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PROSPECTS OF RENEWABLE ENERGY IN LIBYA

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Abstract. Although Renewable energy applications in Libya were started in the middle of the seventies, they have only gained momentum in the last ten years. Considering the past gained experience, a proposed national Renewable Energy (RE) plan aims toward bringing RE into the main stream of the national energy supply system with a target contribution of 10% of the electricity demand by the year 2020. The proposed plan calls for a wide spectrum of renewable energy applications. This paper will highlight renewable energy applications in the country, the gained experience, the RE resources, and the future prospects for the utilization of RE recourses.

Key words: Stand alone PV systems, Applications and loads, Renewable energy

1. Introduction

Libya is an oil exporting country located in the middle of North Africa, with 6 million inhabitants distributed over an area of 1,750,000 Km^2. The daily average of solar radiation on a horizontal plane is 7.1 $kWh/m^2/day$ in the coastal region, and 8.1 $kWh/m^2/day$ in the southern region, with average sun duration of more than 3500 hours per year (Saleh Ibrahim, 1993). The national electric grid consists of a high voltage network of about 12,000 km, a medium voltage network of about 12,500 km and 7,000 km of low voltage network. The installed capacity is 5600 MW with a peak Load of 3650 MW, for the year 2004 (Saleh Ibrahim *et al.*, 1998). In spite of that; there are many villages and remote areas located far away from these networks. Economically these areas cannot be connected to the grid, owing to its small population, and small amount of energy required. In the past these facts dictate the use of diesel generators as a power supply. The use of diesel generators needs continuous maintenance, continuous supply of fuel. For these reasons we are pushed to look into some other sources like renewable energy. Moreover renewable energy provides clean and reliable energy sources which can be used in many applications in remote areas (electricity, water pumping, etc.). The use of renewable energies has been introduced in a wide range of applications due to its convenient use and being economically attractive in many applications. The most important renewable energy sources are solar energy, wind energy, and biomass.

Photovoltaic conversion, which is the direct conversion of solar energy into electricity, may be considered as the most reliable source for rural electrification. The use of wind energy to electrify remote areas will not be a reliable source as wind energy does not guarantee a continuous supply. Beside that the use of wind for electric power production needs maintenance personal. So this option will not be a reliable power supply in remote areas for developing countries. Biomass energy sources are limited to small applications of individuals as an energy source but not to produce electricity.

2. LIBYAN CONVENTIONAL ENERGY RESOURCES

The present energy supply in most countries cannot be considered as a sustainable sources of energy, as the energy costs are exploding, the sources are limited, and because of the environmental issues. For Libya the conventional sources of energy are limited to two sources.

1. Oil: with a total discovered resources estimated to 40 billion bbl.
2. Natural Gas: with a total discovered resources estimated to 1300 billion m^3.

The oil resources for Libya will not last more than 50 years as of today production and discovered resources, while the natural gas is expected to last more than that. Libya is an oil exporting country and most of the produced energy is exported. Table I shows the energy production by the year 2005.

TABLE I
Energy production by the year 2005

Type	Production	Consumption	Export
Natural gas	12 b m^3/y	3 b m^3/y	9 b m^3/y
Oil	0.6 b bbl/y	0.1 b bbl/y	0.5 b bbl/y
Electricity		20 T Wh/y	

In 2050 the price of oil barrel may reach more than 200 $. It is expected that Libya needs about 70 million barrels of oil per year for its electricity requirement and this will cost about 14 billion dollars per year. The question then is whether it will be better to sell the oil or to burn it. The answer will depend on the availability of other sources which can replace the conventional sources of energy like solar energy. The solar radiation in Libya is equivalent to a layer of 25 cm of crude oil per year on the land surface.

3. ENERGY REQUIREMENTS 2050

Libyan energy requirement scenario for 2050 is shown in Table II.

