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A brief overview of solar and wind energy in Libya: Current trends and the future development

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Abstract. Libya is one of the oil exporters and natural gas exporters to become one of the top lists of primary energy sources in the world. On the other hand, Libya, like other countries in the world suffers from high energy consumption, high conventional energy prices and environment issues, combined with rapid demand growth. As a result, the Renewable Energy Authority of Libya (REAOL) has been founded to promote the development of renewable energy in Libya to increase the utilization of renewable energy from 6% to 10% by the year of 2020. This study corresponds to a revision of the current scenario of energy resources, provide future potential of renewable energy resources in Libya and implementation of the future projects for the utilization of renewable energy. This study shows that there is huge potential for renewable energy in Libya, especially solar and wind. The Libyan government will have to be more aggressive targets to promotion of renewable energy to achieve environmental sustainability in Libya.

Keyword: Libya; Renewable energy; Wind energy, Solar energy; Energy resources.

1. Introduction

Libya is a country located in North Africa Libya, is an oil exporting nation in North Africa covers an area of approximately 1,750,000 Km² with a 2000 Km long coast [1]. The country has a population of about 6 million, which includes 166, 610 non-nationals. Libya tends to be a significant nation in the Mediterranean basin and the richest in North Africa in terms of natural resources. 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 [2]. Like other countries, Libya suffered from high conventional energy prices, environmental issues, rapid demand growth and high energy consumption. Libya’s major source of income is oil and the country depends greatly on the oil it produces as the major source of income [3]. It is worth noting that Libya has a high potential of renewable energies, especially wind energy and solar energy, which can create local jobs, drive local economies and reduce carbon pollution [4]. However, Libya wants to reduce the dependence on oil as its source of income through improved investment in the natural gas, fisheries, mining, and tourism industries [5]. Libya attempts to use the large resources it derives from oil to invest in infrastructures that will support the quick realization of oil dependence as its major source of income. Libya wants to achieve these projects by setting up designs, development, and implementations that will support the achievement of this project. In addition, 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, economic reform and a decrease in the government’s direct role in the country’s economy [6]. Libya has plans to reduce dependency on oil as the main 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 past this decade [7]. In this manner, the long-term health of the economy relies heavily on maintaining a petroleum sector that is self-sustaining. The agricultural sector has become a top government priority with hopes that the man-made river, a $30 billion project will help tap water from underground aquifers to reduce dependence on food import and reduce water shortage in the country. Demand for oil resources will reduce greatly if the natural gas, tourism, fisheries, and mining industries designed and implemented effectively. Only with effective investment and implementation of these industries, that Libya will achieve its aim of reduced dependency on oil as a major source of income. Other renewable energy such as the wind energy and solar energy will help Libya reduce the dependence on oil. These renewable energies will help Libya reduce the dependence on oil as a major source of income if their components are properly and effectively designed, manufactured, and implemented [7]. This article provides an overview of renewable energy in Libya, particularly the research on solar and wind energy utilization, introduced the results of historical and recent R&D projects with respect to the solar and wind energy utilization in Libya and situation in order to forecast and give advice on development of renewable energy in the future. This helps researchers learn current research status and help decision making. The second part of this article will discuss availability of solar and wind energy in Libya on the basis of an overview of renewable energy development. Then the authors have attempted to promote the public awareness and inspire local government to devote more funds and efforts in the renewable energy utilization in Libya. The third part of this article sets out short and long term policies, and the strategic plans made by Libyan government in the future, implementing of renewable energy technologies in Libya, their barriers and how the Libyan government intends to achieve these objectives.

