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Feasibility of solar energy in Libya and cost trend

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ABSTRACT
In Libya, there has a rising need for electricity because of the growing population and development of construction projects. Most of the electrical energy comes from fossil-fuel power plants. Natural gas and oil are the main sources of energy and power stations are dependent on them. Also electricity consumption in Libya is typically high because the electricity sector is subsidised and the gap between the generating real price cost and the tariff cost to the customer is significantly high. It is known that oil and gas are limited and non-renewable resources and the increased consumption of the two resources may lead to a decrease in the country's revenue. Therefore, investment in renewable energy can help address concerns about energy security and future energy prices. Renewable energy including solar energy can be used to generate electricity by photovoltaic conversion. Solar energy by far is the most available in Libya as the average sunlight hours is about 3200 hours/year and the average solar radiation is approximately 6 kwh/m^2/day. This paper aims mainly to discuss the feasibility of solar energy in Libya, a brief overview of solar global jobs and the global cost of PV systems during the last decade.
Keywords: solar energy, Libya, electricity, feasibility, solar radiation.

الملخص
في دولة ليبيا يتزايد الطلب على الكهرباء وذلك نتيجة لزيادة عدد السكان والتطور في البناء العمراني. معظم محطات توليد الكهرباء تعمل بالوقود الأحفوري. النفط والغاز الطبيعي هما المصدر الأساسي للطاقة لتشغيل محطات القدرة. من أسباب تزايد استهلاك الكهرباء هو سعره المدعوم من الدولة والفجوة الكبيرة بين كلفة التوليد والسعر للزبون. إنه

من المعلوم أن النفط والغاز من مصادر الطاقة الغير متجددة وازدياد استهلاكهما قد يؤدي إلى انخفاض دخل البلاد. لذلك الاستثمار في الطاقات المتجددة يساهم في توفير الطاقة وتأمينها في المستقبل . الطاقات المتجددة من بينها الطاقة الشمسية يمكنها توليد الكهرباء عن طريق تحويل ضؤ الشمس إلى كهرباء . الطاقة الشمسية قي ليبيا تعتبر أهم مصدر لأن متوسط الإشعاع الشمسي يصل إلى 3200 ساعة سنوياً وأن الطاقة الناتجة عنه تعادل 6 كيلو وات ساعة لكل متر مربع باليوم. هذه الورقة تهدف أساساً إلى مناقشة الجدوى الاقتصادية للطاقة الشمسية في ليبيا وكذلك دراسة مختصرة للتغير في التكلفة في العقد الأخير والوظائف في هذه الصناعة عالمياً.

Introduction

Libya is located in a great solar radiation intensity area with long sunny hours throughout the day. Therefore, solar energy can be considered the most significant source of renewable energy [1]. This tremendous energy should be used on a large scale to produce electricity through the photovoltaic conversion process. According to studies, the demand for electricity in Libya is experiencing a rapid growth and might exceed 115 giga watts by 2030 which will make high demand for fossil-fuel energy unless alternative resources of energy are used to conserve the energy resources [2]. Libya suffers from electricity cuts for long hours during the day as a result of war and political conflicts. Hospitals have been facing electricity shortage and darkness. Therefore, the United Nations help to install solar photovoltaic systems to specific hospitals as shown in figure 1 , where solar panels system provide a clean, stable and reliable energy supply. The united nation development program was launched in 2016 and the result was reducing electricity bills and providing long–term electricity solution [3]. It has become an urgent issue to exploit solar energy as the climate is shining throughout the year.

Fig 1 United Nations help to install solar PV systems in a hospital

The solar energy was used in Libya in the seventies of last century for the first time. It was used for special applications such as electrification of rural areas, powering communication repeaters, pumping of water and cathodic protection for oil pipelines in remote and desert areas [4]. Solar energy used in the previous applications was mainly photovoltaic conversion while solar thermal application used for heating water.

This paper involves a literature review on the status study of the solar energy in Libya covered different applications of PV systems in cathodic protection (CP) of pipes, communication, rural electrification and water pumping**.** The gained experiences from the study are presented to figure out the feasibility of solar energy. In addition, cost of solar PV systems around the globe during recent years are discussed to find out the cost trend and the future prices in Libya and the world. Finally, solar PV jobs and their number globally are discussed to find the capacity of the industry and the leading countries in this field to follow them.

