An Assessment of Renewable Energy Sources (RES) Potential in Libya: An Overview

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Abstract. This paper presents Libyan Renewable Energy Sources (LRES), as Libya relies heavily on conventional energy resources (CER) to fulfil its energy requirements, and these resources are still being used to cover the country's regularly increasing energy needs. Moreover, a mostly Libyan rural area has a quite remote location from the national electrical grid. In the past, (security and political were better), there was trying to solve this problem by focusing more on RES besides CER. Libya has enough potential and is a well-known market for RES, and it is time to invest in renewables. However, there is still a large gap between generating power and the required energy. The aim is to demonstrate the current RE potential in Libya in general, the techniques which have been used so far and compare current and future barriers. Finally, there will be some recommendations that show how Libya may change the current scenario of its energy sector by using the available RES. Admittedly, it is so challenging to develop and improve the GECOL from using CER to RES, if the country is still suffering from a civil war, instability in general.

Keywords: Renewable Energy, Electricity, Energy, Solar Energy, Biomass Energy, Wind Energy.

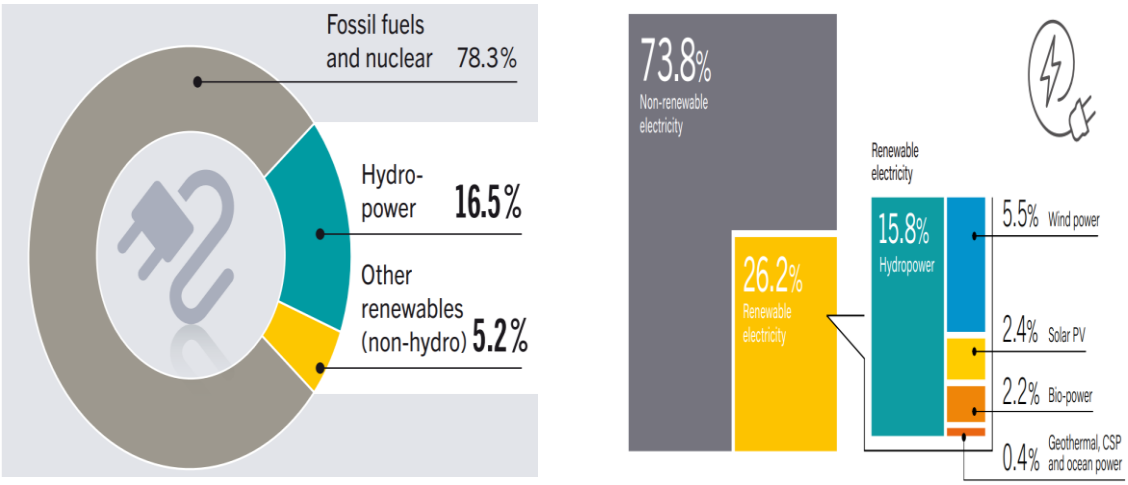
1 Introduction

Renewable energy resources are generally defined as energies that come from inexhaustible resources which are basically natural and do not contaminate the environment such as wind, solar, biomass energy, geothermal, and hydropower energy…etc. Over the last few decades, many developing countries in the world, including oil-rich countries, have begun to diversify their energy resources to remove partially their dependency on non-renewable energy resources (Oil, Coal, and Gas) [1] [2]. The motivation for this is due to the rapid depletion of exhaustible resources (fossil fuels), and their costs are quite expensive.

Another significant reason arises from the awareness of climate change as a result of Carbon emission and pollution caused by using fossil fuels. The considerable improvement of utilizing wind and solar power, static growth in hydro-power and their economical price are supporting the part of renewable energy resources as the critical role of global energy sources. Renewable Global Status Report shows that renewable power global capacity achieved approximately 1,470 GW in 2012, which about 990 GW was the contribution of hydropower and 480 GW was from other renewable resources. From Fig.1 a, it can be concluded that more than 21 percent of global electricity production was renewable energy in 2012 [3], where they became 26..2 % of global electricity production renewable electricity in the end 2018 regard to renewables 2019 global status report [4] . The energy sector of Libya heavily relies on non-renewable energy resources (Oil and Gas) as the main resources to fulfil its energy requirements and these resources are still being used to cover the country's regularly increasing energy needs. "Libya is located in the middle of North Africa with a huge area of 1,759,540 Km2 and along the coast of a length of 1900 km on the Mediterranean Sea with 88% of its area considered to be a desert" [5] [6]. It is the second biggest county in North Africa, located in the west between Tunisia and Algeria, Egypt in the east and from west to the east, Niger, Chad and Sudan as can be seen in Fig.2.

