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Future Study of Renewable Energy in Libya

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Abstract*— Energy is an essential component of any economic development, and electric power is a fundamental indicator of a country's economic and technological progress. Libya is currently wholly dependent on oil and natural gas to produce electricity. In the wake of dwindling fossil fuel reserves, rising costs of this type of fuel, and negative environmental impacts such as air pollution, acid rain, and associated global warming impacts, renewable energy has gained much attention. Libya has a high potential to benefit from electric power generation from renewable energy, such as solar, wind, and biomass energy. In particular, PV technology appears to be the most reliable in Libya's rural areas for its convenient use and economic appeal. Wind energy is an indirect form of solar energy. Between 1-2% of the solar radiation that reaches the Earth then converted into wind energy. The use of wind energy is also becoming competitive compared to conventional sources of energy. Libya has high wind potential. This massive amount of wind is distributed across the country. In 2013, the Libyan government launched the Strategic Plan for Renewable Energy 2013-2025, which aims to contribute 7% of renewable energy to the electrical energy mix before 2020 and 10% by 2025. It will come from wind power, concentrated solar energy and solar PV, And solar heat*.

Keywords*— *fossil fuel, natural gas, Renewable energy, solar energy.

I. INTRODUCTION

Libya is located in the centre of North Africa, with 1,750,000 km2 total land area. One of the largest oil producer countries in Africa, gifted with a 1900 km coastline along the Mediterranean. Its current population is around 6,750,000; most of them live in the coastline area [1,2]. About 88% of its area considered to be desert where there is a high potentiality of solar and wind energy used to generate electricity thermal, photovoltaic, and solar energy conversions. Moreover, it has has been estimated that every year, each square kilometre (Km²) of the desert in the Middle East/ North Africa region receives solar energy equivalent to 1.5 million barrels of crude oil [3].

Libya is one of the primary oil producers in Africa. The oil and natural gas exportation is forming approximately the unique Libyan economic revenue. Most of Libya's industrial sectors depend mainly on oil and gas fuels. The clearest example of this sector is the Electricity Facility, which uses gas and oil to generate electricity to meet the demand for the local electricity market. Like all other countries, the energy demand will substantially increase shortly due to the economic development to build new infrastructure in Libya after the massive destruction that happened during the last four years. This growth in energy demand will result in more oil and gas consumption, which reduces the national economic input and increases the amount of carbon dioxide emission. Therefore, it crucial to start using its alternative energy sources to cover some of its load requirements.

In recent times, Libya has become one of the world's primary energy sources since it is the largest natural gas exporter and oil exporter [4]. Like other countries, Libya suffered from high conventional energy prices, environmental issues, rapid demand growth, and high energy consumption. Libya's primary source of income is oil, and the country depends much on the oil it produces as a significant income [5]. It is worth noting that Libya has a high potential for renewable energies, mostly wind power and solar energy, which can create local jobs, drive local economies, and reduce carbon pollution [6]. However, Libya wants to reduce oil dependence as its source of income through improved natural gas, fisheries, mining, and tourism industries [7]. Libya attempts to use the extensive resources it derives from oil to invest in infrastructures that will support the quick realisation of oil

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dependence as its primary income source. Libya wants to achieve these projects by setting up designs, development, and implementations to support this project's achievement. Also, Libya is planning to make itself one of the most influential economic countries that mediate between Europe and Africa in commercial terms. In recent times, there have been signs that Libya is likely to move towards liberalisation, financial reform, and a decrease in the government's direct role in the country's economy [8]. Libya has many plans to reduce oil dependency as the primary source of income and invest more in agriculture, fisheries, tourism, natural gas, and mining. Diversification is a critical issue since the current production rates indicate that the Libyan oil reserves are less likely to last this decade [9]. Demand for oil resources will significantly reduce if the natural gas, tourism, fisheries, and mining industries designed and implemented effectively. With significant investment and implementation of these industries, Libya will reduce oil dependency as a substantial income source. Other renewable energy such as wind energy and solar energy will help Libya reduce its dependence on oil. These renewable energies will help Libya reduce its reliance on oil as a significant income source if its components are correctly and effectively designed, manufactured, and implemented [9]. This article provides an overview of renewable energy in Libya, particularly solar and wind power research [10].