TABLE II
Scenario evolution for Libya

Type	2005	2050
Population	6 million	10 million
Electric power generation	3500 kWh/cap/y	5000 kWh/cap/y
Electricity demand	20 TWh/y	50 TWh/y
Water	6 billion m^3/y	10 billion m^3/y

4. RENEWABLE RESOURCES

Libya is located in the middle of North Africa with 88% of its area considered to be desert, the south is located in the Sahara desert where there is a high potentiality of solar energy which can be used to generate electricity by both solar energy conversions, photovoltaic, and thermal. The renewable energy sources for Libya according to the MED-CSP (Trans Mediterranean interconnection for concentrating solar power) scenario is shown in Table III, while the electric consumption and its sources in year 2050 is shown in Figure 1.

TABLE III
Renewable energy sources for Libya

Type	Potentiality
Solar electricity	140,000 TWh/y
Wind electricity	15 TWh/y
Biomass	2 TWh/y
Total	157,000 TWh/y

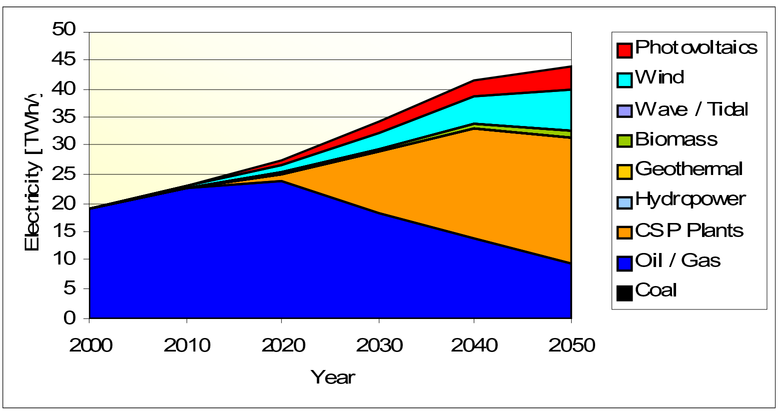

Fig. 1. Electricity consumption in Libya and supply resources.

5. RENEWABLE ENERGY APPLICATIONS

The use of renewable energies has been introduced in wide applications due to its convenience and being economically effective in many applications. The renewable energy sources used in Libya consists of photovoltaic conversion of solar energy, solar thermal applications, wind energy, and Biomass.

5.1. Photovoltaic

The use of PV systems started in 1976, and since then many projects have been developed for different sizes and applications. The first project put into work is a

PV system to supply a cathodic protection for the oil pipe line connecting Dahra oil field with Sedra Port. Projects in the field of communication were started 1980, when a PV system was used to supply energy to the microwave repeater station near Zella. Projects in the field of water pumping were started in 1983, when a PV pumping system was used to pump water for irrigation at El-Agailat. The use of PV systems for rural electrification and illumination started in 2003. PV systems found an increasing number of application types and their role grew considerably.

5.1.1. *PV in Microwave Communication Networks*

The Libyan Microwave communication network consists of more than 500 repeater stations. Only 9 remote stations were running by photovoltaic systems till the end of 1997 with a total peak power of 10.5 KWp. Remote stations in the eighties were running by diesel generators alone, while stations near general electric grid were powered by grid as the main supply and diesel generators as a backup. Nine stations were powered by photovoltaic systems at the beginning of 1980; four of these stations are still running after 26 years of work, the batteries which are of open type were replaced three times with an average lifetime of eight years. It was the technical and economical success of the PV systems that pushed the changing of all possible diesel stations to PV stations in the Libyan communication networks. The total number of stations running by PV in the field of communications currently exceeds 80 stations. The total installed photovoltaic peak power installed by the end of the year 2005 is around 420 KWp. Figure 2, shows the accumulated installed photovoltaic systems in the communication networks in the period 1980-2005 (Saleh Ibrahim *et al.*, 2003).