IMDC-SDSP 2020, June 28-30, Cyberspace

DOI 10.4108/eai.28-6-2020.2298171



a) 2012 b) 2018

Fig. 1. Estimated RE Contribution of Global Electricity Production [7] [4].

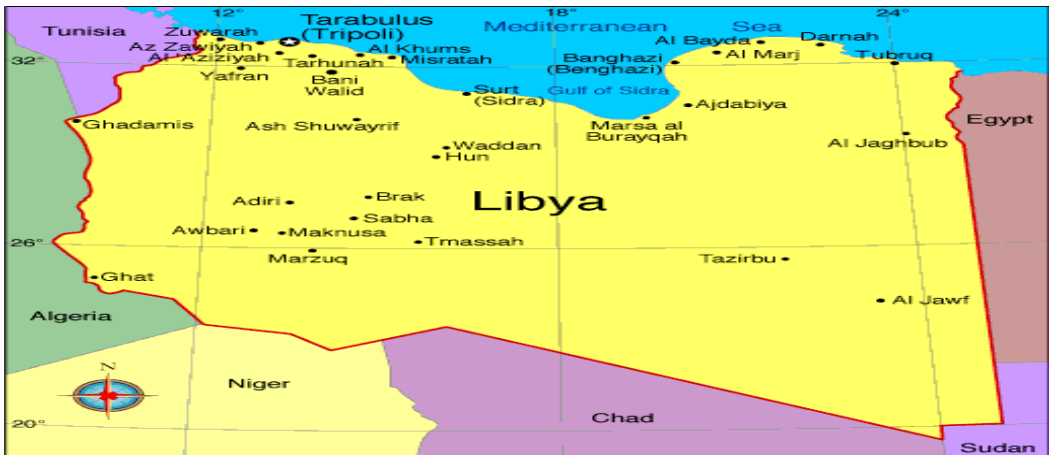


Fig 2. The location of Libya in North Africa

As far as renewable energy resource is considered, the reason for power generation from clean energy resources is not only to achieve the required future energy demands, but also to make the Libyan energy development economically, security and mixture of energy supply, reducing local pollution and emissions of primary energy resources, and starting opportunities for the private energy sector.

2 Energy Situation in Libya

A. Energy Production

The export of oil and natural gas is being the agent for the Libyan's economy. In 2005 the total income resources of estimated to forty billion oil barrels (0.6 b bbl/y), and 1300 billion cubic meters of natural gas (12 b m^3/y). It can be seen from Table1 energy production estimated by the year 2005 [6].

B. Energy Consumption

The public facilities and residential sectors are measured to be the largest consumers of the total electricity load, as can be seen in fig.3 that approximately 55% of energy consumption could be the public facilities and residential sectors in 2009 [3] [8].

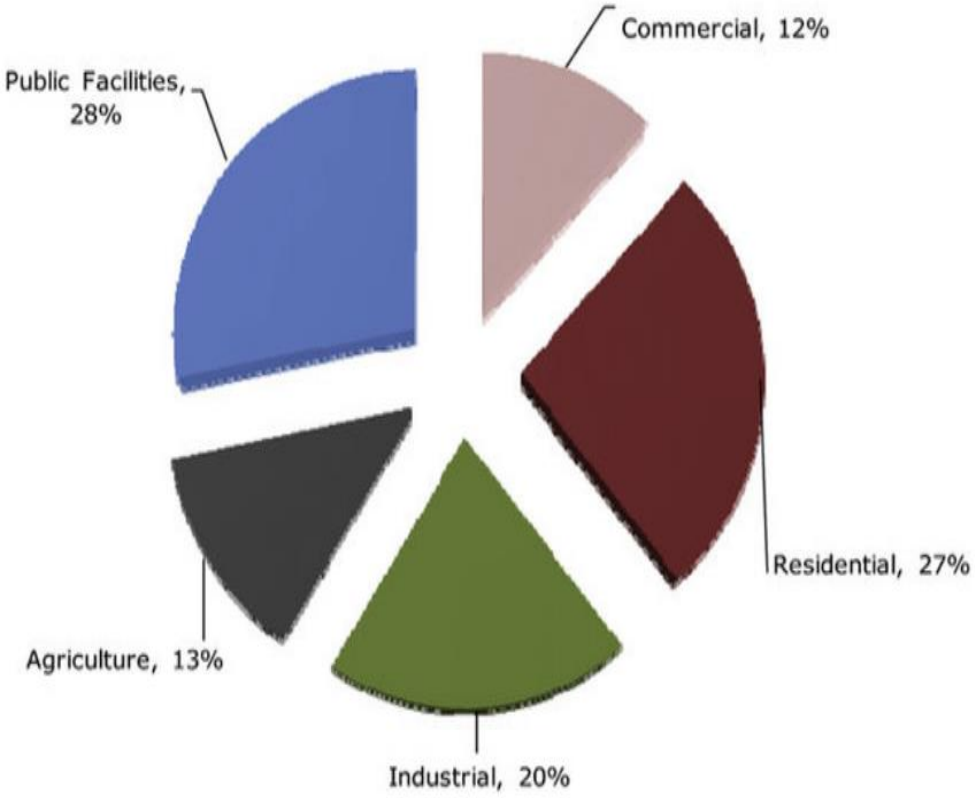


Fig 3. Typical electricity load classification in Libya 2009 [3].