1 Photovoltaic (PV):

The first application of solar photovoltaic (PV) was in 1976. It was in the oil sector to provide cathodic protection (CP) to pipelines to prevent them from corrosion [4]. The CP stations are usually in desert and far away from the state electric grid. Therefore, it was not feasible to connect from that type of source. A study of cost comparison between grid, solar and diesel shown in figure 2 revealed that PV systems were the most economical choice in distant areas [5]. It is not feasible to use 11 KV electric grid line for a CP (15 KWh/day) when the distance between them is more than 2 Km.

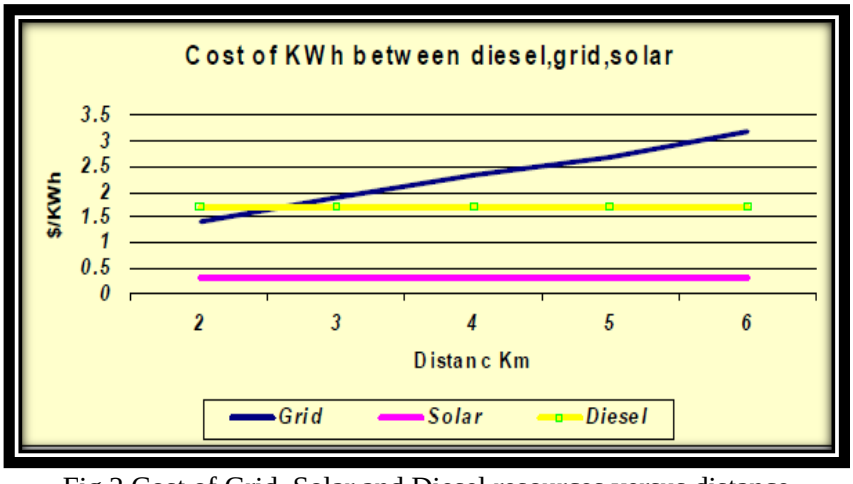

Fig 2 Cost of Grid, Solar and Diesel resources versus distance

The CP stations were used in Dahra oil field and the number of PV systems by 2005 reached about 300 with a total capacity of 540 KWp[5]. The use of PV systems began in 1980 in the field of communication. It supplied energy to the microwave repeater stations near Zella area. In 1997 only 9 remote station were running by (PV) system from more than 500 repeater stations with a total power around 10.5 KWp. Four of the stations worked more than 26 years and their batteries replaced three times with an average life of eight years. This experience revealed the success of photovoltaic systems economically and technically which made a motivation to replace all diesel stations to PV systems in communication. In 2005

more than 80 PV stations were running with an accumulated power about 420 KWp. Figure 3 shows increase of accumulated of PV power in the field of communication during the period 1980-2005 [6].

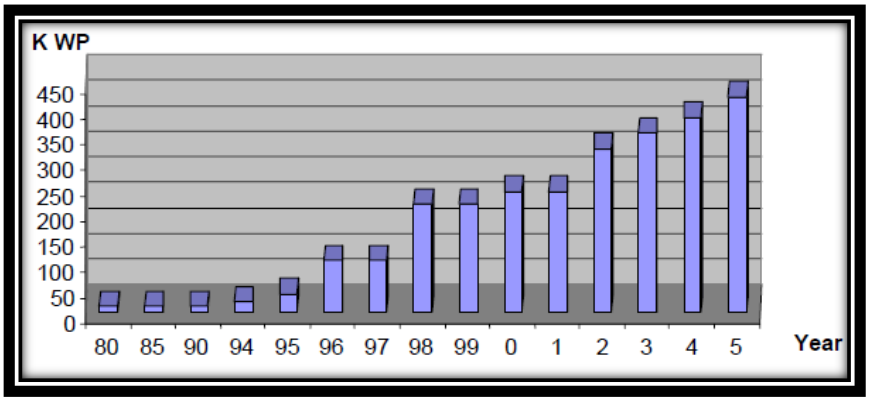

Fig 3 The increase of PV power during years (1980-2005)

The solar photovoltaic systems are also used in rural electrification. All regions of Libya with low populations and being far away from the electric grid are facing of electrification problem. It is not feasible to extend a high line voltage through a very long distance to electrify a few inhabitants. In 2003 the installation of solar PV systems to some rural areas started in Libya . The installation was achieved by the Centre of Solar Energy studies (CSES) and General Electricity Company of Libya (GECOL) with a total power of around 345 KWp. PV systems supplied villages, isolated houses, police stations and street lighting areas [7].

