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The infrastructure of the Libyan electric grid & the opportunities and obstculs of utlizing solar and wind Energies

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البنية التحتية للشبكة الكهربائية الليبية وفرص ومعوقات استغلال الطاقات الشمسية وطاقة الرياح

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Abstract:
Renewable energy is the headline of almost all countries' development plans. Although there are many challenges facing the Libyan electric grid for utilizing renewable energies (solar & wind), such as lack of required legislation to manage the investment in the energy field and mismanagement in addition to several technical problems, there exist big and real chances. These changes include strong and long-hour sunlight, wide areas for installing solar plants in addition to the long coast for wind farms, and the good possibility of financing renewable projects. The main goal of this paper is to present and discuss the current infrastructure of the Libyan electric grid, particularly its weak and strong points and the most important chances and challenges of making use of renewable energies in Libya, especially solar and wind energies for securing the energy demand and energy security, saving money for sustainable development.

Keywords: Conventional energy, Renewable energy, Solar Energy, Power demand.

الملخص
الطاقة المتجددة هي العنوان الرئيسي لخطط التنمية في جميع البلدان تقريبًا. على الرغم من أن هناك العديد من التحديات التي تواجه الشبكة الكهربائية الليبية لاستخدام الطاقات المتجددة (الشمسية والرياح)، مثل عدم وجود التشريعات اللازمة لإدارة الاستثمار في مجال الطاقة وسوء الإدارة بالإضافة إلى العديد من المشاكل الفنية، إلا أن هناك فرص كبيرة وحقيقية. وتشمل هذه الفرص أشعة الشمس القوية لساعات طويلة، ومساحات واسعة لتركيب محطات الطاقة الشمسية بالإضافة إلى الساحل الطويل لمزارع الرياح، وإمكانية جيدة لتمويل مشاريع الطاقة المتجددة. الهدف الأساسي من هذه الورقة هو عرض ومناقشة البنية التحتية الحالية للشبكة الكهربائية الليبية وخاصة نقاط الضعف والقوة فيها وأهم فرص وتحديات الاستفادة من الطاقات المتجددة في ليبيا وخاصة الطاقات الشمسية وطاقة الرياح لتأمينها. الطلب على الطاقة وأمن الطاقة، وتوفير المال للتنمية المستدامة.

الكلمات المفتاحية: الطاقة التقليدية, الطاقة المتجددة, الطاقة الشمسية, الطلب على الطاقة, طاقة الرياح.

Introduction

Electrical energy is the central base of any social and industrial advancement in any country [1, 2]. Studies demonstrate that there is an unmistakable and solid connection between electric energy utilization and economic growth. Likewise, it is notable that the development level in current cultures is estimated by the normal of electrical power utilization [1]. In light of these realities, generally modern and developing nations work hard to get the essential assets for securing every one of their urban areas and towns as well by electric energy [2-4].
Libya is thought of as one of the oil and gas-producing countries [3, 5] hence, all its electric power plants are utilizing a weighty and light oil or gas fuel, especially steam and gas turbine power stations. In fact, this system brings about expanding the expense of the activity in addition to the climate damages [4, 6-8]. The constant development in the power demand and the expanding of oil costs in non-oil-creating nations, in addition to the ozone issues, are compelling most all countries, including Libya, to look for new, perfect, clean, and economic

electric power sources. Indeed, these nations chose and started to use a variety of renewable energy sources, particularly solar and wind energy, which can provide customers with affordable, clean, and sustainable power sources while also saving the cost amount of oil and gas, which were used to run power plants as an additional budget for sustainable development [2, 5].

Though the Libyan energy strategy includes many projects of sustainable power, particularly sunlight-based and wind projects, there are no truly sustainable power plants working right now in Libya, with the exception of a small solar unit that feeds the remote communication systems [1, 9-11]. This paper explored the Libyan grid infrastructure, the chances and challenges for starting to use and benefit from renewable energy, and the main obstacles and problems facing the real attempt to include a reasonable amount of renewable energy in the electric Libyan grid. The work was done by researching several publications in different journals, conferences, and other information and data sources.