2. Current energy scenario in Libya

The main sources of energy in Libya are natural gas and oil. Libya, which has an oil reserve of 35 billion barrels by 2005 and approximately 47 billion barrels by 2012 and 54TCF natural gas, is a crucial oil country to European countries. Essentially, oil stands out with the largest total energy primary supply with a share of 66% by the year 2000 although this has decreased in the past few years to 62% consists of 20% of heavy fuel oil and 42% of light fuel oil due to the introduction of natural gas with a share of 38% to generate electrical power as shown in Figure 1 (a). In the next few years, the electric energy demand is likely to increase rapidly with the use of water desalination plants as the main drive for energy [8]. Notably, Oil exports revenues are significant to the country’s economic development since they account for 90% of the total revenue [8]. In 2010, the majority of Libya's oil is sold to European countries. Europe gets over 85% of Libya's crude exports, such as Italy 376,000 barrels per day (22%), France 205,000 barrels per day (16%), United Kingdom 95,000 barrels per day (9%), Greece 63,000 barrels per day (15%), Germany 144,000 barrels per day (8%), Spain 136,000 barrels per day (12%) and others 14.5%. While, the rest goes to China import 3% in roughly 150,000 barrels per day of crude oil from Libya [8]. The United States stated to import Libyan oil with an average 43 in barrels per day in 2004 higher than 2011 with an average 95,000 barrels per day. In essence, Libya’s energy sector plays a crucial role in achieving economic and social development in the country. The total primary energy supply continues to increase with an average annual growth of more than 5% with oil having the highest share and the highest consumption was in oil sector. Electricity covers about 99% of the population with photovoltaic (PV) systems being used to supply electricity to almost 2000 homes in rural areas. In fact, the economy of Libya is unique in the northern part of Africa. While Morocco, Egypt, Tunisia and Algeria have considerable agricultural potential, established industrial bases and large populations, Libya only enjoys a few of such advantages [9]. Libya has a small population and petroleum-driven economy and this indicates that Libya has a similar economy with that of oil-exporting nations in the Persian Gulf state than other North African countries. According to Oil and Gas Journal (OGJ), Libya has largest proven oil reserves in Africa and among the ten largest countries globally. It has total proven oil reserves of 47.1 billion barrels, followed by Nigeria reserve of 37.2 billion barrels in 2012 as shown in Figure 1 (b). Following an increase in oil export revenues, Libya had strong economic growth in 2004 and 2005, with a 6.5% increase in gross domestic product. Despite the economic growth, the rate of
unemployment continues to rise. Apart from that, Libya has an unclear legal structure with arbitrary government decision-making processes and other structural rigidities that tend to impede economic growth and foreign investment. Although the economic uncertainty is still high and the infrastructure was degraded during the civil war, the National Transitional Council is making efforts to develop a new system of governance and restore the rule of law. The past few years have seen a rapid growth in Libya’s power demand such that current plans call for doubling capacity to generate power [10]. In the summer of 2004, the country was hit by blackouts since power plants were incapable of keeping up with the high demand. It is worth noting that in order to meet the surging consumption of power and prevent such blackouts, general electricity company (GECOL), which is Libya state owned, has built several power plants. Most of the existing power stations in Libya have been converted to natural gas and thus new power plants have been built to run on gas in order to increase the volume of oil for export.

Figure 1. (a) Electricity generation by fuel type, and (b) Libya proved oil reserve 2012.