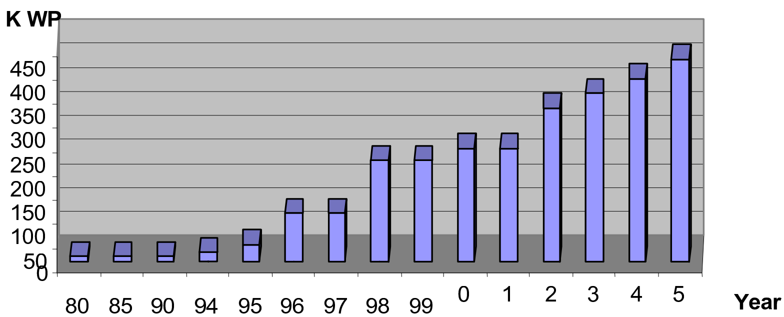

Fig. 2. The accumulated installed PV peak power 1980-2005

5.1.2. *PV in Cathodic protection*

In a previous study (Saleh Ibrahim *et al.*, 2004), it was shown that the cost of one KWh to supply a daily load of 15 KWh for a cathodic protection (CP) station is 1.4$ for a load which is located 5 Km from the 11 KV electric grid. In another study for the supply of a daily CP load of 7.5 KWh it was found that a PV system will be the most convenient solution at a distance of more than 1.2 Km from the 11 KV electric grid. Figure 3 shows the cost comparison to supply a CP station (Hibal *et al.*, 2004). The CP stations are usually far away from electric grid, a conclusion out of this indicate that it is not feasible to use this type of source for this type of applications when a CP (15 KWh/day) station is located more than 2 Km from 11 KV transmission line.

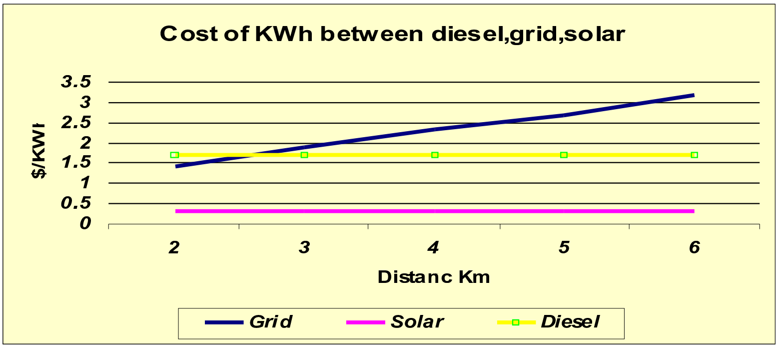

Fig. 3. Cost of KWh versus distance

From the cost comparison, it can be shown that the PV systems are the most economical choice; the choice will be more acceptable when considering real operations which include source failure. The first system in this field was put into work in 1976, the accumulated total power of PV systems in this field is second to PV systems in communications. The total number of PV systems in this field is around 300 by the end of 2005, with a total installed power of 540 KWp. PV technology is considered to be relatively new in developing countries; the problems we are facing have not to do with the technology but with people dealing with it. We are experiencing some vandalism issues: modules are often broken either by direct throwing stones on the module surfaces, or when shooting birds staying on the PV array.

5.1.3. *PV in Rural Electrification*

In most of the world the problem facing the electrification of low population areas or of regions far away from the existing electric networks is a financial one. It is so expensive to extend high voltage lines through desert to electrify few hundred inhabitants. In many low population countries electricity is only available in the cities and no electric network is used to power their rural areas. The Libyan national plans to electrify rural areas consist of electrifying scattered houses, villages, and water pumping. The PV supply systems for ten villages were introduced as a project to electrify remote areas (Saleh Ibrahim *et al.*, 2006). Some of these villages are

1. Mrair Gabis village as an example of scattered houses.
2. Swaihat village as an example of scattered houses
3. Intlat village as an example of scattered houses
4. Beer al-Merhan village as an example of scattered houses
5. Wadi Marsit village as an example of a village having diesel generator
6. Intlat village

The installation of photovoltaic systems started in the middle of 2003. The total number of systems installed by General Electric company of Libya (GECOL) is 340 with a total capacity of 220 kWp, while the ones installed by the Center of Solar

Energy Studies (CSES) and the Saharan Center are 150 with a total power of 125 KWp. The applications are: 380 systems for isolated houses, 30 systems for police stations, and 100 systems for street illumination. The total peak power is 345 KWp.