Methodology

This article is based on a review and analysis of some recently published papers on attempts by Libyan institutions, particularly GECOL and REAOAL, to harness renewable energy in Libya. The reviewing and analyzing were conducted based on the idea and view of the author, simply because the author of this paper was working for around three years as a member of the GECOL board; during his work, he led many committees, and he contributed and was involved in many technical and financing discussions. Therefore, he has practical and valuable experience and can make real and accurate assessments. The starting point for benefiting from the huge opportunities in renewable energy, especially solar and wind, is to successfully identify the most suitable and lowest-cost projects to start with. Defining all obstacles and sorting them out and ordering them correctly is also an important key for success.

Libyan Electric Grid Infrastructure, Strong and Weak Points

General Electric Company of Libya (GECOL) is the utility responsible for the entire power framework in Libya. In addition to performing operation & maintenance tasks, its primary functions include power generation, transmission, and distribution for the entire country [6][4]. The utility is entirely the state's property. This present circumstance put GECOAL before exceptionally colossal difficulties: absence of competition, employment inflation, mismanagement, corruption, and lack of transparency. The main and important one of these is the ability to provide all its customers with the right and enough amount of electric power. The available infrastructure of the Libyan grid is as follows:

Generation plants

Due to population density, load centers, logistics issues, and other technical and financial reasons, the vast majority of the power plants are in the north of the country, especially near the beach. The installed power plants are 17, with a complete production limit around 9000 MW [1, 2, 9]. Table 1 represents the installed power plants as well as their capacity and the used fuel types.

Table 1: The Libyan power stations.

No	Plant	capacity	type	Fuel	
1	Alzawia	990	GT	Gas	cc
2	Alzawia	450	ST	Gas	cc
3	Benghazi	1131	GT	Oil	cc
4	Benghazi	550	GT	Gas	cc
5	Misurata	570	GT	Gs	cc
6	Misurata steel	504	ST	Gas	*
7	Tripoli sou	648	GT	Oil	
8	Khomes	600	GT	Gas	
9	Khomes	480	ST	Gas	
10	W mountain	936	GT	oil	
11	Zewitena	770	GT	Oil	
12	Serrier	570	GT	Oil	
13	Derana	130	GT	Oil	*
14	Tobruk	13o	GT	Oil	
15	Sirat,350*4MW	350	GT	Oil	*
16	Tripoli west	500	ST	Oil	*
17	Ubari	460	GT	Oil	
Installed capacity		9309 MW			

Since 2011, in Libya, the demand for electrical energy has been quickly rising [2, 4, 8, 12]. According to [2, 4, 8], many factors are causing this high increase in electric power demand, such as the district's urbanization cycle, economic development, population growth, industrialization process, cultural rules, practices of social life, and the most key factor is the subsidized electricity tariff, all of which contribute to this rapid increase in electric power demand. Based on studies that have been published [8-10, 13], the yearly increase in demand for electric power is around 6-9% [7-9]; figure 1 shows the yearly increase in demand for electric power by the Libyan national grid.

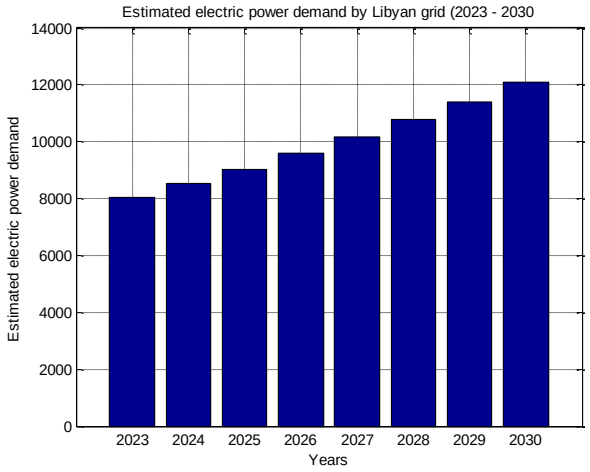

Figure 1: Estimated electric power demand in Libya (2023 – 2030).