3. Conventional energy resources in Libya

Many countries around the world rely heavily on expensive sources of energy that are limited and dangerous to the environment. Libya is one of the countries that are currently relying on these non-sustainable energy sources, since most of her energy needs are satisfied by oil and natural gas. Most of these energy sources are non-renewable and therefore they are not sustainable. It is estimated that with the current production rate the discovered oil reserves, which stand at 40 billion bbl, will not go beyond 50 years [3]. However, natural gas reserves which stand at 1,300 billion m³ is unlikely to be depleted in the next 50 years. A big proportion of Libya’s energy resources are exported. Future prospects of the energy sector in Libya are not promising if the current trend is continued. For instance, it is estimated that in 2050, the country will be spending approximately 14 billion dollars per year on 70 million barrels of oil for the purpose of producing electricity. By this time (2050), the high demand on oil will have pushed its price to about $ 200 per barrel [2]. With high oil prices, Libya will be in a dilemma of choosing between selling her oil or using it to produce electricity. In the absence of other alternatives, the country might be forced to burn its oil to produce electricity, even at a time when oil will be very expensive. Nevertheless, the country can do away with overdependence on conventional sources of energy and embrace renewable sources such as solar and wind energy. Studies carried out on the viability of harnessing solar energy in Libya indicate that in one year, solar radiation on the land surface are equivalent to a layer of 25 cm of crude oil. The total energy used in 2007 stood at approximately 26 GW and since consumption of energy has been growing rapidly due to urbanization and increased industrial activity, it is estimated that by 2030 consumption will have gone up to 40 GW. Overdependence on natural gas and oil for production of electricity is responsible for the increasing levels of carbon emissions. In 2003, carbon emissions associated with combustion of natural gases accounted for 40%, whereas those from petroleum were found to be 60% [2]. It has also become apparent that the level of emissions can be lowered if the bulk of the energy is produced using natural gas instead of petroleum. Response to the high energy demands led to increased energy-related CO₂ emissions. Currently, Libya’s electric power production capacity is about 4.6- 4.8 gigawatts with a peak load of about 3.3 gigawatts [11]. Most of the country’s power stations tend to be oil-fired although some of them are being converted to natural gas. The peak load of electricity continues to increase in a growth rate from 7 to 10% per
annul. Similarly, the power generation and the transmission network are increasing. This is evident in the fact that the rate of electricity generation increased steadily between the year 2000 and 2005. The trends in energy production also indicate rapid decrease in electricity production in 2006 although the level returned to normal in 2007 and continued to rise constantly in 2008. The year 2006 recorded the least amount of energy produced at 14.4 billion Kwh while 23.98 Kwh was the highest attained in years 2008, 2009, 2010 and 2011. In 2000, the electricity produced was 16.2 billion Kwh and continue to rise steadily up to 23.98 billion Kwh in 2008. The electricity production in Kwh in 2008 was 28667000000.00 while in 2009 it was 30426000000.0 [8]. Between the year 2008 and 2011, electricity production remained constant after reaching the highest value over the years. The annual electricity generated is expressed in kilowatt-hours from the inputs that generate electricity. Likewise, the discrepancy between the amount consumed or exported and the total amount of electricity generated is accounted for as loss in distribution and transmission [12].

4. Electricity demand

There is a sharp increase in the peak load in Libya's electric energy sector. The increase in peak load shows a notable increase from 1992 to 2006 as shown in Figure 2 (a). The increase in peak load within these 14 years is about 2,700 MW, which is a reasonable development within that period. However, it is forecasted that electricity generation will experience a rapid increase in the next years. One very important feature in the forecast is that Libya's electricity generation will be on the increase up until the year 2012. Electricity generated from steam power plants constitutes the highest with about 65%, while heavy oil furs, natural gas, and light oil constitute the remaining 35%. From the forecast, the electricity generated will increase as time goes on; this indicates that there is a high demand for electricity as time goes on [3]. The forecast shows that Libya is going to enjoy a steady increase in electricity generation of up to 8,000 MW in the year 2020. This implies that, there is going to be a boost in Libya's commercial and industrial sectors, where electricity demand will be high. Investment in the renewable energy in Libya has for has a bright future, with effective design, proper planning, as well as constructive implementation of the prospective Libya's renewable energy [3]. Figure 2 (b) shows the electricity demand and consumption in Libya in the various sectors, with the residential area consuming 38% of the whole electricity generated. Agriculture sector uses up 13%. The industry sector use up 14%, commercial activities with 14%, other sectors has 21% such as State offices in Libya use up 14% of the electricity generated, while street lighting use up 7% of the whole energy generated in Libya. The Libyan energy market statistics provide an understanding on the dynamics and key issues that shape the energy market as well as the economy. In order to meet electricity demand in the future, the government of Libya needs to develop a strategic long term plan to ensure sustainability. Energy consumption planning is essential for the country’s development. The roadmap includes increasing the use of natural gas, increasing the share of Renewable Energy sources and adopting energy efficiency programs. A national renewable energy plan has been devised with a target of contributing 10% of the country’s electricity demand by 2050. The population of Libya is likely to grow to 10 million by the year 2050. The current electric power generation of 3500 kWh/cap/y will increase to 5000 kWh/cap/y, while the electricity demand is likely to increase from 20 TWh/y to 50 TWh/y by 2050. Likewise, water, which is currently consumed at 6 billion m³/year, is expected to increase to 10 billion m³/y by the year 2050. In planning for the country’s future in terms of energy use, the government of Libya needs to think about the relationship between the amount of energy produced and the population consuming it. An increase in population is likely to exert pressure on the existing energy resources and thus it will be necessary to produce more energy for the population [13]. Libya will continue to grow each year. The potential impact of energy management and energy utilization efficiency can be significant and this could reduce the demand by approximately 50 million barrels of oil by the year 2020. Apart from that, it is possible to reduce the country’s electricity generation with improved energy utilization efficiency by major energy sectors.
5. Current situation of renewable energy resources in Libya