5.1.4. *PV for Water pumping*

Water pumping was considered as one of the best PV applications in Libya as remote wells which are used to supply water for human and live stock that are located in rural places. The water pumping projects consist of installing 35 PV systems with a total estimated peak power of 110 KWp.

Table IV shows the total installed PV capacity in Libya by the year 2005.

TABLE IV
Total installed PV capacity in Libya by the year 2005

Applications	Number of systems	Total power [KWp]
Communication	100	420
Cathodic protection	320	650
Rural Electrification	510	345
Water pumping	40	110
Total		1525

Gained experiences

From the collected data concerning the PV system performance in the local environment, it was proved that PV systems are highly reliable and cost effective. Some remarks drawn from past experience are (Saleh Ibrahim *et al.*, 2006):

1. No spare parts have been used for PV systems which were installed 26 years ago.
2. No failure has been registered for the systems installed 26 years ago.
3. Most of the PV systems had very low cost or no running cost.
4. Batteries have been changed after about ten years from installation.
5. People in developing countries should be informed about PV systems and their technology.
6. The average production energy for systems of 1.2 KWP is 6 KWh/day.
7. The AC option of electricity for rural electrification was the most convenient choice.
8. The closed type batteries option was the most convenient choice.

Social Impacts of PV Systems

Since photovoltaic technology is considered as relatively new; we are experiencing a lot of social changes for instance in the settlement of Bedouins. We are expecting that some small industries will be started. The availability of power supply will give a good chance to involve the populations of such remote areas increasing their knowledge and becoming familiar with the daily life of modern society. The availability of electrical power motivates the population to use more appliances like TV sets, refrigerators that are normally in use in grid connected areas. As a result we have noticed a load increase in some houses which exceeded the maximum capacity of the PV supply systems. We also noticed that some population started to move back to these remote areas causing additional power loads. The reception of TV programs may change the habits of family live resulting in lower productivity.

We have not experienced any vandalism. The only problem reported in one of the system in which the inverter stopped because of overload may be considered to be due to the equipment itself.

5.2. Thermal Conversion

The use of solar heaters started in 1983 with a pilot project which included 10 systems. Since then about 2000 additional solar heaters have been installed in Libya.

Water heating energy consumption is about 12% of the national electricity production but the use of solar heaters has not been spread in all the country due to

1. No national or personal industry has been established for local individuals.
2. Lack of information for the people.
3. Low electric energy tariff.

5.3. Wind Energy in Libya

Wind energy was utilized for water pumping in many oasis since 1940. The use of this energy has not been developed extensively because the wind-mills need some maintenance from time to time.

In 2004 measurements of the wind speed statistics has been conducted and showed that there is a high potentiality for wind energy in Libya. The average wind speed at a 40 meter height is between 6- 7.5 m/s. Figure 4 shows the average wind speed measured in different locations of the Libyan coast area.

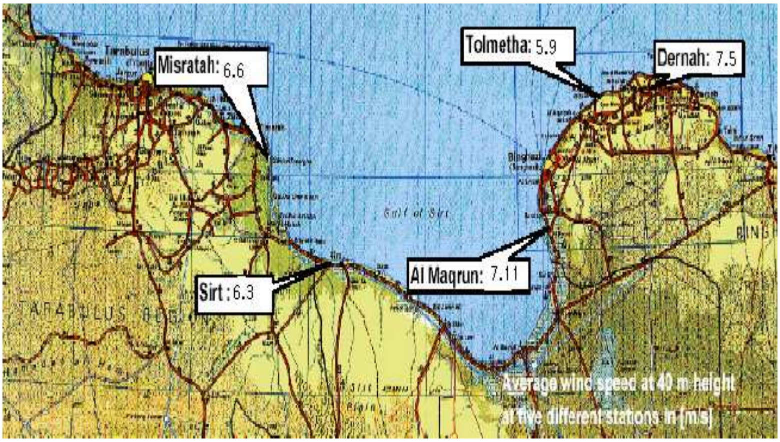

Fig. 4. Average wind speeds in m/s measured in 5 locations along the Libyan coast.

