 72% of relative humidity. Additionally Figure 3.3 shows Ma'an and Mafraq cities are the driest areas in Jordan where the relative humidity was observed to be around 39 % and 39.2 respectively.

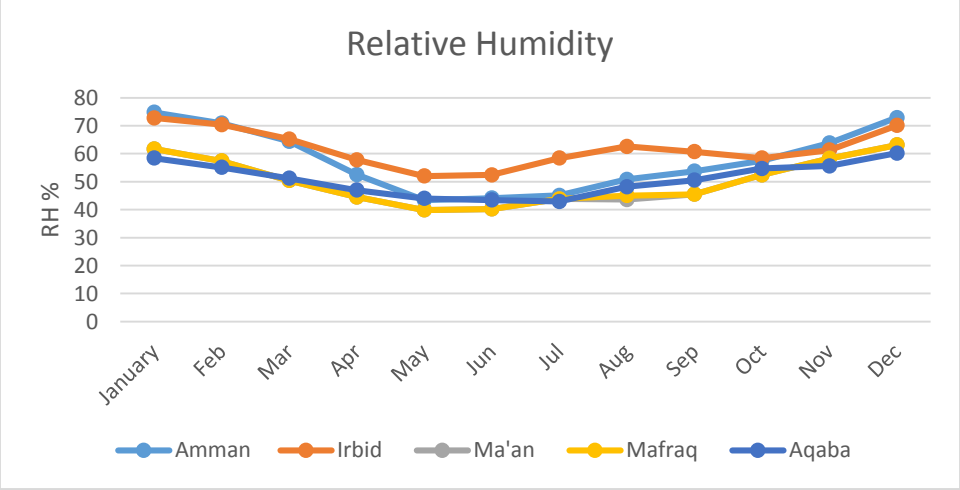

Figure 10: Relative humidity of selected cities

The mixture of Jordan's sunny weather and its position generate a significant motive for locals and internationals to a mass solar energy harvesting. Most of Jordanian cities receive more than of 5.3 kWh/m^2/day of solar irradiance as demonstrated in Figure 11. The highest annual average solar irradiance normally occur in the city of Ma'an at 5.9 kWh/m^2/day followed by the city of Aqaba, Mafraq, Amman and Irbid at 5.88 kWh/m^2/day, 5.84 kWh/m^2/day, 5.5 kWh/m^2/day and 5.5 kWh/m^2/day respectively. It is worth mentioning that, the maximum monthly average solar irradiance was recorded in Amman in June at 8.4 kWh/m^2/day followed by Aqaba at 8.35 kWh/m^2 /day for the same month. The minimum monthly average solar irradiance was received in the city of Irbid at 2.49 kWh/m^2/day for the month of December.

Jordan attains significant potential of wind energy resources as the average annual wind speed reaches more than 7 m/s in some of the countries' remote areas and 10 meters height. However the average annual wind speeds for the research selected cities falls below 5.5 m/s of wind speed. Figure 12 shows that, the highest average annual wind speed was observed to be in Aqaba at 4.5 m/s at 10 meters height followed by Amman, Ma'n, Mafraq and Irbid at 3.1 m/s, 3.1 m/s and 2.9 m/s at 10 meters height respectively. The highest average monthly wind speed was recorded in the city of Aqaba at 5.6 m/s at 10 meters height followed by the month of August and June at 5.3 m/s and 5.2 m/d respectively.