II. RENEWABLE ENERGY IN LIBYA

Libya is one of the countries blessed with a high potential for solar and wind energy. The government currently produces a power of 33 TWH to meet the demand for the local electricity market. The energy demand will substantially increase shortly, leading to more oil and gas consumption, reducing the national economic revenue, and more carbon dioxide emission. Libya's government aims to use renewable energy to produce at least 30% of its total energy demands by 2030 [11]. To achieve this, Libya set itself intermediary objectives, aiming at 20% of total electricity production from renewables in 2020 and 25% in 2025 [12]. Wind energy utilised for water pumping in many cases since 1940. The use of wind energy has not been developed extensively since the exploration of the oil, and later on the natural gas, the country concentrated on developing these resources and ignored these resources. The wind potential is vast, and it must be exploited. According to the World Wind Energy Association (WWEA), wind capacity worldwide has reached more than 282 GW by the end of 2012, out of which more than 44.5 GW was added during the same year. The amount of energy generated by the wind turbines by the end of 2012 is around 580 kilowatt-hours per year. It represents about 3% of the global electric energy demand. WWEA expects that the worldwide wind capacity will exceed 500 GW by 2016 and 1,000 GW by 2020 [13]. The Center for Solar Energy Research and Studies (CSERS) started its wind energy programmer to assess the wind potential since the wind energy department's development in June 1988.

Wind data from meteorological authority analysed for ten years for 16 meteorological stations [14]. Libya's renewable energy authority (REAoL) started a measurement campaign in 2004 by installing ten wind data measuring stations over the Libyan coast and several stations around the country. The wind data analysis showed that the average wind speed at 40 m above ground level (a.g.l.) is between 6 to 7.7 m/s [15]. A wind farm of 60 MW is under development at Al-Fataih, close to Dernah on the northeast coast. It is the first notable renewable energy project in Libya that should open the door for many similar projects. This project's total cost is estimated to be around $180 million (103 million Euros) [15]. REAoL's plan comprises several wind farms with a full capacity of a little less than 1,000 MW as follow [16]:

• Dernah wind farm (120 MW in two stages); the load factor of this plant estimated at 40%

• Al Maqrun wind farm (240 MW in two steps)

• western region farms at Meslata, Tarhunah, and Asabap (250 MW)

• southeastern region wind farms at Jallo, Almasarra, Alkofra, Tazrbo (120 MW)

southwestern region wind farms at Sabha, Gatt, Ashwairef (120 MW). Libya also plans to develop solar energy power plants and is already working on expanding photovoltaic (PV) technology to remote areas. Small solar energy stations with different capacities are installed in many locations in oil fields. The total installed capacity of PV systems about 240 kWp [17]. The solar regime in Libya is excellent; the daily solar radiation on the horizontal plane goes up to 7.5 kWh/m2 with 3,000–3,500 hours of sunshine a year. The technical potential of concentrated solar power (CSP) in Libya is enormous; it has been estimated at 140,000 TWh/year, equivalent to 27,000 GW of capacity at 60% load factor [18]. The proposed solar energy projects, including PV (centralised and decentralised power plants) and solar thermal technology, are as follow [12]:

• three large-scale PV plants connected to the grid at Aljofra, Green Mountain, Sabha, (5–10 MW each)

• extending the use of PV technologies in remote areas (2 MW)

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• 1,000 PV rooftop systems for residential areas (3 MW)

• feasibility study for CSP plant in an unspecified location (100 MW)

• use of 10,000 solar water heaters

• local manufacture proposed for solar thermal water heating and PV modules

• development of a joint venture with local and foreign investors for the manufacture of solar water heaters for the local and export markets (40,000 units/year)

• development of a joint venture with local and foreign investors to manufacture PV systems (50 MW). The Libyan government view of renewable energy is summarised in table 1 [19].