Besides, Libya typically exports 0.5 billion barrels of oil per year in 2005, as can be seen from Table 1. Recently, the average of exporting of crude oil increased gradually, which accounted for about 70% to 80% of its exports to European countries (Italy, Germany, and France), and 19% of its exports to Asia and Oceania in 2013; USA import 43,000 bbl/d of crude oil from Libya which it accounted for about 6% of Libyan's exports. What is more, Libya exported an average of 9 billion cubic meters per year of natural gas in 2005 as can be seen in table 1. Furthermore, the export of gas in Libya rose slowly in 2013 after the civil war in 2011, which is calculated for about 430 billion cubic feet (more than 12 billion cubic meters). Table 1 shows an energy situation in Libya (Production, Consumption, and Export) by the year 2005 and Fig. 4 and Fig. 5 shows Libyan's export of oil and natural gas in 2014 [9].

Table1: Energy Situation in Libya by the year 2005.

Type	Production	Consumption	Export
Natural gas	12 billion m^3/y	3 billion m^3/y	9 billion m^3/y
Oil	0.6 billion bbl/y	0.1 billion bbl/y	0.5 billion bl/y
Electricity		20 T Wh/y	

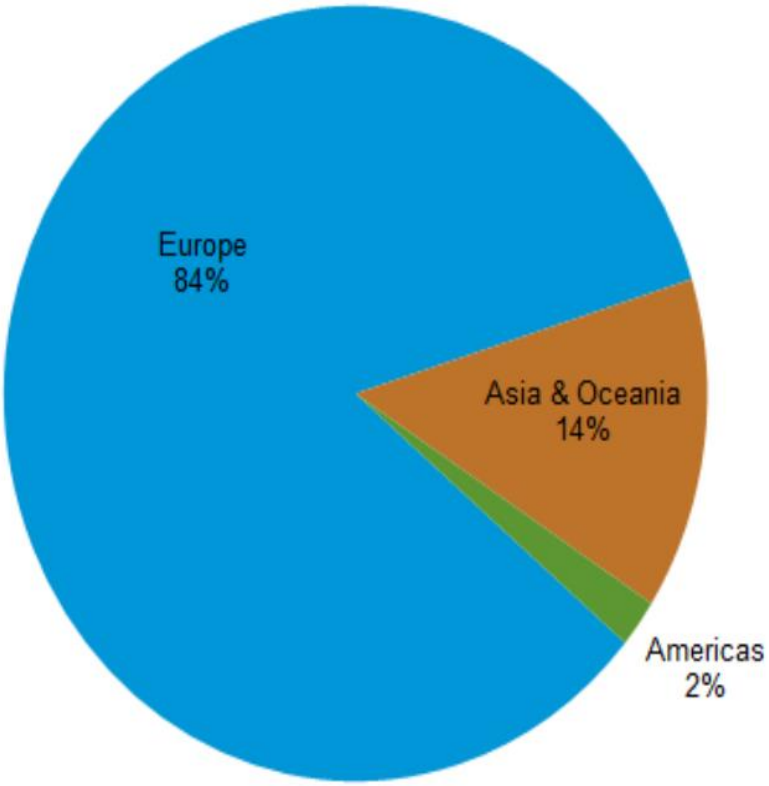


Fig. 4. Libya's exports of crude oil, 2014 [10] [8].