As can be seen from figure 1, the estimated demand for 2030 is around more than 15 GW [9, 10]. Based on these estimations, the Libyan grid needs to install and maintain the generation units, which can be used to provide estimated future demand; figure 2 illustrates the yearly-required installed generation capacity for a normal, safe, and reliable grid.

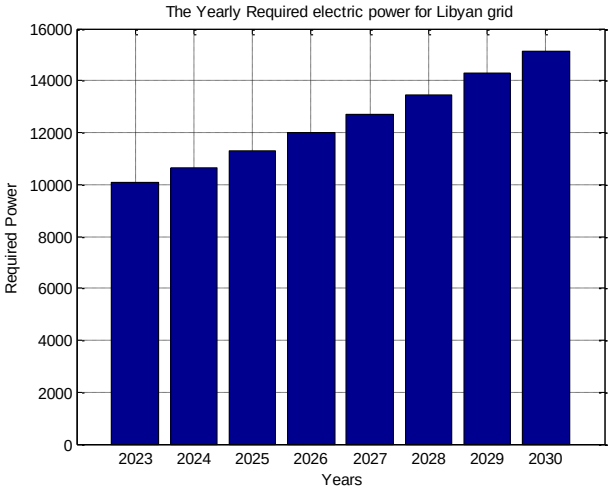

Figure 2: Yearly-required installed generation capacity.

Analyzing the mode of electrical energy consumed in the Libyan grid, the residential sector consumes the highest amount of power. As can be seen from figure 3, the residential sector is the most consuming power energy [2, 9, 13]. It consumes around 36% of the total electric power available in the Libyan grid. The high energy consumption in the residential areas is connected directly to increased use of cooling and warming machines. In addition to residential demand, the street lighting load represents around 19% of the electric energy demand [13]. Based on the facts, the government must find an efficient energy source to overcome the increasing energy cost, which leads directly to a reduction in Libyan national income and increasing CO_2 emissions

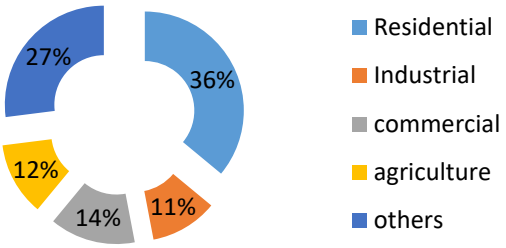

Figure 3: Consumption of electricity by sector.

Power Transmission lines

As with all electric grids, the power plants in various regions were connected with load centers by means of different high-voltage transmission lines. In light of the reality of large regions and fragmented populations in various and far regions, the transmission network confronted and is dealing with numerous issues connected with the activity and support issues. The wide region and dividing loads force the Libyan government to spend a lot of money to save the power continuity for every one of the clients. To cover the annual increase in power demand, which is assessed at around 6-9%, the transmission network with all vital electric power plants stays the main piece of the Libyan power grid. The Libyan transmission power network can be easily divided into three interconnected areas. Figure 4 shows the Libyan high-voltage transmission network.

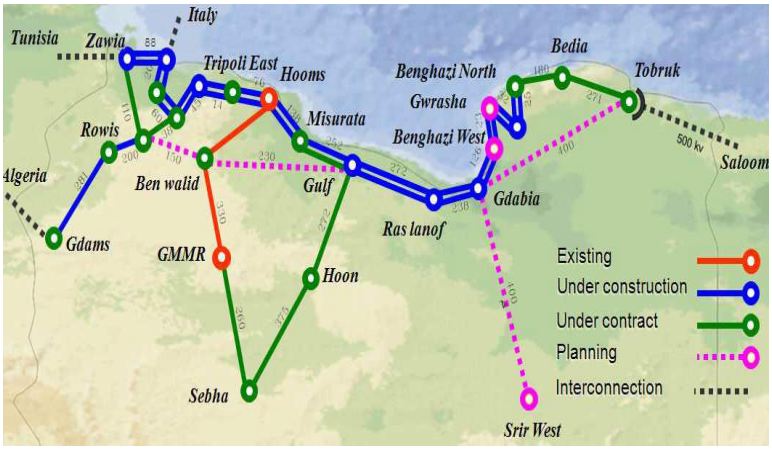

Figure 4: The Libyan transmission network.