Table.1: shows the plan for developing RE in Libya.

Strategic Plan for developing the RE in Libya (2013-2025)			
Year	2013	2020	2025
Wind	260	600	1000
Pv	85	300	450
Csp	25	150	800
Total power	370	1050	2250
% RE	3%	7%	10%

III. SOLAR ENERGY IN LIBYA

In terms of solar energy, it could be argued that solar energy is the most important renewable energy resource. Based on data acquired from The Centre for Solar Energy Research and Studies, the average annual solar radiation in some areas in Libya is summarised in Figure 8. Solar energy could be considered one of the primary resources due to Libya's location on the cancer orbit line with exposure to the sun's rays throughout the year and with extended hours during the day. The daily average solar radiation on a horizontal plane is about 7.1kWh/m 2 /day on the coastal region in the north and 8.1kWh/m 2 /day in the South region, with the average annual sun duration more than 3500 hours per annum.

Fig. 1: Average annual solar radiation in some areas in Libya.

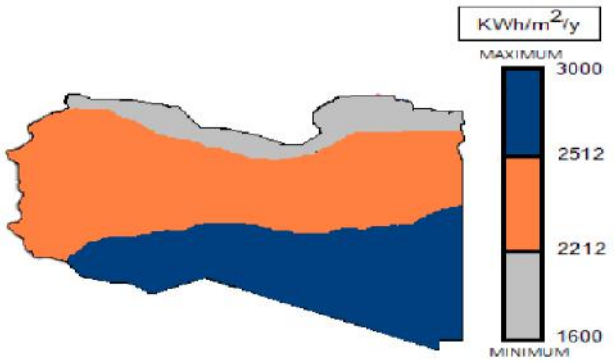

Fig. 2: Estimated average solar energy in Libya in kWh/m² per annum. It concerns wind energy resources.

Fig.3: Shown Libya Construction of 100 MW Solar Power Plant in Kufra Town.

Libya's renewable energy authority stated that the average solar brightness hours are about 3200 hours per year, and the average solar radiation is 6 kWh per square meter per

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day. This will equal = 10 6 × 1.5 / 365 ≈ 4110 barrels of oil per days. Therefore, if we use only 0.1% of the Libyan area, this would lead to (0.001× 1.7 × 10 6), and this equivalent to (1.7 × 10 6 km 2 × 0.001) × 4110 = 6.986 million barrels of oil per day of energy. This number is six times more than the current Libyan production of oil. Therefore, wind and solar energy could provide a good complement to meet peak loads. And this, in turn, can be a good reason for encouraging wind and solar energy projects in Libya [3].

Construction of a 100MW solar photovoltaic power plant in the town of Kufra in southeastern Libya has commenced. The Prime Minister of the Eastern Government launched the project and laid the foundation stone for the construction. The solar project is in line with the 2030 vision of the General Authority for Electricity and Renewable Energy, based in the East, which aims to exploit alternative and clean energies, particularly solar and wind power. The power plant will occupy 200 hectares, and construction has entrusted to a Chinese company. Upon completion, it will reinforce the electricity network of Kufra, which is currently supplied by a thermal power plant consisting of 3 units of 25 MW each. The power plant has been out of service for several months due to a fuel supply problem following the unrest in this North African country. Two of the three units of the thermal power plant have recently been rehabilitated.

IV. WIND ENERGY IN LIBYA

Traditional energy sources in Libya are limited to two sources: oil and natural gas. Studies have confirmed that oil resources will not last for more than 50 years of production, while natural gas is expected to continue for a more extended period in Libya.

A previous study reported that the possibility of utilising wind energy in electricity generation in some locations and connecting it with the national grid is high as in Benina, Sirt, Dernah, and Sebha, and Tolmetha [19]. In contrast, in other areas such as Ejdabia and Sorman, it is more favorable to use wind energy for water pumping and other applications. The data extracted from the Wind Atlas of Libya [15].