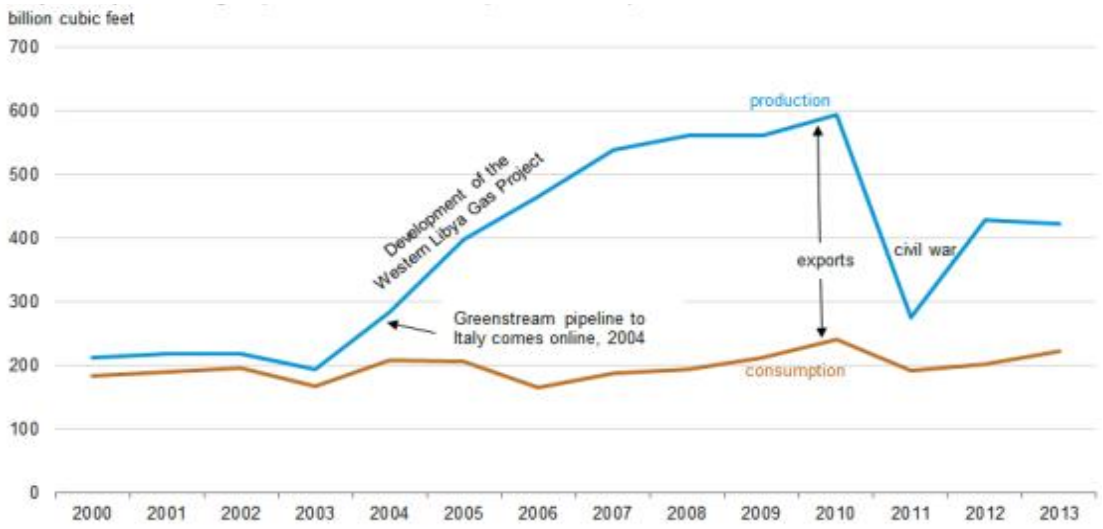


Fig. 5. Production and consumption of natural gas from 2000 to 2013 [11].

3 Libyan Electric Power System

The national electrical grid contains more than 30,000 km of voltage network, and it is divided into three types of network, the high voltage network where it is around 12000 Km; and approximately 12,500 km of a medium network which is the biggest and a low network about 7000 km. Furthermore, most of the power stations are located along the Mediterranean coast, which is connected with standard transmission systems as can be seen in fig.6. “Libya has Africa’s highest electricity generation Per capita consumption, which was 4.60 kWh in the year 2009 compared to only 2.65 kWh in the year 2000” [3] [12]. However, a large rural area and many western villages located far away from these power stations and still cost the government costly budget for delivering the power from far stations. Due to the population in the past, they use diesel generators as a power station [6] [12].