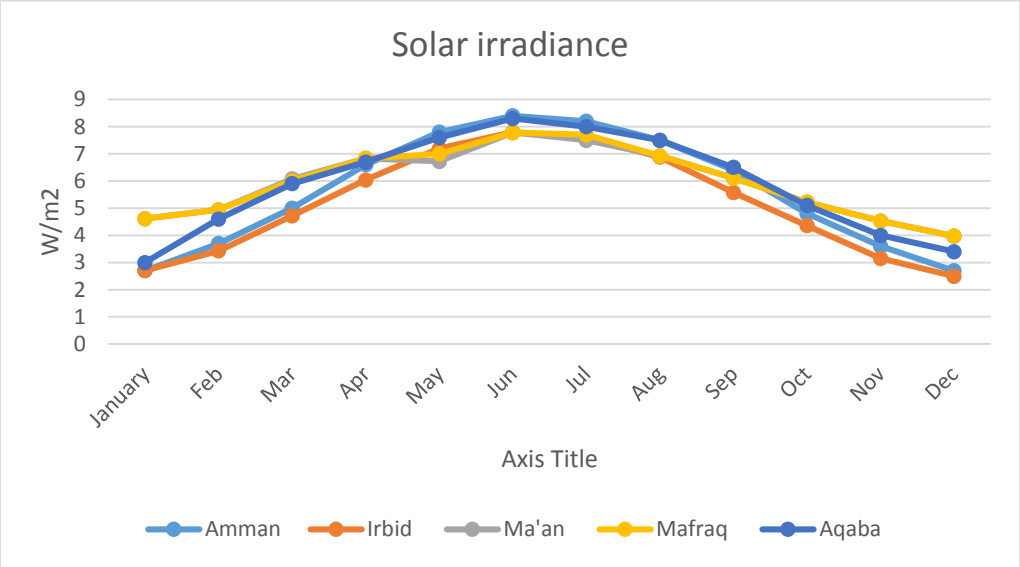

Figure 11: Solar irradiance of selected cities

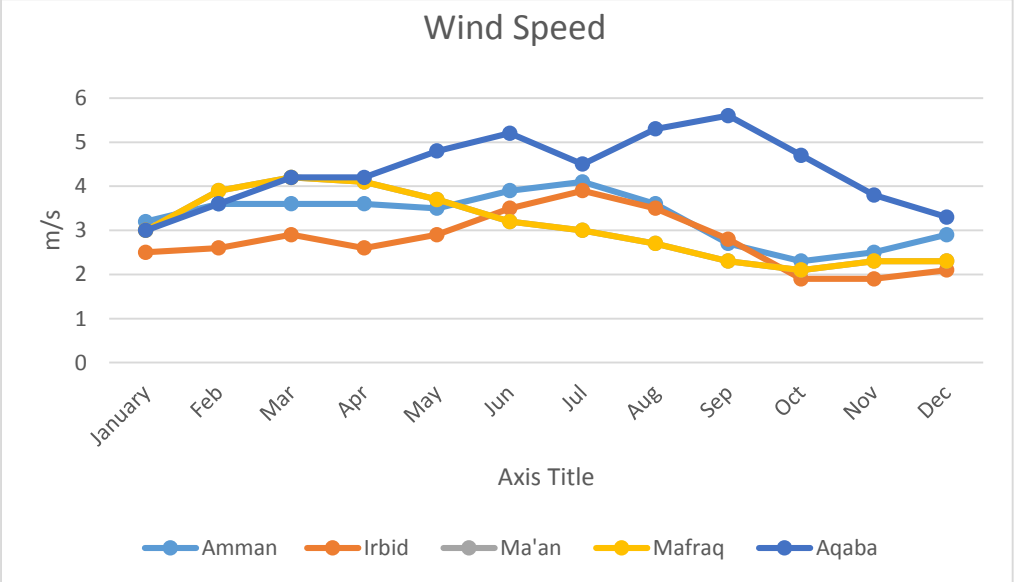

Figure 12: Wind speed of selected cities

POTENTIAL OF SOLAR AND WIND ENERGY IN JORDAN

Renewable energy potential in Jordan is remarkable and there are immediate opportunities for environmentally friendly energy harvest growth. The execution of different strategies and plans by the Jordanian government has raised the public understanding and awareness of renewable energies importance specifically in the role of solar and wind energy in a sustainable energy and economic system. Jordan holds the opportunity to be a key pioneer and mentor between Middle East countries for using renewable energy resources especially solar and wind energy. Also Jordan receives one of the topmost solar energy irradiance in the globe as demonstrated in Figure 13. However, in Jordan there are a lot of issues that are confronting the wide spread of renewable energy employment mainly in the solar and wind energy industry. An example of these obstacles and barriers are: the government's unclear policies and legislations, the long and slow process of private sectors' renewable energy projects approval and the lack of support and grants. The governmental and private sector in Jordan are invited here to work and co-operate together and to escalate their efforts in order to conquer such slowing barriers.

Consequently the procedure of renewable energy projects must be simplified by the grid stake holders mainly the national electric power company (NEPCO) in order to allow national and international investment in the local electricity market using renewable energy resources. The previously mentioned facts are very effectual means to escalate renewable energy developments in Jordan. Furthermore, the availability of accurate and good quality renewable energy related data and an information data base such as comprehensive and specified wind speed mapping, transmission lines integration, and solar irradiance details have to be available for public and potential national and international investors in order to allow them to select the best-possible site. Both Jordanian solar and wind energy are proved to be trustworthy and sustainable, however the government of Jordan are slow in implementing renewable energy technologies compared to other countries in the region' like the Arab Gulf countries.

