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SOLARNE FN ELEKTRANE U LIBIJI – POTENCIJAL I KAPACITETI

SOLAR PV POWER IN LIBYA – POTENTIAL AND CAPACITIES

Sulaiman MILAD, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
Vladimir KATIĆ, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
Omer MOHAMOUD, Faculty of Economics and Engineering Management, Novi Sad, Serbia

KRATAK SADRŽAJ

Većinu energije proizvodi fosilna goriva u Libiji, a očekuje se da će potražnja za energijom postepeno rasti. Svet je već preduzeo dalji korak ka korišćenju obnovljive energije, tako da korišćenje fotonaponskih sistema povećava pouzdanost, efikasnost i fleksibilnost električne mreže. Imajući dug solarni dan, Libija ima najbolji potencijal za fotonaponske sisteme i to će pomoći da se smanji potražnja za električnom energijom jer se Libija suočava sa nedostatkom energije. PV sistemi povezani na mrežu i van mreže (samostalni) fotonaponski sistemi su opcija za ispunjavanje potražnje i korišćenjem solarne energije. U ovom radu se razmatra potencijal Libije za primenu fotonaponskih sistema. Takođe se razmatraju trenutni operativni fotonaponski sistem i budući pristup.

Ključne reči: Obnovljiva energija, Solarni FN sistema, Solarni potencial Libije, PV elektrane u Libiji

ABSTRACT

Most of the energy is produced by fossils fuel in Libya, and it is anticipated that the energy demand will increase gradually. The world has already taken a further step to utilize renewable energy, hence using PV system increase the reliability, efficiency, and flexibility of the electrical supply grid. Having a long solar day Libya has the best potential for PV systems and this will help to reduce the demand for electricity as Libya facing an energy shortage. Grid-connected PV systems and off-grid (standalone) PV systems both are an option for fulfilling the demand and utilizing solar energy. In this paper, the potential of Libya for a PV system application is discussed. Current operational PV systems and future approaches are considered, as well.

Keywords: Renewable Energy, Solar PV system, Solar potential of Libya, PV plants in Libya.

1. INTRODUCTION

Sun is one of the largest sources of energy the Earth has and it provides enough energy to fulfil all its needs. Solar energy reaches the Earth in eight hours and is equal to 23,000TWy (=201,480 10^3TWh) annually. According to the research total, the final energy consumption of the whole World is between 18.53 TWy (=162,323 TWh) and 20.13TWy (=176,339 TWh) [1]. Therefore, it is obvious that this energy should be used to fulfil the requirement, but its daily limitation (available only during the sunlight) and intermittence urge for specific solutions, like storage and others. Although this is not a 100% efficient solution still it would help to minimize the use of fossil fuels and prevent the negative effects of climate change.

Libya is one of the biggest producers of fossil fuels and it uses them for electric energy generation, as well. On other hand, Libya has a 1,750,000 km^2 area with an average of 5.7 kWh/m^2 of irradiation with almost 3,000 to 3,500 hours of sunshine [2]. As the political situation of Libya in recent years has been unstable, the General Electrical Company of Libya was unable to fulfil the electric demand of the country. The use of oil for producing electricity has also become limited, and even after access to oil is enabled, Libya is still unable to fulfil the need for electricity. On the other hand, the emission of CO_2 is rising and would be dramatically increased if the oil and gas were maintained to be used solely for electricity requirements. Used of natural resources like gas and oil as the primary source of energy directly affect energy prices, rapid demand, growth, environmental problems, and emission of more environmentally unfriendly gases.

Libya's geographic position has one of the best World peak hours for utilizing solar energy and this provides high potential for solving the Libya energy shortage. It gives the Libya possibility to utilize this renewable energy resource to increase some of its load requirements. As the location of Libya is ideal for sun exposure these properties make Libya high prospective and opportunities to utilize solar energy [3,4,5]. Keeping in fact that oil is the basic source of income for Libya, the use of solar energy will also provide lots of jobs and help build a healthy environment. [6]

The use of solar energy on a large and small scale is helping to reduce the energy problem and reduce the emission of gases that affect the environment [7, 8]. Solar energy is converted into electricity using photovoltaic (PV) cells grouped into PV modules or panels. In Libya´s case, it is the most reliable source for open areas like rural areas, remote areas, and other open lands where the sun has full exposure. Along the long coastal line of Libya, there is a possibility to use wind power, also, but roof-top PV systems and other suburban PV plants provide a lot of opportunities for a more reliable power supply and a decrease in losses.