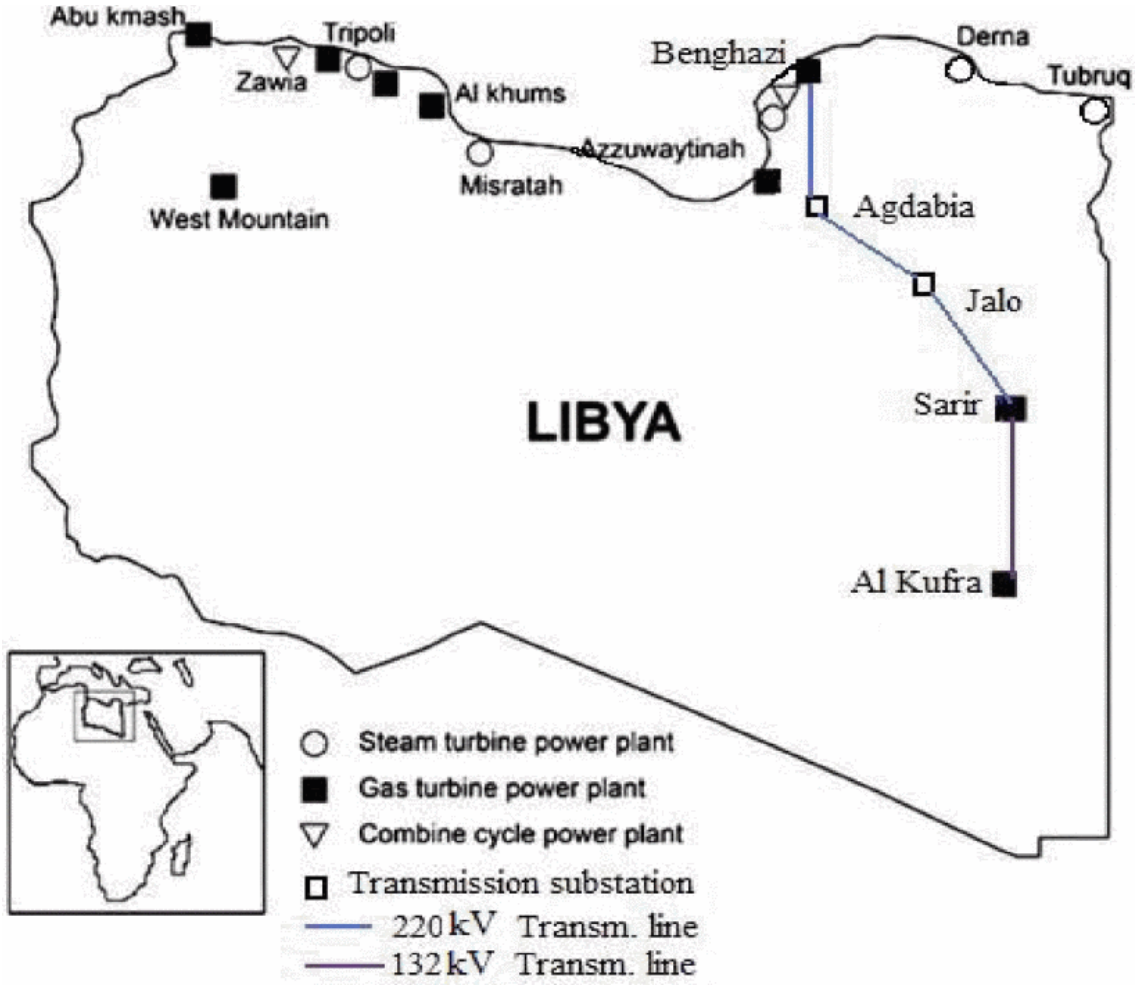


Fig. 6. Libyan electric power stations[13].

4 Government Policy on Energy

The use of electrical energy is essential to develop the community, manufacturing, and commerce. The government's policy plans to modernize all Libyan sectors including electricity sectors for which the General Electric Company of Libya is responsible, GECOL is generating, distributing and delivering electrical power to approximately all residents in Libya. It supplies about 99% of the Libyan population.

The government's policy supplies electric power to the west of Libya by using power stations which are operated by fossil fuel and gas stations. However, the future energy requirement is going to increase slightly [14]. It is estimated that the energy requirement will be 50 TWh per year in 2050, as shown in Table 2. Moreover, S.M. Ibrahim has writen that " The oil resources for Libya will not last more than 50 years as of today production and discovered resources, while the natural gas is expected to last more than that" [6]. Since the continuity of supply of fuel and maintenance of using diesel generators and the required future energy demands, we have to use other energy sources such as renewable energy which is reliable and clean sources, and also renewable energy resources might be used in other applications like water pumping. Table 2 shows that the Libyan energy requirement scenario for 2050.

Table 2: Libyan Energy Requirement Scenario for 2050.

Type	2005	2050
Population	6 Million	10 Million
Electric power generation	3500 KWh/cap/y	5000 KWh/cap/y
Electricity demand	20 TWh/y	50 TWh/y

5 Potentials and Limitations of RES

The North Africa area is generally known with extensively diversified renewable energy resources; Libya is located in a lively zone in the middle of North Africa with a large area of 1,750,500 Square kilometers (Km2) and about 1,900 Km2 of a coastal length along the Mediterranean Sea. Over the last few years, there have been sustained efforts done by the Libyan Government to identify renewable energy resources for electric generation in some locations in the country, where Renewable Energy of Libya was established in 2007. It has been observed that a considerable potential for investment renewable energy resources is being present potentially in Libya.

5.1 Solar Energy

Owing to the Libyan geographical location where it is with more than 85% of its area measured to be a desert. Libya receives a huge density of solar radiation per day. The daily average of solar radiation on a horizontal plane is measured by more than 7000 Wh/m2/day in the coastal area and approximately 8100 Wh/m2/day in the southern area making Libya one of the best solar countries in the world. In short, the average sun duration is greater than 3000 hours per year, as can be seen in Fig. 7 [2] [6]. And the average solar radiation is approximately 7.5 KWh/m^2/day [15]. To sum up, solar radiation (Monthly) in some Libyan cities can be seen in Fig. 8 .

A few years ago, there was a study that been done by General Electric Company of Libya (GECOL), mentioned that the huge aptitude of solar energy in Libya is progressively known to play a serious role in decreasing the dependency on primary energy resources in the next few years, it also approved that the domestic energy requirements of Libya will be covered by the correct investment of the intense daily energy. It can be clear that the high-est of intense sunlight in the summer, which the electricity requirements reach in the peaked period. However, the desert zones and Southern villages have the highest intensity of solar radiation compared to the other regions in Libya, so these ideal zones can be used for generating many quantities of solar power. The information clearly shows that it is theoretically possible to power Libya to small utilization area of the desert from solar collectors; it will be an excellent advantage to interconnected electric pow-er to many villages and rural regions in Libya. “Research suggests that a 0.1 percent Libyan land use for solar energy production would lead to energy production equivalent to 7 million barrels of oil a day, or almost five times the daily amount of energy produced from oil in 2012” [3] [6].