The voltage levels that are utilized in the Libyan network as principal power transmission between the producing power plants and the load centers in various districts are 400 and 220 kV, while the power is communicated in every neighborhood locale through 66, 32, and 11 kV lines. It is vital to make reference to the fact that the Libyan transmission network has problems that are connected with the natural impacts, for example, salt residue, wind containing huge volumes of extremely delicate sand… and so on. These problems are causing various faults or even nearby power outages. Subsequently, accurate examinations should be done not just to decrease power outages caused by these faults but also to increase and improve the network reliability. Table 2 sums up the current Libyan transmission lines and their rough length as well as the main substations.

Table 2: Libyan power transmission network.

No	Voltage	Length km	Substations numbers
1	400 KV	2290	13
2	220 KV	13706	87
3	66 KV	14311	195
4	33 KV	11142	461
Total lengths		41449	756

Distribution Network

Distribution networks extend from step-down substations, which reduce the medium voltage (66 or 32 kV) to the main distribution voltage (11 kV), where electrical lines are connected to distribution networks through underground or overhead lines. The voltage (11 kV) is further reduced through the distribution transformers to (380) volts maximum and (220) depending on the type of load. Most of the house loads are 220 V, while the industries and workshops include machines that use 380 V. Many Libyan distribution networks are suffering from voltage drop problems, especially those operating at lower voltage levels and those feeding large loads over long distances at poor power factors. Voltage drops, which means poor voltage regulation in the distribution network, poses an undesirable threat to the operational stability of the distribution system. In addition to voltage regulation, Libyan distribution systems are facing many problems, such as unplanned connections, an increase in technical losses, loaded transformers, and absence of staff training. It is important to mention that GECOL could not be able to restore all its operation and maintenance costs in addition to the required interest, simply because the electric energy in Libya is subjected to a subsidy policy, and many government institutions do not pay for its power consumption. Figure 5 left introduces the yearly average consumption of power in North Africa (kWh/capita), while the right figure presents the cost of kWh in North African countries.

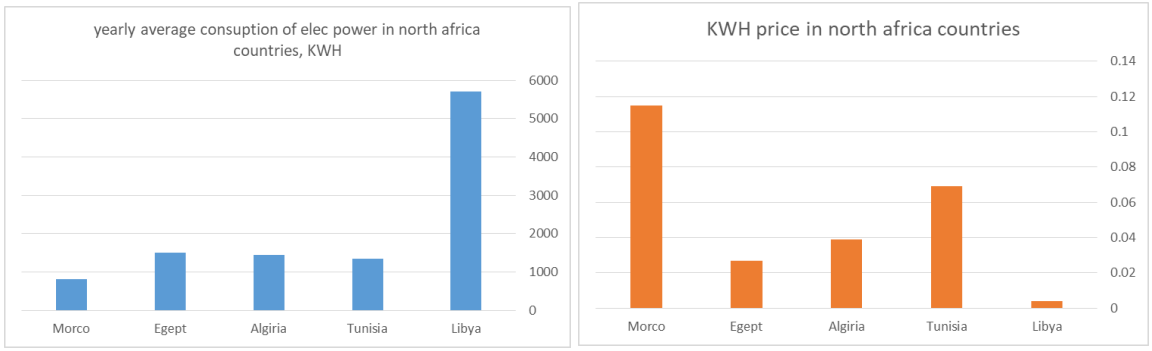

Figure 5: yearly average consumption of electric power in North African countries and its price