Water pumping was one of the feasible photovoltaic solar applications in Libya which was used to supply water for rural places, humans and live stock from remote wells. In 1983 PV system was firstly used in the agriculture sector, however, at the beginning of 1984, projects of solar water pumping were initiated with a peak power about 110KWp [7].

Furthermore, the start of using water heaters was in 1983. It was used in houses, however, this system has not spread rapidly in all country because there was no information or proper covering from the media at that time and the electric state tariff was cheap.

The experience of solar photovoltaic systems in Libya proved to be cost effective and high reliable because of the following [8] :

- Approximately no spare parts have been used for the installed systems.
- Failure has not happened in the systems.
- Batteries have replaced after about (8-10) years.
- The spread of PV systems can reduce pollution resulted from greenhouse gases.

In 2021, a solar panel car park project was achieved at the Centre for Solar Energy and Research in Tajura area at the east of Tripoli as shown in figure 4. The project was implemented by a private sector Alhandasya company which was funded by the government by supporting both Ministry of Education and Libyan Authority for Scientific and Research. The project was planned to be connected to the national electricity grid with 62KW [9].

Fig 4 Solar panels car park in Tajura area

It also can be designed to be used of the grid independently to generate electricity for different needs.
In June 2022, the General Electricity Company of Libya (GECOL) , France's Total Energy and the Renewable Energy Authority of Libya (REAoL) lunched Sadada solar power plant with 500MW as

shown in figure 5. Sadada area is about 280 km south east of Tripoli [10].

Fig 5 (GECOL) , France's Total Energy and (REAoL) lunched Sadada solar plant

This plant will be the largest solar project in Libya with the latest technological application in the field of solar energy. According to the Renewable Energy Authority of Libya that about 1.2 million solar panels will be used in the project to generate up 152 TWh per year. It is planned that the implementation of the strategic project to reach 25 percent of the generation capacity during the year 2022 [10].

2 Solar Photovoltaic Cost

In the last decade, the trend in cost declines continued of Solar PV systems, in spite of the impact of the global pandemic and the disruptions caused by Corona Covid-19 virus. According to International Renewable Energy Agency as indicating in table (1) [11].

Table (1) Cost decline of renewable energy and solar PV around the globe from (2010-2020)

Total installed cost, capacity factor and levelised cost of electricity trends by technology, 2010 and 2020

	Total Installed costs (2020 USD/kW)			Capacity factor (%)			Levellsed cost of electricity (2020 USD/kWh)		
	2010	2020	Percent change	2010	2020	Percent change	2010	2020	Percent change
Bioenergy	2 619	2 543	-3%	72	70	-2%	0.076	0.076	0%
Geothermal	2 620	4 468	71%	87	83	-5%	0.049	0.071	45%
Hydropower	1 269	1 870	47%	44	46	4%	0.038	0.044	18%
Solar PV	4 731	883	-81%	14	16	17%	0.381	0.057	-85%
CSP	9 095	4 581	-50%	30	42	40%	0.340	0.108	-68%
Onshore wind	1 971	1 355	-31%	27	36	31%	0.089	0.039	-56%
Offshore wind	4 706	3 185	-32%	38	40	6%	0.162	0.084	-48%

The table shows generation costs of renewable energy around the globe have fallen sharply during the past decade, driven by improving developer experience, economies of scale and competitive supply chains[11]. Solar PV systems cost in the world has decreased 85% from 2010 to 2020 .

The growth in solar energy around the world is driven by the dramatic falling in prices, for instance, in U.S.A , the cost of solar power installations has dropped by about more than 60% during the last decade. Subsequently, it is leading solar PV industry expanded to many different new markets and spread thousands of systems nationwide. The figure 7 shows the growth and expansion of PV solar systems around U.S.A and the dramatic fall of their prices[12].