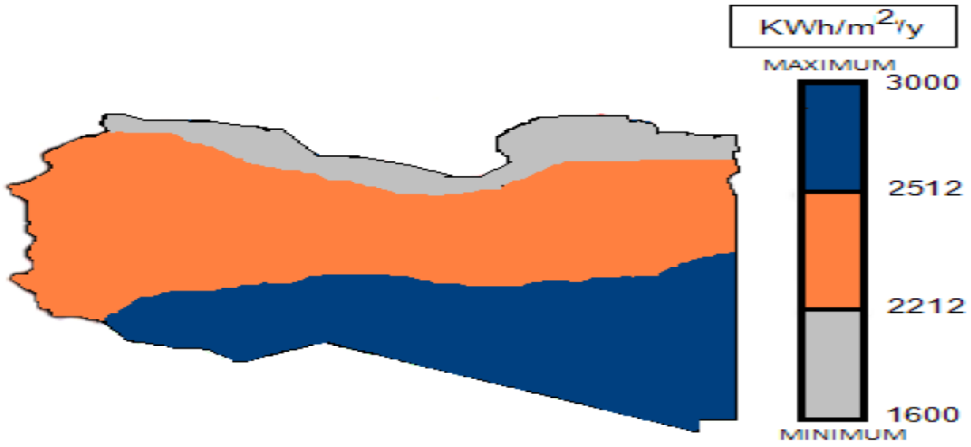


Fig. 7. Estimated average solar energy in Libya in KWh/m2 per year [3].

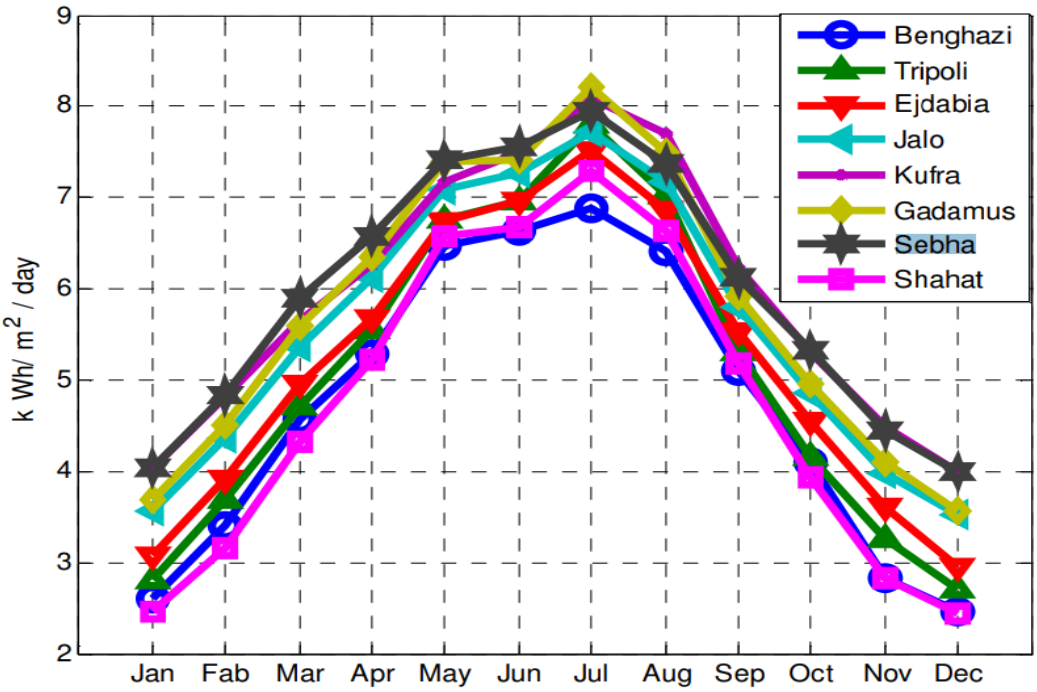


Fig. 8. Solar radiation (Monthly) in some Libyan cities [11].

Moreover, detail has been known from; Regional Centre for Renewable Energy and Energy Efficiency (RCREEE), Renewable Energy Authority of Libya (LEAOL) has established a plan for the first two large-scale PV Plants in Sabha (40MW) and Al-Jofra (14MW), which the Libyan government has Already authorised the land for these projects. On the other hand, there are some disadvantages of generating power from the desert. One of these is that desert zones are often an easy target for to dust storms in the summer, which impact the solar energy system, and to clean and remove it, thousands of litres of water would be requirements

5.2 Wind Energy

Libya has a 1,900kilometer-long coastline in the Mediterranean Sea, which it might be appropriate wind energy resources in this country. Historically, Wind energy has used intermittently in many Libyan oases for pumping water since 1940 [1] [16]. These days, wind power could play an essential role to meet a massive part of required future energy demands. According to the Renewable Energy Central Authority of Libya in 2005, there are a number of the potential wind in the coastal regions which have high wind speeds, the average speed is accounted for around 5 m/s in most cases. Table 3 shows the average wind speed in 5 top Regions in Libya, and also the average wind speed (Monthly) in some Libyan cities is shown in Fig. 9. [9] [11] [17].