Libya energy sources currently being used are largely unsustainable. It is predicted that the current oil reserve will serve Libya for the next thirty years but these statistics have not been verified [14]. Even though this is true, the country would need to look for alternative energy sources before the 30 years expires. Libya has been famously known for being a major supply of non-renewable fuel in form of oil and natural gas. However, research has shown that the country is lying on huge potential resources that can be used to generate renewable energy which would be sufficient for domestic use and be exported to countries in Europe [15]. Currently, much of the renewable source of energy is not being utilized. The country uses 42% of heavy fuel, 20% light fuel, 38% natural gas and zero % of renewable energy. One of the potential renewable sources that it could look into is the solar energy. Being a country that receive ample amount of solar energy throughout the year, it can tap a lot of energy from the sun which can be used in the industry and for lighting purposes [16]. This could be practiced on both small and large scale level. It could also tap energy from the wind [17]. The average speed of wind in Libya studied in 2004 was seen to be 12-14 mph at 40m altitude. This is lower than the wind speed of other countries that generate energy from wind. Tides could also be used to generate a small amount of energy [18]. With the current energy crisis and the feared doom of depletion of natural oil, the country has also started exploring ways in which it can obtain energy from renewable sources [19]. The Renewable Energy Authority of Libya (REAOL) has put on measures which to increase renewable energy source use by 2020 to 10% which is currently below 1%. It is targeting to develop various wind farms and other renewable power generation plants which will enable it achieve its goals. The renewable energy sources in Libya are underutilized and form less than 1% of the energy used in the country. The country has used renewable energy in form of biomass, photovoltaic energy, wind energy and solar thermal energy. PV energy is the most popular and has been used since 1976. Currently there are over 100 PV stations all over the country. The PV beside the installation costs involves no further costs. These have been used more in electrifying the rural areas. Solar energy is almost totally untapped except for the solar bond created in 1994 whose purpose has been to desalinate water. Wind energy has been used for water pumping water [20]. The country however has a plan to increase the current use of renewable resources form 1% to 10% by the year 2020. These are the estimated increase by the type of source. This project is expected to cost around 184m Libyan Dinar. Plans are also underway to set up PV plants in three main locations which are projected to produce 45MW every year. Currently, renewable energy is not available to most Libyan citizen. However, by the time the project stated above is completed, all Libyans will be able to access clean energy. This project is intended to be the start of the road towards the transformation of the Libyan energy from then non-renewable form to the renewable form [21]. Although the initial cost is seen to be high in comparison to the price of oil, it is believed by the time this project is completed, the cost of creating renewable energy will have reduced to a cost which is reasonable as a result of technological development in this field. Solar energy is the energy source of with the highest potential [22]. The cost of producing solar energy which equals one barrel of oil is quite
high at around $50. However, it still lower compared to the cost of a barrel of oil which is about $70. Libya is the part of middle North Africa with area of almost 1.8 million square kilometres. Approximately 90% of this area can be considered as hot sunny desert that helps to generate solar energy as renewable source. The sun duration ranges from 3000 to 4000 hour per year. Libya introduced renewable sources for producing electricity because of having a one of the highest solar radiation in the world. It has many villages and remote areas situated far away from the nationwide network. These regions having less population cannot be connected to grid because it demands more cost in spite of need of small amount of energy. In this concern, solar energy has been introduced widely in these remote areas due to its use with ease and being cost-effectively in several applications [22]. According to the MED-CSP (Trans Mediterranean interconnection for concentrating solar power) scenario, it can be predicted that solar electricity will be the most important part of renewable energy sources for Libya till year of 2050 [23]. At present time, there are about 2000 thermo siphon solar water heaters that are placed in all over the country. For this, in 1976, the Centre for Solar Energy Research and Studies (CSERS) has been established that is responsible for research and development of solar water heating technologies [24]. Some appreciable initiatives like solar system projects and programs have been taken by CSERS that helped to aware the people about use of this renewable resource. This technology can be said a reliable source that helped for rural electrification in Libya. In 2007, REAOL has been also established that assists different industries and companies, which produce renewable energy.