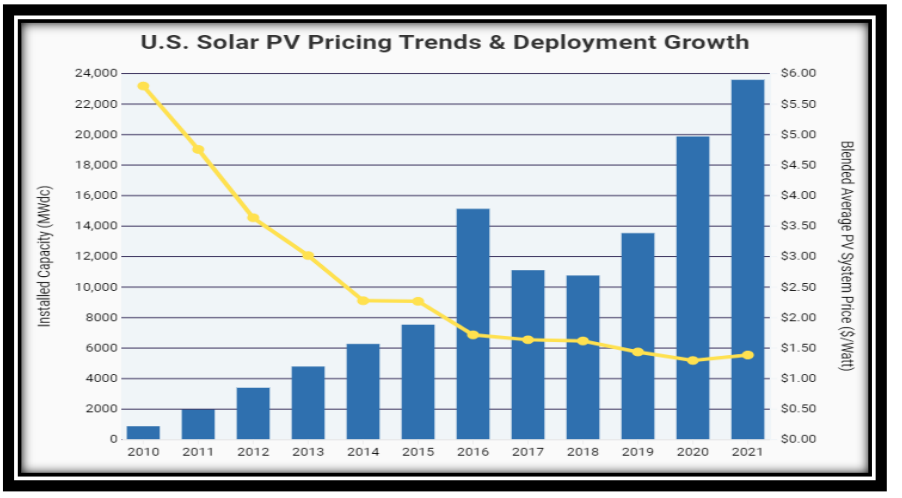

Fig 7 Deployment growth of U.S solar PV and Pricing decline

Despite the cost of solar electricity has declined through the past ten years and the popularity of PV solar systems have risen, capturing energy from the sun and converting it to electricity is still relatively expensive. Furthermore, calculating solar electricity cost is sometimes difficult. It varies depending on the location of installation, the technology is being used and in which country being made. For instance, the situation looks much more different in China, India than it does in U.S and Germany. Figuring out the PV solar electricity cost requires some guesses such as, how long the system will last, the quality of performance and how much sunshine it will get over next 25 years[13], fortunately, in my country Libya, the sun shines for a long hours and its location is optimum for using this technology. A study made by the U.S department of Energy's Berkeley Lab revealed that 'Libya should be prioritised for solar projects as it is one of some African nations which are home to high number of potentially cost- effective sites [14].

3 Cost breakdown of PV solar power

It can be classified into a hardware PV costs, soft costs**,** Marketing and Sales. Hardware costs include all parts needed to construct the PV system such inverters, panels and batteries. Soft costs comprise

installation, warranties and permits. In addition, marketing costs are required to sell the systems.

3.1 Solar PV hardware cost:

Solar PV hardware is expensive as it makes about 25% of the total cost [15], the hardware includes the following :

- Solar panels: they are expensive as semiconductor material used in them requires a great deal of energy and effort to purify it. The most commonly material used in semiconductors is Silicon. However, a new semiconductor material made a thin-film solar cell has lowered the panels cost considerably which was made from Cadmium Telluride[16].
- Inverter: it is one of the most important parts in the solar system and it is a device which converts direct current that solar panel generates to an alternating current and regulate the flow of electricity. There are three kinds of solar inverters, string inverters, centralised inverters and power optimisers. Each panel in the system requires an individual string inverter or power optimiser which makes them more expensive than the centralised[17].
- Battery: it is required for getting an uninterrupted power supply. It can store energy to be used when the sun is not present.
- Mounting system: it is a mounting framework installation used on a rooftop, parking yard or in a large-scale which drives up the cost. It is an essential part and can be equipped with tracking system to increase energy and improve efficiency.

3.2 Solar PV Soft costs:

Soft costs resembles around 55% of the cost of a new solar PV installation which include labour costs, overhead, permits and might be transactions fees and sales tax.

- Labour: the cost for installing solar system varies depending on many factors. cost increases when a rooftop has unusual angles with multiple levels. In some cases, the existing building

electrical system might need an upgrade or modification to make it compatible which also raises the cost. Large-scale solar installations require a great effort and time for a achieving a solar farm which includes clearing large areas of land, removing vegetation, fixing the mounting system and installing solar panels.