To generate electricity PV modules are connected with a DC-to-AC converter into a PV system and interfaced with an electrical power grid. PV systems may be constructed as on-grid and off-grid [9, 10]. In the on-grid PV system, PV modules produce DC, which is converted into AC by using inverters and directly transferred to the grid [9]. The inverter can operate the PV on the MPPT (Maximum Power Point Tracking), so solar power maximum harvesting is achieved. The system is controlled and interconnected by a PCU (Power Conditioning Unit), which consists of a PV system control unit, filters for smoothing output voltage, and switches. It fulfils the load demand if the power of PV is less than the requirement, also. The PCU is capable of taking power from the utility grid, so the demand is always fulfilled and satisfied. Similarly, if the PV supplies more power than the demand, PCU is capable of handling excess power and it sends it back to the utility grid. The off-grid concept has the same structure as the on-grid one, with the addition of a battery bank and dump load [10]. Battery bank for providing voltages to the load when PV output is lower and it is charged when PV is working on full peak performance. The dump load is used when there is excess power and the battery is full and providing dumping of the excess energy.

This paper aims to give an overview of the potential and actual usage of solar power in Libya for electricity generation. The future possibilities and effects on CO_2 emission reduction are discussed also.

2. ELECTRICAL ENERGY IN LIBYA

2.1 Electric power grid

Libyan high voltage (HV) electricity transmission network is mainly developed across the northern part with some lines going deep to the south. It consists of 400 kV and 220 kV HV lines concentrated into two regions, western and eastern. The western region has a load of 3,300 MW, while the load in the eastern part is 1,050 MW [11]. The total length of these lines is 41,499 km [6]. More details about the HV lines and power network are presented in Fig. 1 and Table 1, respectively. From Fig. 1 it can be seen that the electrical transmission network of Libya is large and widespread, but the whole country is not covered. Moreover, transmission lines faced problems in maintenance and operation, especially in the present time of political instability. Table 1 shows the total lengths of transmission and distribution lines in Libya and the number of respective substations. These data show potential and possible locations for inclusion of the renewable energy sources (solar and wind) into the power system.

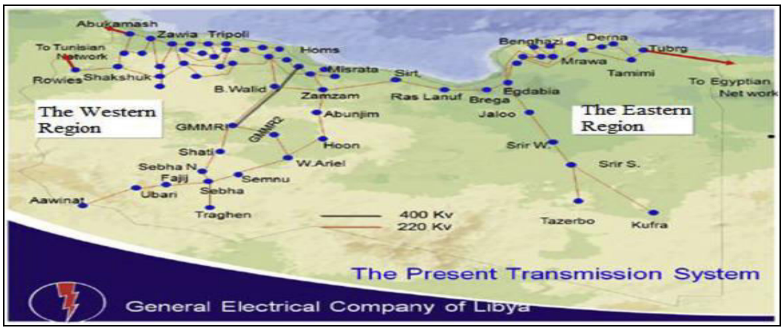

Figure 1. Grid Network map [11]

Table 1. Libyan Power Transmission lines [6]

No	Rated voltage [kV]	Length [km]	Substations number
1	400	2290	13
2	220	13706	87
3	66	14311	195
4	30	11142	461
Total:		41449	756

A variety of data are available for electricity generation and consumption [12-15]. According to the research survey done by the World Bank and according to the global economy organization, Libya's consumption from 1980 to 2018 was on average 15.24 GWh per year and a maximum of 28.49 GWh per year, while total electrical consumption per capita dropped from 3,793 kWh in 2007 to 1,811 kWh in 2014 [12]. Fig. 2 shows an annual increase in demand with a growth of 11.4% planned in 2013 [11], but actual energy generation and consumption have not followed this trend. Fig. 3 shows the annual electricity consumption (left) and net generation (right) [13]. The data from various other sources are different, but on average they are similar [12][14][15].

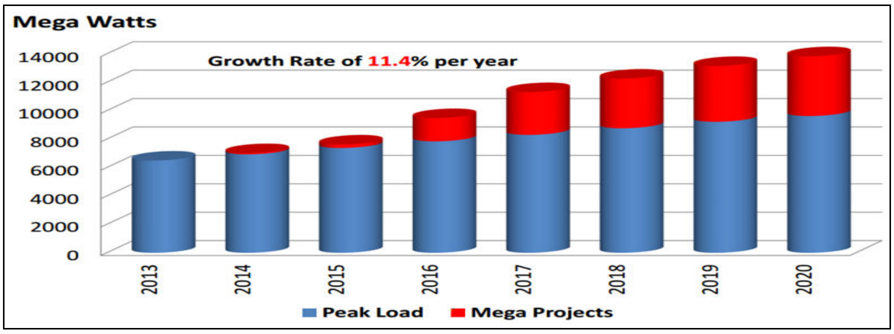

Figure 2. Electricity demand growth from 2013 to 2020 [11]