Solar energy source is the one with the largest potential for creation of renewable energy in nature. Moreover, unlike other renewable energy sources such as biomass which have some detrimental effects on the environment, production of solar energy has absolutely no known effects on the environment [25]. This is because it does not release any greenhouse gases to the environment. The country is located in the desert and receive adequate amount of solar radiation throughout the year. The amount of solar radiation reaches its peak around June and July (Figure 3 (a)) when the country receives around 7.5 KWhr/m^2 per day and there are no dark clouds to obscure the sun. Most of this land has been left unutilized since it is unproductive. As a matter of facts, the solar radiation in most parts of the country is 2,470 kWh/m^2/day. This is because the country is located at the core of the solar belt. It is also a large country with an area of 1.6 million square kilometre. Research has shown that every square kilometre in the desert can generate energy equivalent to 1.5 Million barrels of oil annually, which is the amount of oil Libya produces every year [26]. This means that if the large percentage of the Libyan land which currently lay unused could be utilized. Most of the oil producing oil is a major hurdle but has to be overcome. In fact the country is planning to tap this energy then export it to countries in Europe. The country has a great potential for solar energy production and is ranked second in the world. It comes second after Algeria which has the highest potential for energy. Egypt which has a lower potential has already started out on a project used to generate solar energy. The other counties like Yemen, Morocco and Syria. What makes solar an important source of energy is the fact that it is available in immense quality, harvesting of this energy has no known effect on the environment either. Furthermore, solar energy can be utilized on small scale by families using small solar panels which are easy to acquire besides the large scale production. The country has shown no effort previously in the harvesting of solar energy [27]. However, with the plans underway, it will be possible for the country to generate enough energy from the sun for domestic purposes and export. Although solar energy is seen to be inefficient since it requires large panels and technology of storage has not been fully established, it is believed that with development of technology, these challenges will be overcome.

Wind energy has not been developed properly in Libya because there is a need of more maintenance timely. Libya is more dependent on fossil fuels for generating electricity. It shows that this country is not secure in energy sector that can affect its economy in future. Due to this, country can also face some problems like exhaustion of valuable non-renewable energy resources, adverse effect on climatic conditions and global warming [27]. In order to avoid these problems, different regulatory bodies decided to include renewable energy as power source. In year 2000, the Libyan electricity utility GECOL with the Centre for Solar Energy Studies (CSES), started to identify the existence of potential renewable energy resources in form of wind energy and construct and develop commercial wind farms to generate electricity economically. In 2004, the wind speed survey was conducted by these authorities.
that indicated about high potential for wind energy in Libya. It raised the possibility of production of wind energy in Libyan coastal areas. In Libya, a contract has been signed to install 25 MW as a pilot project, through which several wind mills will be established and wind energy will be produced in future [28]. Through this project, technical knowledge will also be transferred to the selected candidates, who will work in the field of wind power technology in coming projects. Therefore, main emphasis of this project is on building a wind farm through best engineering experience and giving training to local engineers on the projects. In addition, Libya has contracted another project to obtain the reliable solar and wind data throughout Libya that will allow for analysing effectively the available wind and solar resources anywhere in the country [28]. Both projects aim to prepare and generate wind energy in Libya. For using wind as renewable source, this strategy allows Libya to collect needed information and knowledge that will be beneficial for it further to develop the favourable environment for wind energy production. In order establish wind tower in Libya, some projects were started at different locations. For this, responsible authorities started a research on selection of best sites for installing wind towers to generate wind energy. This project was conducted to collect the wind data available from 16 meteorological stations in Libya at different height levels. This research helped to select proper sites for wind energy projects and to establish first wind farm in Libya. Figure 3 (b) shows top seven average wind speed all time year and month. Wind pattern in Darna is better than other levels in Libya. Wind rose for Darna indicates that north-east coast is favourable for supportive wind conditions. Average wind speed in different months can generate different level of power in Darna. Overall, this location is more supportive for generation of wind energy. These all data were used to describe wind speed distribution through Weibull distribution. In this, the variations in wind speed are determined by the two functions that are probability density function and cumulative distribution function. All data were interpreted through statically analysis that gave appropriate information about a suitable site for establishing wind farm. On the basis above research, renewable energy authorities concluded that in Libya, Darna could be regarded as a suitable place that have high capability to generate wind energy. In Darna, wind conditions were optimum for production of wind energy. It was obvious from data analysis that in Darna, average wind speed was recorded 9.8, 10.8 m/s at height of 50,100 meters respectively. This wind speed pattern was most favourable among different locations in Libya. With this, at that location, mostly, wind flows from north east coast to south-west coast, so, Libya has started to construct a 61.75 MW wind farm at Al-Fetaih, near Derna on the north east coast. It is also estimated for installation of a power plant in Libya in two stages that for construction of a power plant consisting of two wind farms of 60 MW, total installation costs will be 103 million Euros. Cost of wind tower depends on the plant size, height, capacity, etc. In addition, this country has also planned to start other wind projects at different regions like south eastern and south western regions due to having good conditions [29].