- Warranties and permits: in most countries, getting permission and warranties considered to be essential and unavoidable for solar PV system installation which adds to the cost.

3.3 Marketing and Sales:

Educating public about the advantages of solar system on the environment and learning them the possibility to make the solar generated electricity cost-effective. The rise in incentives can convince people to buy solar PV systems and countries to adopt solar energy industry. Marketing and sales resemble about 20% of the total cost[16].

4 Jobs and Solar Energy

Solar energy has a major role to play in the transmission to the low greenhouse gas economy. A key way to reduce these harmful emissions is to switch from fossil fuels to solar and other renewable energy sources. This urgent need to cut carbon emissions make the development of all kinds of renewable energy and solar photovoltaic in particular is essential. As the number of solar installations around the globe continues to grow, there is more demand and opportunity for people to join this industry. Additionally, people who are in this industry can expand their knowledge as solar PV systems becomes more ubiquitous. for instance, In 2020, more than 230,000 American citizens worked in Solar Energy sector in U.S.A with more than 10000 companies in each U.S state[12]. In the previous year 2021, more than 33 billion dollars were generated of private investment in the U.S economy [18].

Figure 8 shows the largest jobs in solar industry are installation and construction-related employment, which representing about 67% of

all jobs in 2020 . Manufacturing jobs resembles around 14% while sales and distribution workers represent 11% , 4% for maintenance and 4% for other jobs comprised finance, research, legal, communication and advocacy workers [18]. Figure 9 clarifies an estimation of solar PV workers made by the International Renewable Energy Agency in 2020 revealed that their number globally about 4 million up from 3.8 million in 2019 [19].

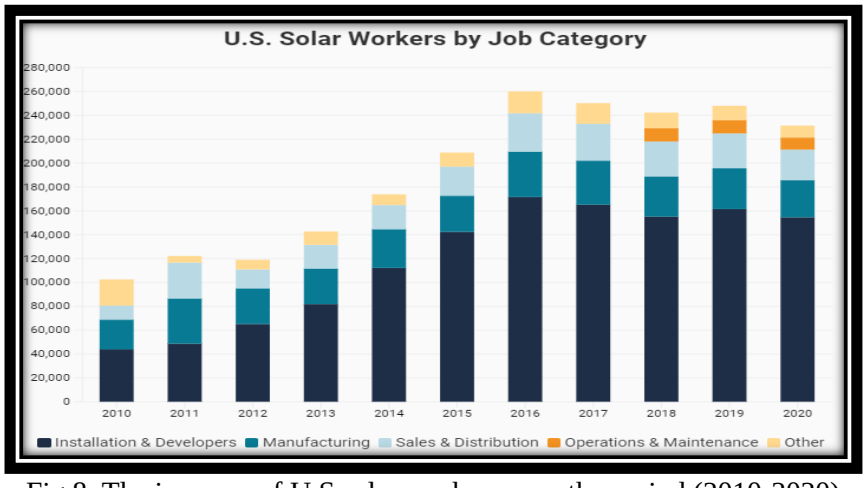

Fig 8. The increase of U.S solar workers over the period (2010-2020)