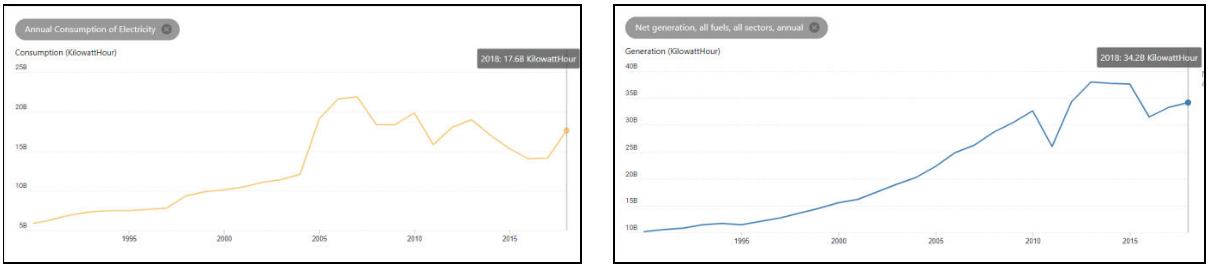

Figure 3. Annual electricity consumption of Libya (left) and net generation of electricity (right) [13]

3. SOLAR POTENTIAL OF LIBYA

3.1 Grid-connected PV data

This section will explain in detail the reading values regarding the generation data for a grid-connected PV system. The data were taken from the PVGIS software and updated on March 1st, 2022 [16]. Fig. 4 (left) shows the monthly energy output per year from a fixed angle PV module of 1 kWp in kWh, while Fig. 4 (right) monthly in-plane irradiation. The graph shows that Libya's yearly average generation is above 150 kW/h and stable over the year. Fig. 5 shows the summary of the solar energy data of Libya to the angle of the array, technology used, losses that the system could face and yearly production of energy, and year-to-year variability due to global warming. Fig. 6 shows the peak hour horizon of Libya and the peak height of the sun in June and December. Fig. 7 shows the irradiance of temperature reading throughout the year, average monthly electricity production in kWh, a monthly sum of global irradiation per square meter, and the standard deviation of the monthly electricity production. All these data show that there is high potential for PV solar energy usage and generation of electricity.

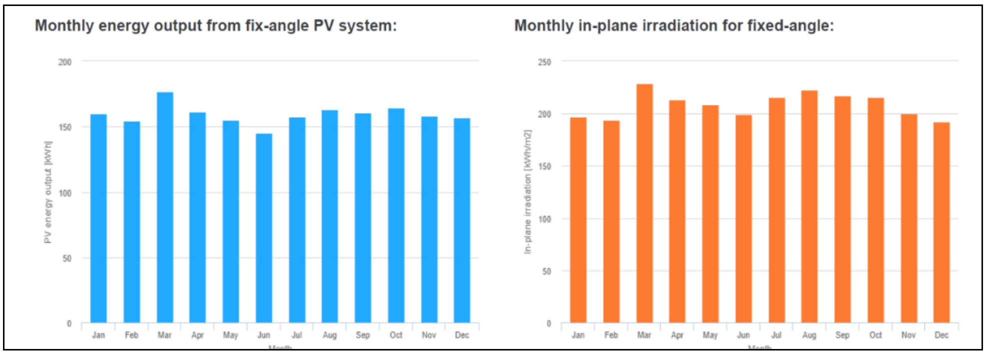

Figure 4. Libya's energy output from the fixed angle of solar panels [16]

PVGIS-5 estimates of solar electricity generation:

Provided inputs:

Latitude/Longitude:	27.448,18.031
Horizon:	Calculated
Database used:	PVGIS-SARAH2
PV technology:	Crystalline silicon
PV installed:	1 kWp
System loss:	14 %

Simulation outputs

Slope angle:	35 °
Azimuth angle:	0 °
Yearly PV energy production:	1913.72 kWh
Yearly in-plane irradiation:	2506 kWh/m²
Year-to-year variability:	28.25 kWh
Changes in output due to:	
Angle of incidence:	-2.59 %
Spectral effects:	-0.05 %
Temperature and low irradiance:	-8.8 %
Total loss:	-23.63 %

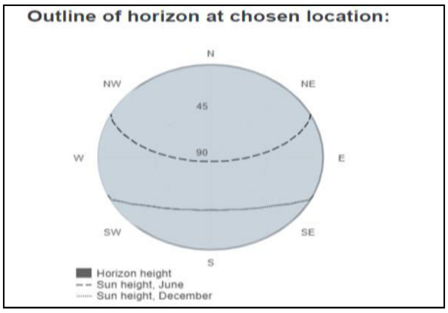

Figure 5. Estimation of solar energy generation in Libya [16] Figure 6. Libya's solar energy horizon outline [16]