The renewable energy in Libya, chances & challenges

Chances

Libya is one of the principal oil producers in Africa; therefore, the oil and natural gas exportation are shaping roughly the unique Libyan income [9]; in addition, it is considered one of the primary sources of energy for most Libyan industrial sectors [2, 9, 13]. The clearest model area for using the oil and gas energy is electric utility, which utilizes gas and oil to produce electric energy to fulfill the country's need for electric energy. As with any other nation, the interest in energy will considerably increase sooner rather than later in light of the increase in using cool and heating services. This development in energy request will bring about additional utilization of oil and gas, which causes a clear decrease in the country's income in addition to increasing the amount and the effects of the carbon dioxide outflow [2, 12]. Consequently, it is extremely critical to begin utilizing the renewable energy sources to cover a sensible piece of the expected electrical energy demand and to save however much as could reasonably be expected the oil exportation incomes for real sustainable development.

The high-centred radiation area and a long coastline on the Mediterranean make Libya among the most advanced countries in the field of renewable energy, especially solar and wind energy. in addition to other renewable sources such as geothermal, biomass, and tidal waves; however, now all these sources have not yet been utilized in proper, efficient ways. The main reason for ignoring renewable energy source is subsidy policy, which prevents the creation and development of any kind of energy competitive market. The view and plan of the Libyan government for utilizing renewable energy are summarized in Table 3. This plan does not include any chance for initiating private electric companies, which leads to a competitive electric energy market, simply because electric energy is not priced according to real and transparent commercial prices but applies a subsidies price policy instead.

Table 3: Shows the plan for developing RE in Libya.

Strategic Plan for developing the RE in Libya (2013-2025)			
Year	2020	2022	2025
Wind	260	600	1000
PV	85	300	450
CSP	25	150	800
Total power	370	1050	2250
RE (%)	3%	7%	10%

- **Solar energy**

Libya has a high opportunity to take advantage of producing and using energy from sun-based sources. Simply because a sun time duration of over 3500 hours of the year As indicated by [1, 3, 8, 11, 12], it has a high capability of sun-powered energy, essentially in light of the fact that the day-to-day normal of sun-oriented radiation is around 7.5 kWh/m²/day [1, 3, 8, 11, 12]. Some researchers estimated that every year, each square km of desert in North Africa receives solar energy equivalent to 1.5 million barrels of crude oil [3, 6, [14]7]. Figure 6 illustrates the average monthly daily global radiation on the horizontal surface. Due to its ease of use and low cost, solar energy, which includes CSP and PV technologies, appears to be the most suitable choice in Libya, especially in rural areas. As per the Trans Mediterranean Interconnection for Concentrating Sunlight-based Power, solar energy in Libya is the most encouraging source. It can give energy around 140,000 TWh each year [1, 2, 4], while wind and biomass have just possibilities of 15,000 - 2,000 TWh each year, individually.

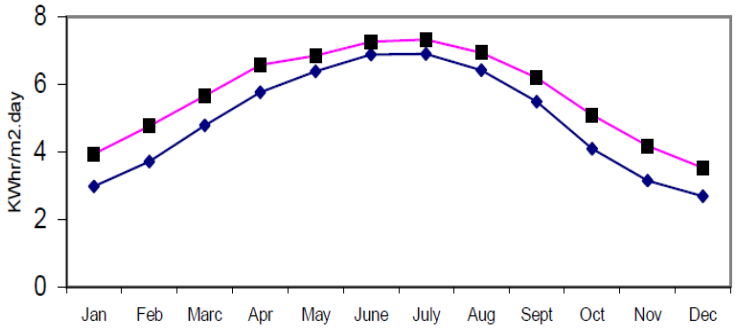

Figure 6: The average monthly Daily global radiation on the horizontal surface[15]

Although, the utilization of photovoltaic technology started early in Libya, since 1976. It was used as a pilot project to supply electricity for a Catholic protection station, a power supply for a mobile communication system, and water pumping in the far distance area [8-10], but it does not have any real and reasonable contribution to the Libyan electric power demand. It presents a very small amount of power, around 0.03% of the total demand. All of these systems generate approximately 1.5 MW in total.

