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RENEWABLE ENERGY IN LIBYA: PRESENT AND FUTURE

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The presented trends and future forecasts of the electricity demand, and how photovoltaic and wind power may grow in percentage of the total demand are discussed in this paper. The historical data on the market developments in similar basic-need industries growth model indicate that the photovoltaic and wind power may reach their full potential in the year 2065. The probable impact utility restructuring on the renewable is reviewed.

Key words: renewable energy, wind energy, solar energy.

World Electricity Demand to 2015

According to [1], electric power is expected to be the fastest growing source of energy to the end users throughout the world over the next two decades. The electricity demand is projected to grow to 19 trillion kWh by the year 2015 (fig. 1) at the annual growth rate of 2,6 percent. Forecasted growth of electrical energy in Libya is shown in table 1.

Table 1. **Forecasted growth of electrical energy in Libya**

Category	2008	2015	2020
Installed Capacity [MW]	6000	15000	
Electricity Generation [TWh]	29	73	109

The electricity demand in the industrial and developing countries projected to 2015 is shown in fig. 2, indicating a fast growth rate in the developing countries. The Organization for Economic Cooperation and Development (OECD) countries constitutes 20 percent of the world's population, but consumes over 60 percent of the world's electricity. The non-OECD Asia is expected to grow faster than the Eastern European and Former Soviet Union (EE/FSU) countries. This is a result of the relatively high economic growth rate projected for the non-OECD Asia. Although the United States is the largest consumer of electricity in the world, it has the lowest projected growth rate of 1.3 percent versus the world average of 2.6 percent. Mexico has the highest projected growth rate of 4.7 percent per year to the year 2015. The developing Asia is projected to experience the strongest growth than any other region in the world at a growth rate of 5 percent per year (fig. 3). As the electricity demand grows, the coal will remain the primary fuel for power generation, especially in China and India. The share of nuclear generation worldwide has reached the peak, and is expected to decline in the future. The coal, the natural gas, and the renewable, all are © 1999 by CRC Press LLC expected to grow to replace the retiring nuclear power plants. However, the renewable are expected to take a greater percentage of the growth. For example, in February 1997, the Swedish government announced that it ((World electricity consumption 1970–2015. (Source: U.S. Department of Energy, International Energy Outlook 1997 with Projections to 2015, DOE Office of the Integrated Analysis and Forecasting, Report No. DE-97005344, April 1997.) would begin shutting down the country's large nuclear power industry, whose plants supply 50 percent of Sweden's electricity. This announcement was in response to a referendum vote to end nuclear power in Sweden. To compensate, the government is to step up intervention in energy market and force a switch to greater use of no fossil alternatives. Other industrial countries have serious commitments to reduce pollution of the environment.

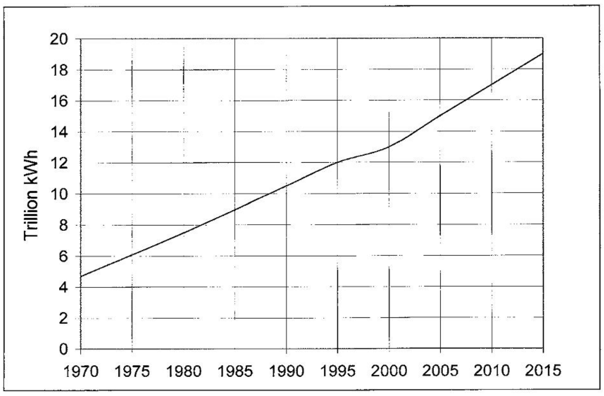

Fig. 1. The electricity production and forecast [1]

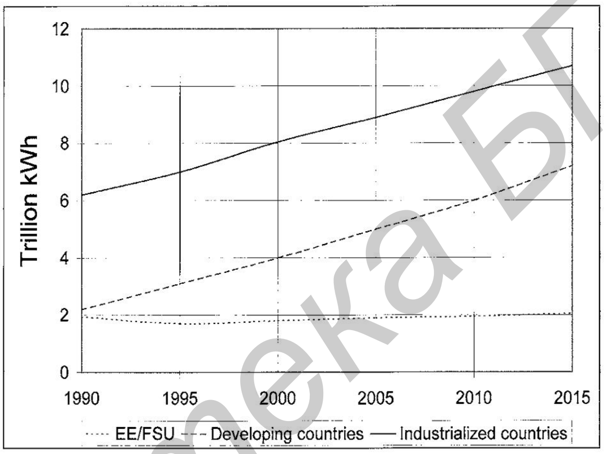

Fig. 2. The electricity consumption by industrialized and developing countries for 1990-2015.