Monthly PV energy and solar irradiation

Month	E_m	H(i)_m	SD_m
January	160.3	197.0	15.9
February	154.5	194.2	11.4
March	177.0	228.7	7.7
April	161.4	213.1	7.0
May	154.9	208.8	8.3
June	145.0	199.2	4.4
July	157.3	215.9	1.7
August	162.9	222.9	4.4
September	160.5	217.4	4.9
October	164.4	215.7	9.2
November	158.5	200.5	5.9
December	157.0	192.7	8.3

E_m: Average monthly electricity production from the defined system [kWh].
H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].
SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

Figure 7. PV Energy and solar irradiation of temperature [16]

3.2 Off-grid PV systems

Off-grid PV systems are convenient for remote areas, where the electricity grid is not available, or for micro or nano grids with preferred self-generation. Fig. 8 shows the data of the off-grid (standalone) PV system of Libya [16]. In the design, the main component is the battery as it is essential to drive the load during no grid operation. The values are according to the 600 Wh battery storage and a 50 Wp PV system. Furthermore, the results of the calculation of an off-grid PV system performance are of three different types: Monthly and yearly averages of daily energy production and a monthly average of energy not captured due to full battery (both given in Wh). Monthly and yearly averages of the number of days where the battery becomes full or empty. A histogram of the state of charge (SoC) of the battery is also shown. It can be seen that the generation is stable through the year and that the battery capacity is used in full.

4. GENERATION POSSIBILITY

As Libya's geographical location in North Africa, Libya has great potential for PV systems because of the high solar radiation intensity present throughout the year. Due to the geographic location exposure to the sun during the day is long, and the estimated daily solar average radiation is approximately 7.1 kWh/m^2/day, in the northern coastal area, and 8.1 kWh/m^2/day in the southern region, with an annual average above 3,500 hours of sunlight [17]. The 'Libyan Renewable Energy Authority' has estimated that the average solar sunlight hours are approximately 3,200 hours/year and that the average solar radiation is 6 kWh/m^2/day [18]. According to the survey, the daily/annual average forecasting for solar horizontal irradiance in Libya is presented in Fig. 9 (left).

The global horizontal irradiance distribution over the period from 1994–2018, as has shown the coastal regions (north) have average daily radiation of about 6 kWh/m^2, and the average annual is about 2,264 kWh/m^2. In in-depth south regions of Libya, the average daily global horizontal irradiance distribution is about 7.1 kWh/m^2, although the annual average is about 2,556 kWh/m^2. The forecasting of the potential distributions of solar PV power in the Libya area from 1994–2018 is depicted in Fig. 9 (right) [18]. Hence, in the coastal regions (north), the solar PV systems are estimated to generate power of about 5 kWh daily, and the annual forecasting is about 1,826 kWh. In in-depth south regions of Libya, the daily average solar PV power potential is greater than 6.5 kWh, although the annual average is greater than 2,045 kWh. So, according to the literature and survey in total Libya can produce 900 MW of solar power by considering finance and availability of resources [19].

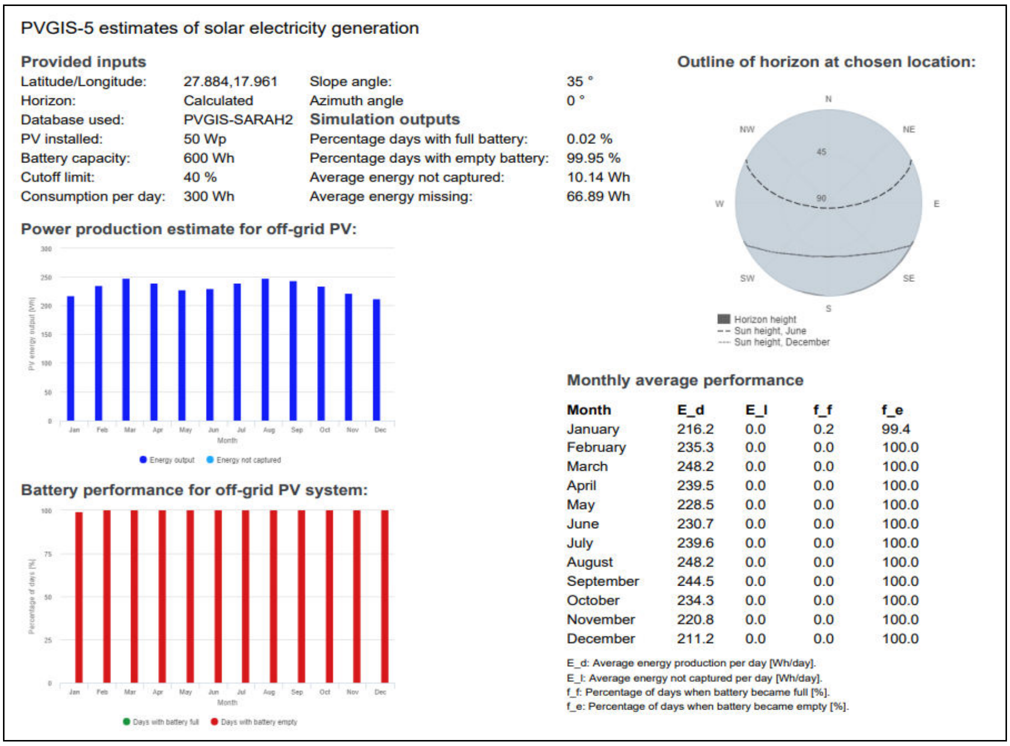

Figure 8. Off-grid solar data of Libya [16]