The Renewable Energy Authority of Libya (REAOL) and the General Electric Company of Libya (GECOL) have plans for installing photovoltaic systems in various parts of the country, where GECOL plans to install 340 units for a complete limit of 240 kWp (kilowatts-top) [1, 2, 4], while REAOL likewise pre-prepared all necessary documents and technical specifications for introducing three PV systems, network-associated type. These systems will be installed in the Aljfra, Sabha, and Green Mountain regions [2, 16]. Moreover, both GECOL and REAOL intend to utilize thermal solar for water heating; they are planning to produce around 12% of total Libyan energy needs from solar energy for water heating purposes [2]. Yet the past and present security circumstances obstructed those promising projects.

- **Wind energy**

The Libyan wind atlas indicates that the country experiences winds between 6 and 7.5 m/s [2, 4, 8, 17], which is sufficient for wind power generation units to operate. In view of these foundations, there are a few reasonable destinations along the coast that can be utilized as wind farms, like Dernah, Almagron, Msalata, and so forth. Figure 7 shows the appropriate locales for wind. The utilization of wind in Libya has not been implemented yet except for using this idea for pumping water in some rural areas, simply because it needs continuous maintenance [4].

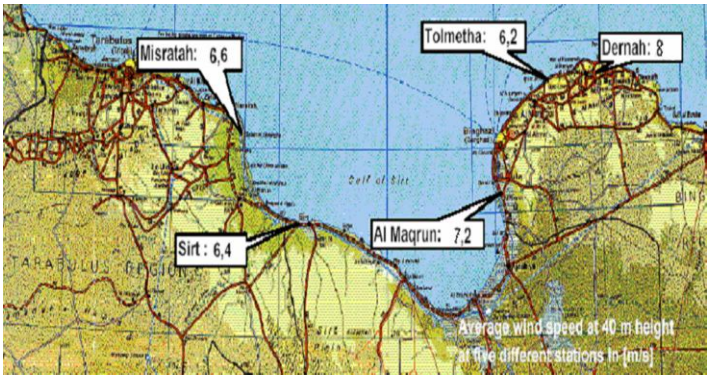

Figure 7: Farms and their assessed speed.

In 2000, a German-Danish consortium signed an agreement with GECOAL to study and build a 25 MW wind farm. In order to carry out a year-long wind condition survey, several suitable locations were chosen and masts were erected. Technical specifications for all components of the pilot wind farm and the tender documentation were prepared, but the project has not been put into practice yet. Table 5 depicts the plan for wind energy projects. The renewable energy development plan for 2008–2012, which calls for the installation of several wind farms with capacities in the range of 1000 MW. However, none of these projects have yet been constructed. These projects were supported and funded by the government [2].

Table 5 The wind projects in Libya.

Cities	Output	Status
Dernah	60 MW	Under construction
Almagrun	120 MW	Awarded
Meslata, Tarhuna	250 MW	Under construction
Southern region	250 MW	Projected

Although in Libya, the renewable energy opportunity includes both solar and wind energy, solar energy is the dominant of these new promising energy sources. Many reasons exist for the suitability of solar energy over wind energy; the most important reason is the possibility of utilizing solar energy probably everywhere, while wind utilization is limited in some specific areas. In addition, the construction, operation and maintenance of solar system is easier than the wind. This important note is not inclusive of Libya, but it sounds valid for most of the countries. Based on the global national strategy that was presented in Figure 8, it shows the higher increment in solar PV energy in comparison with wind energy.