In general, the average wind speeds range between 5 and 10 meters per second in the Libyan areas. One of the main advantages of the wind in Libya matches the current and electric power demand in most places [20,22]. Furthermore, Libya is exposed to dry and hot winds, which blow several times during the year [23]. The neighboring countries to Libya have started to utilize the wind resource with different scales ranging from demonstration projects to commercial-sized wind farms, which indicates its feasibility in that region [24].

Table.2. The estimated average wind speed in different Libyan cities.

Location	Average of Wind Speed (m/s)
Ejdabia	2.5-3.0 m/s
Sorman	3.5-4.0 m/s
Benina	5.0-5.5 m/s
Chat	5.0-5.5 m/s
Tolmetha	5.5-6.0 m/s
Sirt	6.0-6.5 m/s
Sabah	6.0-6.5 m/s
Tarakin	6.5-7.0 m/s
Tubruq	7.0-7.5 m/s
Al magrun	7.0-7.5 m/s
Tukra	7.0-7.5 m/s
Jbalzaltan	7.5-8.0 m/s
Al-Fattaih- Darnah	8.0-8.5 m/s

Fig.4: wind turbines.

As far as renewable energy considered, it is not a well-investigated subject in Libya due to the availability of oil as Libya is one of the leading exporters. Although renewable energy, such as solar and wind energy, as discussed above, is widely available in Libya, it remains difficult to break the dependence on oil and natural gas, not only for the power supply but also for revenue to finance community development and infrastructure [3].

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V. CHALLENGE OF USING RENEWABLE ENERGY IN LIBYA

The distribution network of electricity in Libya is expensive due to its vast area, with about 200 scattered villages with population ranges between 25 and 500 inhabitancies and far away from the grid by not less than 25 km [25]. The distributed generation is a new significant tendency in energy systems, which should be considered an alternative to traditional energy production. This concept is marked to prevent power failure, which can be avoided if an area does not depend only on one energy resource. The utilization of renewable energy resources makes distributed systems more feasible because energy can be produced closer to the demand centers, decreasing the need for long transmission lines, and reducing power loss across those lines. The use of renewable energy resources in its simple form of direct benefit for heating water solar ovens, geothermal heat pumps, and mechanical wind turbines, or in its more complicated way of indirect use in creating other energy sources to produce electricity by means of photovoltaic cells and generation through wind turbines, could save the public budget huge funds, as well as providing exemplary service to people, particularly in remote areas [3].

VI. CONCLUSION

The most important renewable energy factors in any country depend mainly on solar radiation, wind, biomass, and geothermal resources. Wind energy can play a significant role in partially contributing to the energy needs and overall electrical energy demand in Libya so that wind energy can be used for various purposes, such as electricity generation, communication systems, and mechanical activities. Solar energy can be used for street lighting, communication system, home electricity, and swimming pool water heating. It will be beneficial for the country to produce electricity at a low cost and provide economic benefits in terms of revenue. This paper can also conclude that Libya has implemented effective strategies for developing its renewable energy. Still, there are different challenges and barriers, such as legal, political, economic, and financial barriers in implementing and developing renewable energy technologies in Libya. These barriers will make the development of renewable energy in Libya difficult, but it can be resolved by effective planning and its execution by the government. The government will have to take initiatives to improve the investors' conditions to invest in these projects to generate solar and wind energy for the country's benefits. For this, the Libyan government will have to provide financial support and remove legal and political issues for the investors to be able to invest in energy projects to a great extent.several plants were decided to build as following: wind farms: Dernah (60 MW); Al-Maqrun (120 MW); Western region wind farm (250 MW); Al-Maqrun, 2nd stage, (120 MW) Large scale PV plant grid-connected in different locations about 5–10 MW; Expanding the use of PV technologies to feed remote areas about 2 MW; PV rooftop systems to supply certain residential areas about 500 designs.

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