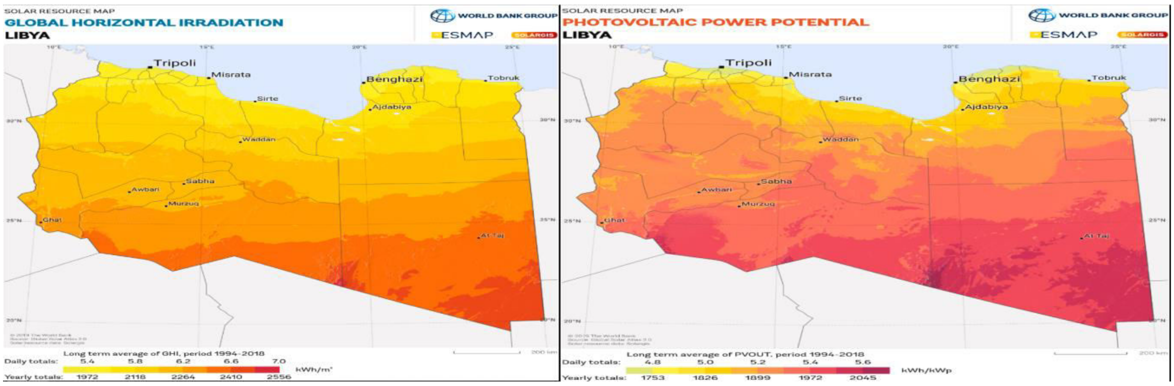

Figure 9. Libya´s global horizontal irradiation (left) and PV potential (right) [18]

4.1 PV Capacity in Libya:

Libya`s renewables wealth gives the ability to diversify its home strength matrix and offer decentralized electricity solutions, with 22% of the country`s strength technology aimed to be derived from renewables through 2030. Such objectives are aligned with 2030 imaginative and prescient of the General Authority for Electricity and Renewable Energy, which seeks to develop smooth strength capacity, especially in sun and wind. While Libya presently produces 33 TWh of electricity to fulfill its growing strength call for, the world calls for a large influx of personal funding and greater supportive regulations from the authorities in fostering aggressive bidding and long-time period electricity buy agreements for renewable builders. The Libyan Government is in talks with builders approximately tasks on the way to lessen hydrocarbon calls for and CO_2 emissions, at the same time as enhancing get right of entry to strength in far-off communities, inclusive of photovoltaic flora with battery storage. In 2013, the Libyan government launched the Renewable Energy Strategic 2013-2025 Plan, which aims to achieve a 7% renewable energy contribution to the electric energy mix by 2020 and 10% by 2025 [20]. This will come from wind, Concentrated Solar Power, solar PV, and solar heat.

4.2 Total energy supply (TES) by source, Libya 1990-2019

Fig. 10 depicts almost 20 years of energy supply from natural gas, oil and biofuels, and waste. As can be seen, oil usage for the production of electricity is dominant and increasing, while generation from renewables is few percent.

Table 2. Libya's energy production vs consumption [20]

Year	Energy Production (TJ)	Total Consumption (TWh)
2010	4,385.673	20.84
2011	1,400.0659	17.74
2012	3636.2	27.8
2013	2,648.5697	30.76
2014	1,529.438	30.63
2015	1,463.7053	30.38
2016	1,418.0692	25.47
2017	2,440.007	26.9
2018	2,916.5249	27.74
2019	3,225.092	27.38

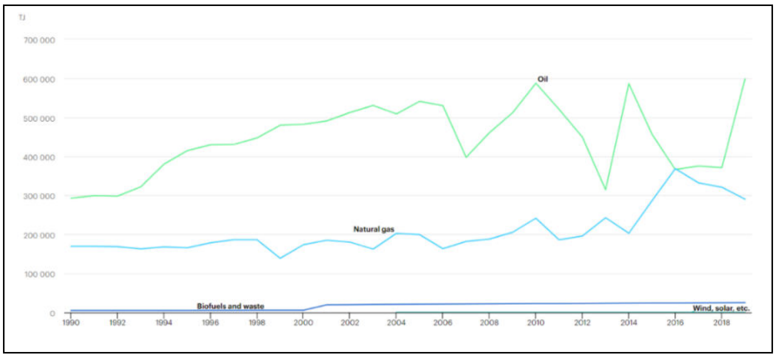

Figure 10. Total energy supply (TES) by source, Libya 1990-2019 [13]

5. INSTALLED PV SYSTEM CAPACITY IN LIBYA

Solar PV energy is already in use in Libya and numerous PV plants have been installed and put into operation. Here is an overview of the most significant ones.