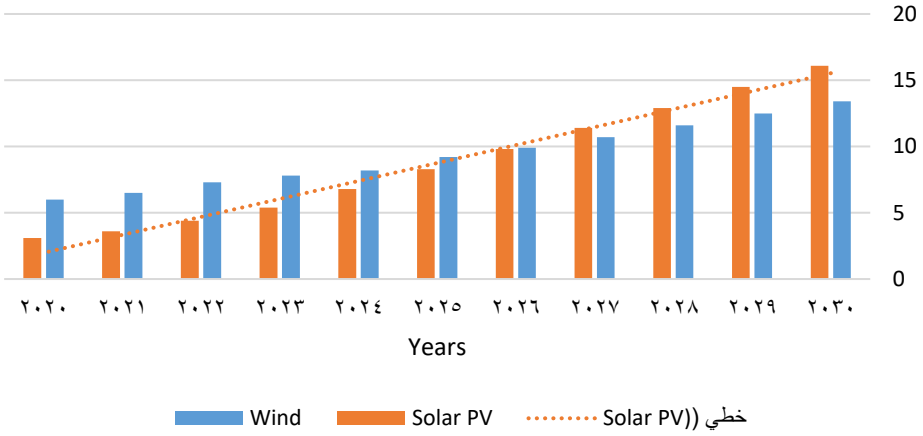

Figure 8: Share of renewable electricity generation by technology, 2000-2030 [18].

Obstacles and Difficulties

As brought up in past segments, Libya as of now depends firmly on oil and natural gas[1, 9, 10, 12, 19]. These assets are not practical and sustainable power. All expectations show that the energy needs are increasing rapidly in Libya for different purposes, which, without a doubt, will influence the oil and gaseous petrol creation by diminishing the nation's income [2, 4, 9]. This large increase in energy demand pushed the energy authority toward a quick and not very well-arranged interest in sustainable energy [1, 2, 9]. In view of the REAOL information, the sustainable power share is supposed to reach 12 % of energy interest by 2025 [1, 2, 9]. That Libya's government aims to use renewable energy to produce at least 30% of its total energy demand by 2030. All proposal projects are mainly solar and wind energy systems. Even though renewable energy technology now is economical, clean, and reliable, it faces many barriers and obstacles. The most important of these obstacles is the lack of competition since all the planned projects are financed by government through GECOL and REAOL companies, which are totally state-owned bodies with no chance for any privatization or competition [1, 2, 9, 19]. According to the Libyan renewable energy sector has been stagnant due to many challenges, such as inadequate policies, limited funding, lack of infrastructure and political instability [5, 14, 19, 20].

Because of subsidies policy, the vast majority of sustainable power projects are postponed or suspended. In addition, the absence of real and accurate field information makes the planning and the decision-making difficult and cumbersome [[14]15]. Moreover, the Libyan renewable strategy is suffering from a lack of good surveys or

detailed studies about the current energy situation and demands evolution in Libya [1, 9]. As soon as environmentally friendly power share expanded, numerous issues could show up, for example, the effect of the sustainable power penetration on the Libyan grid, which has not been investigated sufficiently yet [9].
Because of the all-aforementioned reasons and the lack of awareness and experience in renewable energy technology, this new technology is still viewed by many public and private sectors as suspicious technology.

Conclusion

As a result of economic turns of events and the rising in populations, the interest in electric power will rise quickly in the following years. In view of the way, that Libya has an excellent area, which makes it ideal for deploying sustainable power, particularly solar and wind-based innovation. Libya has a very good chance to put to use off-grid and grid-connected photovoltaic systems, as well as large-scale grid-connected electricity generation using CPS and wind farm systems. According to numerous significant studies in the field of future energy, the quick and efficient use of renewable energy needs suitable and effective energy laws and regulations. These laws and regulations will make and ease the competition in the energy market real and possible. At the same time, it needs good field studies, good planning, and enough funds. Solar energy resources, in particular, can be a great source of energy for the country after oil and natural gas and can be developed to be a reliable national revenue resource; therefore, the electricity sector must be reformed and privatized in order to increase the transparency, decrease the corruption, and attract the private investments. It is also worth mentioning the absence of the practical role of the universities and educational institutions in the field of implementation of renewable energy systems. Establishing good and strong cooperation platforms between electricity sectors and research institutions will positively affect the process of transferring and implementing renewable energy technologies in Libya. Finally, all the active bodies in the field of renewable energy, particularly GECOAL & REAOAL, must cooperate and unify in order to have a common vision, plan, and goals. This important step will strongly help Libya to start the first real and promising renewable energy project, particularly in the field of solar energy.

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