6. Renewable energy action plans

REAOL was founded to promote the development of RE in Libya. A goal has been set by REAOL to reach 10% of the energy supply from renewable energy resources by the year of 2020 as shown in Figure 4. Although Libya has a great potential for production of energy from renewable sources, not much has been done to utilize this energy formerly [30]. However, since the year 2006, the governments have developed a plan that is expected to see the country increase its production of energy from renewable sources from less than 1% to 6% in the near future. This would include construction of several plants to tap energy from the sun and the wind [50]. This would comprise the construction of several wind farms.
expected to generate a total of 750 MW, PV centre should generate 50MW and solar heaters which should generate 100 MW. This is anticipated to be realized through increased government spending in this area. The government plans to use $52.7 billion on this project in the 2012 budget alone [31]. The plan would be executed by development of four wind farms in several stages, creating extensive PV grid system in different location including the remote areas and expanding the solar heating factories by encouraging outside investors to invest in these projects. The government also plans to increase the demand for renewable energy by implementing the national program that promotes the use of solar heating systems in the residential areas. By the year 2020, the country plans to have expanded the renewable projects set up to increase the utilization of renewable energy from 6% to 10%. This means that the country will have promoted a wide based solicitation of renewable energy through various forms. The government therefore plans to utilize the renewable energy sources to their full potentiality by the year 2050 in order to satisfy the energy requirements of the country and still export the excess energy. This means that by 2050, Libya will be using the renewable energy more that the fossil energy a reverse of the situation as it is now. Since the country has been a supplier of fuel to other country, it wishes to have developed its renewable energy industry to produce enough energy for export to Europe through the use of undersea cables. In line with this thought, the country unveiled a $3 billion plan and contracted Abu Dhabi’s Al Maskari Holdings in December 2010. This corporation is mandate to create an energy hub meant to supply domestic energy needs and have the ultimate goal of supplying energy to Europe through the Mediterranean. The project plans to incorporate renewable energy and conventional sources of energy such as natural gas and utilize the high-voltage subsea transmission line connecting Libya and Italy [31].

![Figure 4](image)

**Figure 4.** Renewable energy authority of LIBYA action plans.

7. Process for implementation of renewable energy technologies in Libya

For implementation of any renewable resource project, it is very necessary to recognize applicable stakeholders and possible project locations. After identifying stakeholders and potential projects, they should be engaged to ensure protection of area or location, full utilization of resources and good decision making [32]. On the absence of needed requirements after appropriate review, lawsuits may be taken or work orders can be cancelled. It is required to estimate the cost and determine funding options before starting work on a solar project. After fulfillment of these all requirements, the project can be implemented. To evaluate the effects of the project can be a beneficial approach to enhance the success rate of such projects in the future. The Middle East and North Africa (MENA) regional renewable energy project provides different opportunities for Libya country to develop its CSP (centre solar power) technology at wider scale. In this concern, Libya has conducted a feasibility study to select a site for a 50-100 MW CSP plant. There are different locations in the country that provides good solar conditions for establishment of the solar plant. The Tripoli is selected to establish a CSP station due to good solar energy conditions. It provides the daily solar radiation with great intensity for whole year [33]. This project is planned to perform in two stages, first is related to launch of its first CSP Plant of 100 MW and second is related to export its power to the Europe. The stakeholders are GECOL, REAOL, CSES, Ministry of Planning & Finance, Libya, Spanish Abengoa Solar Company, energy savings performance contractors, property owners, environmental groups and local government. Among them, REAOL and Spanish solar company Abengoa are major stakeholders that have made a contract for establishing CSP plant in Libya country [33].