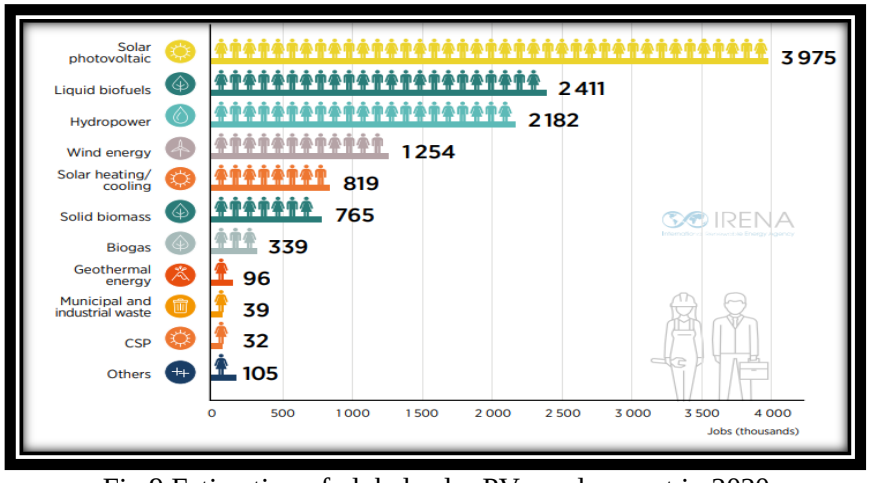

Fig 9 Estimation of global solar PV employment in 2020

The leading ten countries around the world are shown in figure 10, the majority of them, seven are in Asia, one in Europe and two in the Americas.

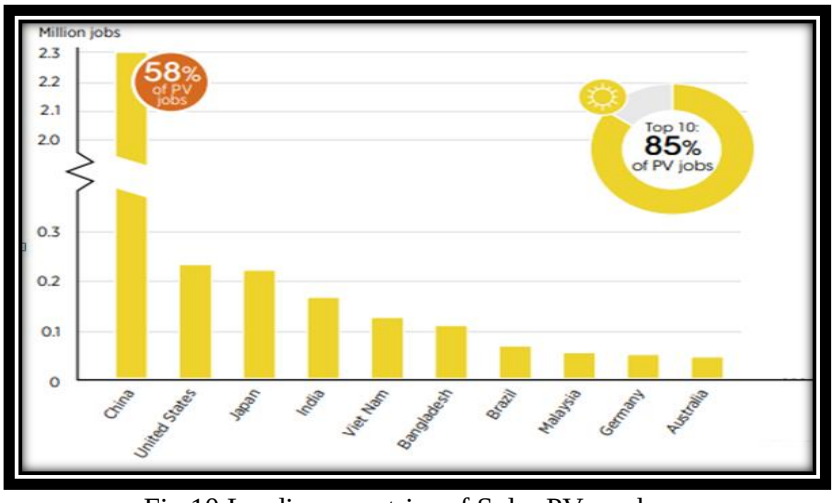

Fig 10 Leading countries of Solar PV workers

The top ten countries represents for almost 3.4 million jobs which is about 85% of the global total [19]. The Asian nations among all countries accounts for 79.4% of the globe's PV jobs, which is reflecting the dominance and strong presence of this region in manufacturing and installations. The number of Libyan solar PV workers is definitely lower than Australians which means low in both state and private sector .In spite of the significant potential of solar energy in Libya, there is no a suitable development and investment in this sector. In summer 2013, the Libyan government should have started a long-term renewable energy strategic projects called RES(2013-2025) [8], unfortunately, these projects have not implemented on the ground due to instability and conflicts in the country. Subsequently, numerous private companies established to invest in the solar PV systems in electricity generation. In the light of electricity outage, Libyan Authorities should have the readiness to bring expertise from the previous top leading countries in solar energy and have the assistance to implement more projects in this field to generate electricity, support private companies, make new jobs and combat climate change.

Conclusion

The perfect climate in Libya where the sun available most of the year with a big area make the solar energy a strategically choice. The solar PV system is quiet operating with a low cost of maintenance, longevity and renewable source of energy. It does not depend on fossil- fuels which participate to decrease carbon emissions. Solar energy is economically needed to preserve oil and gas from high consumption which can cover some of the country's loads. Furthermore, it can be a sustainable, effective, reliable source of energy after the end of oil and gas because it depends on a continuous radiation from the sun and Silicon material for making solar panels and Libya is rich in both of them. the trend in cost of solar PV systems is still declines around the globe since more than ten years which gives an indication that they will be able to compete on large scale in the future. Solar energy development can create more jobs and attract the private sector in this technology. For a period of time 20 years and more, the photovoltaic systems are much more economical than other conventional resources of energy as they need no fuel with low maintenance. There is an urgent need for regulating laws and enhancing the infrastructure to attract investors in solar technology. Investment in this sector offers considerable scope of jobs opportunities in relation to project development, installation and construction. Moreover, the government should make a clear strategy, scheduled plans for achieving new solar projects and also making centres for developing the skills and providing the knowledge required for the private sector for installations and maintenance in order to fill skill gaps and labour shortages in the future.

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