5.1 Bani Walid – 50 MW

In August 2021, the Renewable Energy Authority of Libya (REAoL) announced plans to construct a 50 MW renewable energy plant on 75 hectares of land in the municipality of Bani Walid [21]. The project will be connected to the electrical grid in the municipality and could be subject to additional development and expansion. The primary objectives of the plant include localizing technology, expanding the public grid, alleviating power shortages, and supplying power to the region and network at large.

5.2Kufra – 100 MWp

The construction of a solar photovoltaic power plant is already underway in Kufra, with a planned capacity of 100 MW [22]. Occupying an area of 200 hectares, the plant will help achieve energy security for the local population by fortifying the electrical grid, which was previously supplied by a now out-of-service thermal power plant. In total, Libya is home to daily average solar radiation of 7.1 kWh/m^2 in its coastal region and 8.1 kWh/m^2 in its southern region, along with more than 3,500 hours of average annual sun duration and 140,000 TWh/year of concentrated solar potential.

5.3 REAoL 2,000 MW

REAoL recently announced its plans to implement projects totaling 2,000 MW, [23] leveraging PV technology across multiple stages in the forthcoming years. The projects will primarily use public-private partnerships as the investment vehicle, although some projects with more urgent demand will be implemented solely through state participation. To advance the projects, REAol has requested that other authorities and institutions working in the renewable sector do not interfere and has solicited government support in streamlining processes and procedures.

5.4 Tajoura Solar Power Plant – 62kWp

In the Centre of solar energy and research in Tajoura located near the capital Tripoli 62 kWp PV plant has been installed. The project has been connected to the national grid and will serve the wider north-western region, it helps in reducing the country's power shortage of 1500 MW. The construction of the plant had been led by Alhandasya, a Libyan company that specialized in engineering services, renewable energy development, and electromechanical works and implementation. [13]

5.5 UNDP Solar Power Project for Hospitals

UNDP has installed PV plants for 15 hospitals to fulfil the demand for electricity 24 hours for emergencies. Especially when maternity wards, laboratories, medical stores, etc. don't have enough electricity these PV plants will help out in providing the power. It was estimated that more than 100 kW has been installed in the following 15 hospitals [24]:

1. Tripoli Heart Center in Tripoli
2. Sebha Hospital (Stabilization Facility for Libya)
3. Zintan Emergency and Surgery
4. Ubari General Hospital
5. Abu-sleem Hospital in Tripoli
6. Zintan Obstetrics and Gynecology Hospital
7. Al Gwarsha clinic in Benghazi
8. Rujban Hospital
9. Ali Omar Askar Neuro in Tripoli
10. Cordoba Center for Services in Tripoli
11. Benghazi Al-Kwefia Hospital
12. Benghazi Dermatology Hospital
13. Kikla Municipality (Support to the resilience of local communities' project)
14. Zintan General Hospital
15. Ubari General Hospital – Dialysis

5.6 Rural Electrification PV Plants

In 2003 Rural rectification was started to fulfil the need of rural areas. According to the survey total of 318 small PV system has been installed to supply electricity to remote areas with the total power of 236 kWp [24].

5.7 PV Plant for communication network

As the communication network needs electric power and it is necessary to install a communication network where even electricity is not available. The microwave repeater station near Zella has a total number of almost 120 PV system are running to provide power to the communication network. The total installed power is almost 3 MWp [24].

5.8 Total Energies Grid Connected Solar Projects in Waha – 500 MW:

Total Energies, a French company developed a 500 MW solar power plant to add power to the national grid to facilitate industries in WAHA. According to the memorandum signed between Total energies and the Libyan national electricity company the project will fulfil the energy demand for the industrial sector [24].

5.9 Plant Al-Jofra 14 MW

The national electric company of Libya installed 14 MW of Solar PV in AL Jofra to connect with the utility Grid. This PV plant is providing electricity to Al Jofra city and fulfilling the requirement. The PV system can enhance production by integrating more systems [7].

5.10 Plant Al-Sabha 15 MW

National electric company of Libya installed 15 MW of Solar PV in AL Sabha to provide electricity to the commercial place for fulfilling the load shedding. The system is equipped with all the modern technologies and capable of integration with the main grid. The System has the capability of cascading with further PV systems [24].