The response has been positive to the solar project by the public, community, solar installer and the governing agencies. Stakeholders will be engaged throughout the project. The engagement process will be based on the project objectives and interests of the stakeholders. It will be maintained through
establishing good communication network with the stakeholders and conducting meetings related to needs and requirements of the project [34]. For this, a technical agreement has been made by REAOL with Spanish company (Abengoa), which will install CSP plant in Libya. This company is engaged through the Clean Technology Fund in concern of the funding. With this, it is required that a portion of production should be met by renewable electricity supply [34]. Green certification process is part of accountability to maintain renewable energy facilities. Apart from this, there is need of a long-term power purchasing guarantees from the government that can reduce the cost of installation. Local government will have to engage in this project by providing supportive schemes like tariffs and subsidies [35]. In addition, a contract will have to be made with property owner because installation of a solar plant needs a large land. All the legal requirements will have to be fulfilled while making these contracts with different stakeholders [36]. In this project, some review processes will be required to follow. It will have to be ensured about the environmental protection processes. Surroundings will be protected by preservation or conservation ways that will support the guarantee of green energy production [37]. Requirements will be relevant to codes for local and national requirements, electrical codes and environmental goals. Contracts will be made under the control of legal authority that will avoid future conflicts between manufacturing company and regulatory boards. Review of availability of needed resources will be required that will give assurance for continuous supply of resources for establishment of plant in future. With this, it will be also followed that by which source, funding requirements are being fulfilled like grants or incentives or third-party financing agreements. Agreements can be in form of an Energy Savings Performance Contract (ESPC), Utility Energy Services Contract (UESC), or Power Purchase Agreement (PPA) that will be reviewed properly [38]. All legal formalities and codes are followed or not that will be reviewed before implementing the project. It is necessary to review the requirements of all authorizations, laws, acts and orders and funding options before beginning of the work on this project [32].

It is estimated that 50% of the funding can be arranged from traditional financing sources and remaining can be collected as soft loans, grants or other support schemes. The major funding source for this project is the Clean Technology Fund (CTF) that can provide about 10-15% of the capital cost same as other North African countries. The CTF Trust Fund Committee uses some criteria before funding like potential for greenhouse gases emissions savings, cost-effectiveness, capacity to demonstration and implementation of the project. Other major sources of finance will be World Bank Group (WBG) and the African Development Bank. These organizations are more committed towards this program. The World Bank Group and the African Development Bank also has collaborated with other donors for launching a program to scale-up CSP in this region. Other sources may be bilateral aid agencies and support schemes launched by government. On the basis of per unit cost, currently, CSP is highly expensive than other renewable resources like wind. With the help of scale up, expected cost will be reduced in coming time. Initial capital cost is estimated between $4,500 and $7,150/kW that is a big investment for this country [39]. Total cost to establish a solar tower of 100 MW will include costs for tower, owner and labor costs, engineering and site preparation, thermal energy storage, power block, receiver system and heliostat field [40]. It can be expected that total cost for this plant will be $978 million, in which costs for the solar field and receiver system have a large portion while the thermal energy storage and power block costs are as a little part [40]. In addition, operating and maintenance costs like replacement of receivers and mirrors, mirror washing, etc. will be significant. It is also estimated that operating and maintenance costs will be approximately $0.04/kWh [41]. It is necessary to implement the project in proper manner. All requirements for this project should be provided effectively. The project will be ready to be implemented after identifying project location, technology and size. All stakeholders previously mentioned will be engaged and all requirements will be considered before implementation of the project. For manufacturing the plant, all workers and engineers will be guided by project manager to perform different production and operational activities in this project. In this concern, documentation for all activities will be required on daily basis. Project should be completed on time and within the budget estimated. Moreover, there will be requirement of managing the information and providing updates to different authorities on progress, future work and any conflict or issue [42]. After construction, governing authorities will inspect the quality of the work and system. The
installing company will fill all needed applications and documentation and all paper work will be reviewed. Any enquiry will be answered by the company regarding the plant installation. It is forecasted that solar energy equal to one barrel of oil from this project would be collected at a cost of approx. US$ 50. Moreover, this cost is expected to fall to around US$ 20 in coming years [35]. Therefore, it can be said that cost efficiency will come with the time and advancement in technology. It is because the cheaper technology will support to reduce the plant cost in the future. Decrease in oil supply and raise in oil prices would make this project more feasible. It is expected that it will make available cheaper energy than other resources and will not have a negative impact on the property and environment. It will generate renewable energy in the form of electricity that will be beneficial for the rural areas of the country. Additionally, it will generate more jobs by CSP investments in this country. After generating electricity through this project, country can be able to provide this energy to European countries that can be proved as its large revenue source. The drawback of the project can be related to the initial cost of the project. There will be a possibility that this project would not cover its initial costs.