Table 3: Average wind speed in 5 high regions in libya.

Region	Speed
Tolmetha	5.9 m/s
Sirt	6.3 m/s
Misratah	6.6 m/s
Al-magrun	7.11m/s
Dernah	7.5 m/s

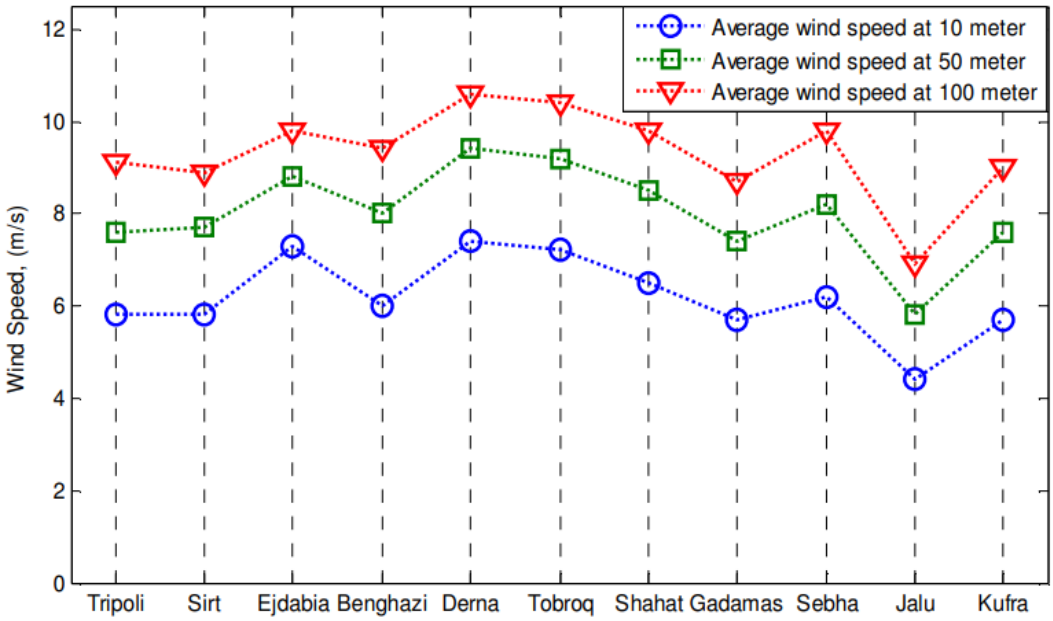


Fig. 9. The average wind speed (Monthly) in some Libyan cities.

It is clear that most potential for wind power cities located in the east of Libya such as Dena & Tobroq. In Addition, "A couple of studies have been performed to implement wind energy on a large scale so that it contributes to the electric energy consumption by a penetration level of 10% in the next few years" [9]. An economic analysis has discussed and performed to convince decision-makers that wind energy has to be one of the commercial sources of Libyan power energy. In addition, wind energy provides a clean source of energy and avoids tons of CO2 and other pollutants, which are emitted when using oil in conventional power plans. Wind energy could play an important role in future energy needs. A couple of studies have been performed to implement wind. There were a plan for the first two public wind projects; Darna (60MW) and Al-Magron (80MW) . However, wind energy has not been invested considerably owing to the fact that the wind turbines require special special company for building, and General Electric Company of Libya is suffering from the civil war [18] and still a dependency on primary energy resources to fulfil its energy requirements [2] [6].

5.3 Biomass Energy

Biomass is considered one of the most commonly renewable energy resources, which used to generate electricity in our present days. This kind of renewable energy uses lower carbon emission and is as emerging renewable power that may meet the growing energy demand in some countries [19] [20]. Biomass is basically fuel, created from organic matter that stores heat as a result of the photosynthetic process. There are two ways to produce Biomass energy; one of them is to generate heat directly by combustion of organic matter, and the second way has generated it indirectly as heat energy by converting organic matter to different sorts of biofuel. Currently, the utilization of biomass energy is limited in Libya due to several factors. One of these is the lack to find and collect these materials since they are utilized as the main fertilizer in Libya. In spite of that, there are several vast landfills that can be harnessed for methane fabrication in Libya. Owing to this, the opportunities for developing biomass energy are theoretically found in Libya [10].