5.11 Plant South Green Mount 50 MW

An investment company in Libya installed 50 MW of Solar PV in at south Green mount area to provide electricity to the commercial place for fulfilling the load shedding. South Green Mount PV system transferred the power to the adjacent grid station with maximum efficiency and power with fewer power losses. Electric Power has been provided to the Adjacent area of the PV system [25].

5.12 Roofing System PV Plants 5 MW

Local companies installed almost 5 MW of Solar PV plant to provide the power to the houses directly. Most of the houses in Libya have their own small-scale standalone and grid-connected PV system so that they can reduce the electric shortage on their own. Most of the houses have a standalone system so that they can have full power at night as well [24].

5.13 Rural Electrification 10 MW

In rural areas, small farmers installed almost 10 MW of Solar PV plants to provide the power for watering and farming in the field. As for farming and for watering the plant to use the water turbine most of the farmers have installed their PV system as the power peak time is a day so it is worth full [24].

5.14 PV projects in Libya

Libya has the wide potential of generating power from solar energy, there are operational PV projects that are installed and providing electricity to the grid. But these PV systems are still not fulfilling all the requirements as they have the potential to increase the generation. Some of the active PV systems are as follows.

- 40 MW Solar PV project in Sebha city.
- 14 MW solar PV plant in Hun (Al-Jufra district).
- 100 MW solar PV power plant in Al-Kufra city.
- Other small-level commercial PV plants 100MW

By summing the actual PV power plants available and dividing them by the actual potential Libya can generate, we can calculate the efficiency of Libya's authorities responsible. Total efficiency = 254/900 = 28% (This efficiency is according to the per hour production=. Total generation is shown in Fig. 11 [24]. It can be seen that had high growth, but in the last decade, it is in stagnation and amounts to around 8 GWh.

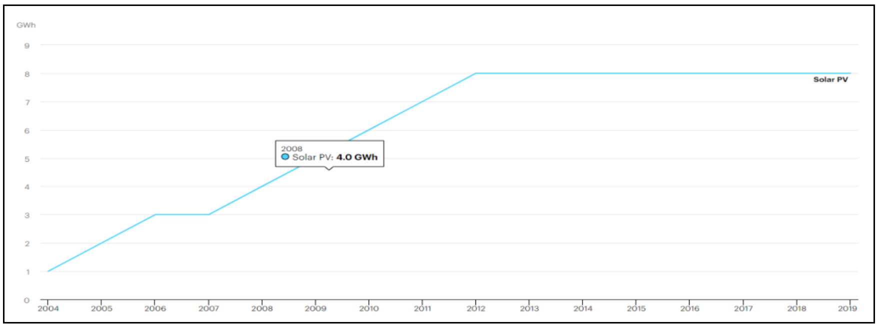

Figure 11. Libya's power generation from 2004 to 2019 [24]

6. FUTURE POSSIBILITIES

General Electric Company of Libya is responsible for electricity generation and distribution. The company has faced and facing a lot of challenges in the distribution and generation of electricity. Libya has the potential to fulfil all the energy crises by utilizing the complete sources of energy. As we discussed renewable energy Libya can be able to fulfil the demand only by solar even without using fossil fuel. The electrical distribution network in Libya is not easy to install and is too much costly because of its wide area and hardness of weather. Libya has almost more than 200 scattered villages with a single grid of not less than 25 km.

6.1. Future Renewable Energy Share

The use of Renewable Energy automatically decreases the use of traditional energy resources that will result in the fewer release of CO_2 emissions. Due to its erratic nature, renewable energy cannot be relied upon everywhere. The hybrid system's overall reliability will decline with the integration of renewable energy. The shortcomings of renewable sources will be made up for by conventional sources when they are combined with renewable sources. The Libyan Renewable Energy Authority has set goals up to 2030 to lessen the country's

reliance on fossil fuels and encourage renewable energy. According to long-term projections, renewable energy sources will provide 25% of Libya's energy needs by 2025 and 30% by 2030. According to Table 3, intermediate goals are 6 percent by 2015 and 10 percent by 2020.
However, covering the load growth and providing the continuous flow of power is not an easy task but by using a PV system this problem can be solved by installing the PV system for every area separately which could help in providing energy, and then long-distance lines can be avoided to transfer power.

Table 3. Energy share of Libya from all sources [11]

2015	2020	2025
6% RE Share	10% RE Share	25% RE Share
750 MW Wind	1500 MW	2000 MW Wind
100 MW CSP	800 MW CSP	1200 MW CSP
50 MW PV	150 MW PV	500 MW PV
150 MW SWH	300 MW SWH	600 MW SWH

6.2. CO_2 Emission

Fig. 12 shows the emission of CO_2 as it can be seen that as fossil fuel use increased it increased the emission of CO_2 gas as well because the demand for energy increases eventually it increases the utilization of fossil fuels and it can be decreased by using the PV system.