8. Barriers of implementation and development of renewable technologies in Libya

Libya, being a country which is predominantly an oil producing nation, has many policies and regulations that favour this trade. Unfortunately, this works against the development of the renewable energy sector. The existing national policies in Libya are focused more on the contemporary sources of energy which has been given major incentives [30]. In order to promote the renewable energy sector, there is need to evaluate the regulation laws and policies and energy and develop new policies that favour the renewable energy industry. The lack of balance in regulation regarding energy can make the penetration of the alternative sources of energy to the market hard. The government of Libya has subsidized its oil for the domestic market so that the citizens can access fuel at lower prices. This works at the detriment of the alternative sources of energy which, because of the high cost of production, are more expensive and can thus not beat the price of oil. A major challenge that faces the renewable energy sources is their intermittent nature. Solar energy and wind energy can only be tapped at specific times and may not be available at other times. This increases inefficiency since the energy cannot be tapped at all times. Geothermal power, although continuously available, faces major challenges in energy storage and management of the facilities. Technological development in renewable energy industry is still at its juvenile stage which explains the existence of the myriad technical challenges. The projects related to renewable sources also take long to be implemented as some of them are untested and require pilot projects to be conducted first. This, coupled with the problem of corruption, hinders the speedy transition from non-renewable energy to renewable. Most of the organization and industries in the country may be unfamiliar with the existence of the renewable energies and may thus prefer to use the old sources of energy. They may also be aware of the renewable energy but have since they believe it is inefficient fail to invest in it. The costs involved in changing infrastructure and the uncertainty of the new source of power is a source of repulsion to entrepreneurs [43, 44]. As such, the power project may generate enough power but because of low demand, they may end up collapsing. This can be overcome by coming up with policies that require institution to utilize renewable energy and creating awareness among the public on the need to switch to renewable energy. Renewable energy project are often small compared to the existing non-renewable energy projects. As such, they do not enjoy the benefits that come with increased economies of scale which results in higher operating costs. Moreover, since the renewable energy sector has not been given much focus in Libya previously, it faces additional challenges. For instance, the new project may require new information on things such as weather patterns of precipitation, wind and solar radiation which may not be currently available [44]. The investors would therefore need to invest first in carrying out survey before embarking on the main project. The cost of production of energy using the renewable sources therefore ends up exceeding the other non-renewable alternatives making investors to choose the latter. This high costs and poor technological development in the industry makes it difficult for people to invest in it collapsing.

9. Conclusion

On the basis of previous discussion, it can be concluded that there are immense opportunities in Libya
for production of solar and wind energy. Libya can be a favourable place for the renewable energy producing companies, which can find huge availability of conventional resources in this country. It can also be concluded that Libya can improve its economic environment through using low cost renewable energy sources and generating more revenues effectively. In this country, wind energy can be used for various purposes like electricity generation, communication system and mechanical activities. With this, solar energy can be used in street lighting, communication system and electricity for houses and warming pool water. This will be beneficial for the country in production of electricity at low cost and will provide economical benefits in terms of revenue. Through this paper, it can also be concluded that Libya has implemented effective strategies for developing its renewable energy but 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 difficult the development of renewable energy in Libya but it can be resolved by effective planning and its execution by the government. Government will have to take initiatives to improve the conditions for the investors to invest in these types of projects that will help to generate solar and wind energy for benefits of the country. For this, Libyan government will have to provide financial support and remove legal and political issues for the investors that they could be able to invest in energy projects with great extent.

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