5.4 Geothermal Energy

Geothermal energy is another kind of renewable energy resource, which is the natural heat that is taken from the core of the earth, between water and rocks in the earth's crust. Libya has not yet been analyzed the aptitude for large scale geothermal power generation. Nevertheless, In recent years, one study demonstrated that there is a location near Waddan City in the south of Libya, where has low-temperature geothermal resources, which is estimated to generate (1.3MW of potential) or refrigeration (1284 tons at 5ºC, or 835 tons at 0ºC). Economically and enviromentally, this study is feasible for building a sustinable power station [21] [22].

5.5 Hydroelectric Energy

Libya has a weakly developed hydroelectric power resource in North African countries. Currently, Libya still does not have any real steps to implement hydro-power energy program due to unavailable resources in the country, power production from hydroelectric sources is (0% of total) in Libya. According to the Renewable Energy Authority of Libya, there are some plans to try using the Great Man-made River project (GRMMP) [23] [10] to create a hydropower sector. However, those plans have not yet come to success.

6 Barriers and Challenges to Renewable Energy Development

To ensure energy demands by clean energies and the pressing demand for utilizing renewable energy resources is oftentimes come as a result of barriers and circumstances in other energy supply. Furthermore, the challenges to develop the renewable energy technologies widely are primarily political, the question is why fossil fuel supply is still used to generate power without creating renewable energy resources if it is possible, and interestingly, RE is cheap and clean and compared with primary energy resources. From these features, the application should become cost-competitive in the Libyan energy marketplace. According to (REA), another major challenge is that there are no sufficient investments from the government to deployment this supply. A few years ago, REA still has some plans to need an adequate budget to start generating electricity by renewable energy technologies and contact these technologies to the national electrical grid. However, it is not easy to develop and improve the GECOL from using conventional energy sources to RES if Libya is still suffering from a civil war in general.

7 Recommendations

Presently, Libya has considerable opportunities to make rapid progress in the renewable energy sector, as Libya is considered as the second-highest levels of solar radiation in the world and high average wind speed in many regions. From these truths and be-cause non-renewable energy resources (Oil and Gas) are very limited to fulfil the current and future energy demands, Libya can change the current scenario of its energy sector by using the available renewable energy resources. However, the main development of the renewable energy sector must be by more active ef-forts from Libyan Government; the government must support and implement the studies and research plans and encourage the private sector in the country. The next step to develop using RE must be by improving policy organization. The General Electric Company of Libya (GECOL) should hugely recommend starting independent electricity product, especially solar and wind resources in rural areas; and to invest in the sustainable energy market, which it is important, economically and environmentally. Last but not least, the development of the technical renewable energy sector in Libya must be guided by a skilled workforce.

Of course, in the summer, by the penetration of solar energy (best Libyan RES) may cover a large demand of the load, where, the wind energy will be very sustainable power production in the winter. As the location of Libya near to Europe, the great recommendation for developing Libyan renewable energy resources will not be useful just for Libya; it also will be helpful in the energy market in Europe, it is possible to generate renewable electricity in Libya's coastline or the desert and export it to the European energy market.

8 Conclusion

This work illustrates an overview of renewable energy potential in Libya. Renewable Energy Sources (RES) are considerably obtainable in several locations in Libya. To sum up, solar energy is known as the best potential renewable energy resource in Libya. For wind energy, there are a number of areas that have high wind speeds, such as the coastal regions. The average wind speed is accounted for more than 5 m/s in most cases, which can contribute hugely to the required future energy demands and reduce the dependency partially on primary energy resources (oil and gas) in the country. However, Libya is still weakly developed in using other renewable energy resources such as biomass energy, geothermal energy, and hydropower energy, even although there is highly evidence that leads to building a geothermal power station in Waddan city and also using the Great Man-made River project (GRMMP) for establishing hydropower station. Admittedly, it is so challenging to develop and improve the GECOL from using conventional energy sources to RES if the country is still suffering from a civil war in general.

To conclude, Libyan people should find a way to make their country stable (Security and Political well), and they should continue these sustainable project plans: Sabha (40MW), Al-Jofra (14MW), Darna (60MW) and Al-Magron (80MW). Besides, attract smart local and foreign investors into the Renewable

Energy Authority of Libya (LEAOL) and Libyan renewable energy markets. Honestly, enthusiastic efforts are required from the Government to develop the renewable energy sector in the future.

Acknowledgements

The Authors would like to take this opportunity to thank everybody who has helped me in one way or another during the preparation of this work. We could not have written this manuscript without the continuing confidence and support of Professor Abdalla Idris Fadel and Professor Raed Abd-Alhameed. Thank you for your help and guidance throughout the project, for seeing the potential in me all those months and giving me opportunities that developed this paper for what it is now. Many thanks are also extended to all employees in the Renewable Energy Authority of Libya and in the General Electric Company of Libya GECOL.

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