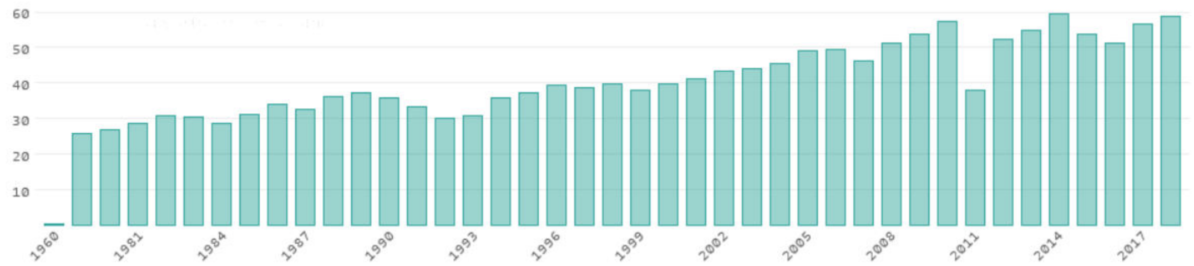

Figure12. CO_2 Emission of Libya [26]

Fig. 13 illustrates the main sources of CO_2 emissions in Libya, which include fossil fuel-burning power plants at 40%, transportation at 22%, manufacturing at 10%, and the rest of the sector as a whole at 28%. Petroleum products account for 58% of carbon emissions, while natural gas accounts for 42% [27]. Natural gas use will become more prevalent, reducing carbon emissions. The expansion of the energy industry over time has boosted Libya's contribution to global CO_2 emissions.

6.3. The PV system in Libya, Chances & Challenges

One of the major oil producers in Africa is Libya. The export of natural gas and oil accounts for the majority of Libya's economic income. The majority of Libya's industrial sectors rely mostly on gas and oil as fuel. Electric utilities, which produce electricity using gas and oil, are the industry that best exemplifies this. to supply the local electrical market with enough energy. Due to economic growth and the need to rebuild Libya's infrastructure following the extensive devastation that occurred over the past four years, energy consumption will rise significantly soon, as it has in all other nations. This increase in energy demand will lead to greater oil and gas consumption, which will reduce national economic input and raise carbon dioxide emissions. Using alternate energy sources to meet some of its load requirements is therefore essential. Libya is one of the countries with a very high potential for solar and wind energy, as well as other renewable sources like geothermal, biomass, and tidal waves, but at the moment all these sources have not yet been utilized in proper and efficient ways due to its location on the high cantered radiation area and its long coastal line on the Mediterranean. Table 4 provides a summary of the Libyan government's position on renewable energy.

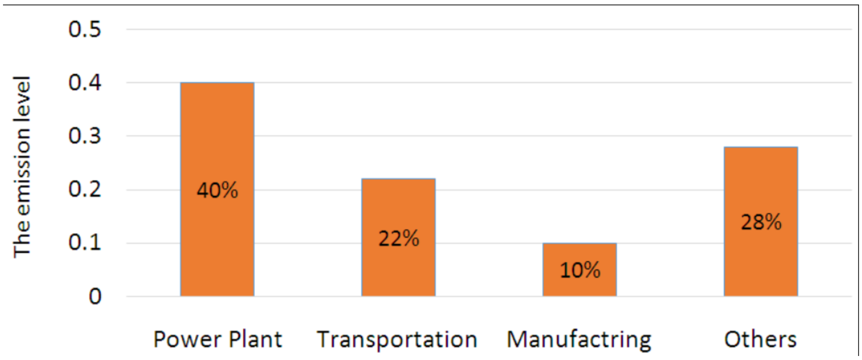

Figure 13. CO_2 Emission by sector [27]

Table 4. Strategic plan for developing the RE in Libya (2013-2025) [8]

Year	2013	2020	2025
Wind	260	600	1000
PV	85	300	450
CSP	25	150	800
Total Power	370	1050	2250

7. CONCLUSION

Due to the continuous supply of sunlight, quiet operation, low maintenance costs, fuel independence of the source, environmentally friendly operating conditions, and a share of low CO_2 emissions, PV systems have higher solar energy resources. Provides the Mediterranean and North African regions. Libya has a great opportunity to build and use a large-scale solar system. In the paper overview of the potential and capacities of the PV applications in Libya is presented. It is shown that there is great potential, but more efforts can be put into further promotion and use of solar PV systems for the generation of clean energy.
In summary, healthy competition between players in this sector and the new PV system production industry needs to be promoted. A solid government strategy in the field of solar energy is essential to support the growth of the PV market. Other proposed future works include exploitation, analysis, characterization of double-sided PV modules, and concentrating PV CPV technology. Also, studies of technical, thermal, and electrical aspects of high-efficiency solar cells/modules/systems are valuable.

8. REFERENCES

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