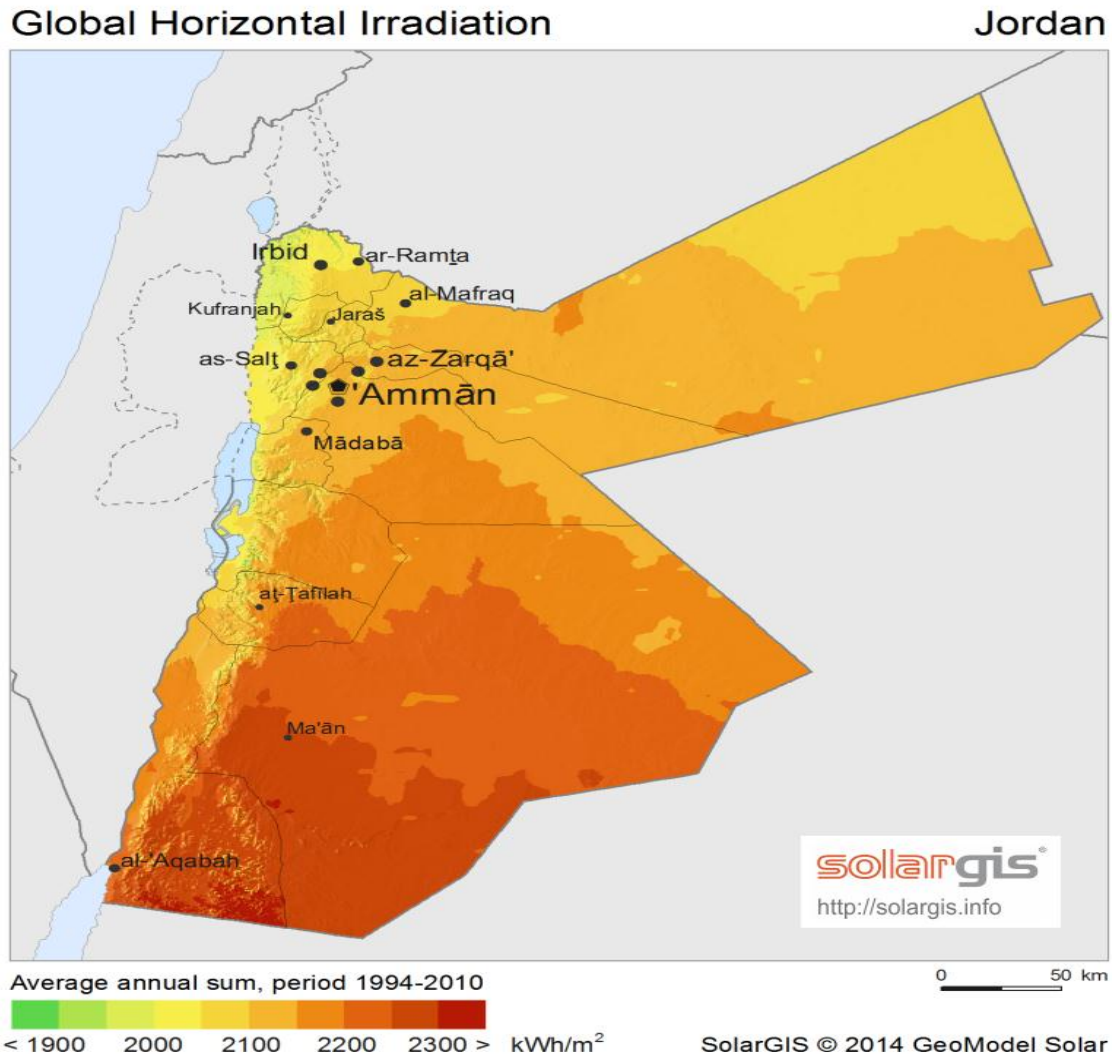

Figure 13: Solar irradiance in Jordad

CONCLUSION

This research article presented the renewable energy potential in selected Jordanian cities. The article also included a detailed discussion on the Jordanian selected cities' weather data. Data was collected from Applied Science Private University, Amman, Jordan, Retscreen and Moeonorm software in order to assess and evaluate of the potential of Renewable energy in Jordan.

Wind and Solar energy are thought to be cost-effective, available to every-one and environmentally friendly. It is known that, Renewable energy availability is controlled by climatic conditions such as solar radiation, wind speed and temperature. Furthermore and in order to enhance the usage of Renewable energy, a comprehensive data base should be available such as solar map and wind speed records for major cities and regions. Based on previous discussions, it was obvious that The development of renewable enrgy will contribute considerably in minimizing the greenhouse gas emissions, fossil fuel burning and will also it will improve the country economy. Relying on renewable energy in order to generate electricity is a growing technology. Due to the Jordanian abundance of renewable energy resources, hence wind and solar electricity generation are able to meet a huge fraction of the daily electricity demand. Therefore Jordan are now invited to take part in renewable energy projects future development and installation despite the fact that renewable energy systems are characterised by high capital costs and the lack of technical information and related weather data base.

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