The use of wind energy for electricity production has not been started yet in

Libya, but a project was contracted for installing 25 MW as a pilot project to be erected in two years time. A project to prepare two Atlas that provide fast access to reliable solar and wind data through out Libya is also been contracted for. The Atlas will allow for accurate analysis of the available wind and solar resources anywhere in Libya, and will be therefore very important for planning profitable wind farms and solar projects.

6. FUTURE PROSPECTS

Based on the past gained experience, a national Renewable Energy (RE) plan has been proposed with the aim of bringing RE into the main stream of the national energy supply system with a target contribution of 10% of the electricity demand by the year 2020. The proposed plan call for a wide spectrum of Renewable energy applications. Table V shows the planed renewable energy contribution in Libya from different sources.

TABLE V
Planed renewable energy production in Libya in 2020.

Total	Technology
10 MWp	PV
150 MW	Wind
20,000 m^3	Thermal Water heating
20 MW	Thermal electricity
20,000 m^3	Thermal Desalination
20 KW	Hydrogen

Due to high potential of renewable energy sources in Libya and its location near the energy market in Europe, it is possible to plan in the future to generate electricity from renewable sources in Libyan southern regions and to deliver it to Europe. Figure 5 shows a map for future electricity supply scenario from renewable sources.

7. CONCLUSION

Libya can be considered as a place with high potentiality for renewable energy production. The use of a stand-alone PV power supply in communications, cathodic protection, rural electrification, and water pumping, is justified. Finally we can say that:

1. There is a good potentiality for PV systems which can be used in different applications.
2. Photovoltaic systems for supplying electrical energy to remote areas are justified based on economical and technical reasons.
3. Social changes have been noticed in the villages which have been electrified.
4. There is a potentiality of renewable (solar & wind) energy which can be used in different applications.

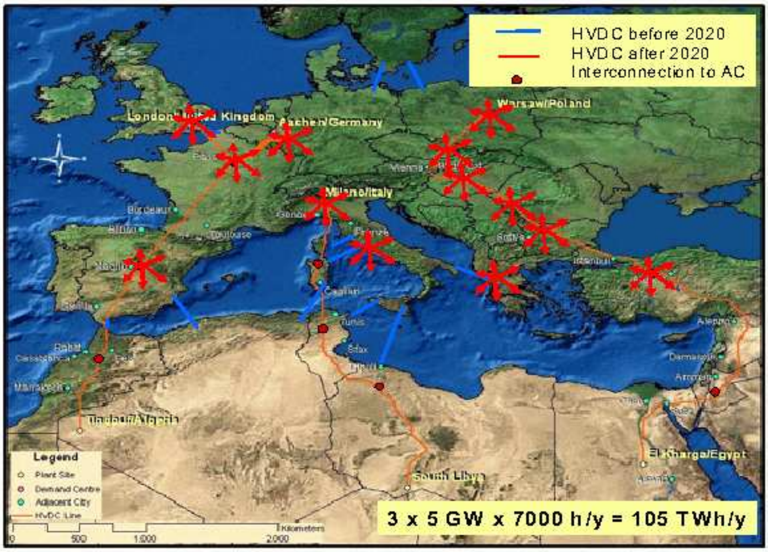

Fig. 5. Map for future electricity supply scenario from renewable sources MED-CSP.

5. A national plan has been adopted to rise the share of renewable energy to 10% by the year 2020.
6. Number of projects are progressing in the field of renewable energy

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