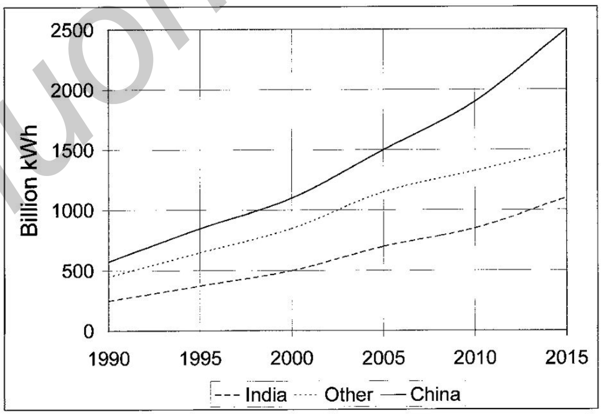

Fig. 3. Electricity consumption in developing Asia 1990-2015. (Source: U.S. Department of Energy, International Energy Outlook 1997 with Projections to 2015, DOE Office of the Integrated Analysis and Forecasting, Report No. DE-97005344, April 1997.)

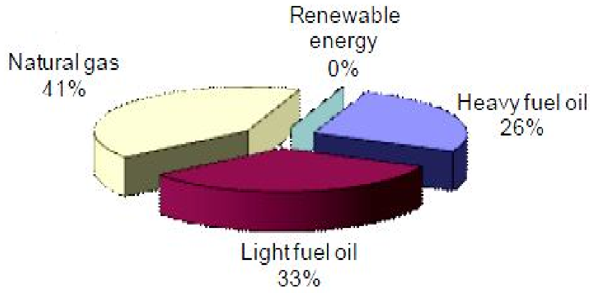

Fig. 4. Energy production in Libya by fuel type

This is a significant challenge and would certainly require an aggressive policy on the renewable energy sources. The developing countries have additional reason for promoting wind and PV programs. With significant rural population, they would benefit from the distributed power generation near the end users. It is interesting to note that in some countries governments make interventions in power development in the countries. Besides already mentioned Sweden in US Energy policy act of 2005 [1–3] «will encourage energy efficiency and conservation, promote alternative and renewable energy sources…». Electrical energy production in Libya by fuel type is shown in fig. 4

Electrical energy consumption for the year of 2007 in Libya is presented in table 2, Which together with fig. 5, showing PV Rural electrification Sites of Libya leads us to the conclusion, that major consumers are residential stand alone type (remote users) (residential + agriculture), which gives in summary 46% of all electricity consumption (table 2).

Table 2. **Electrical energy consumption for the year of 2007 in Libya C**

Category	Percentage
Residential	32%
Industrial	10%
Agriculture	14%
Commercial	14%
General Services	17%
Street Lighting	13%

Even though, Libya has an important potential of solar and wind energy but the role of these resources in the energy mix is negligible.

In the past, several steps have been taken to develop the renewable energy sector in Libya as showing next. Photovoltaic (PV) to supply small remote users [300 systems].

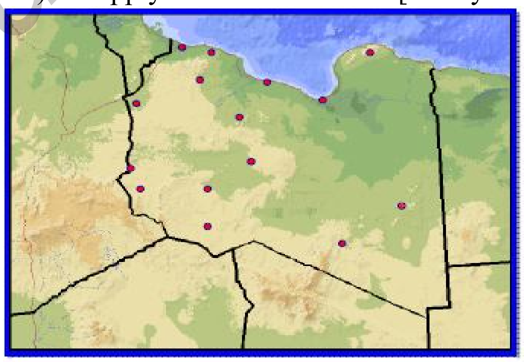

Fig. 5. PV Rural electrification Sites of Libya

EAOL (Renewable Energy Authority Of Libya) was founded to promote the development of renewable energy 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. To achieve the target mentioned, several plants were decided to build as following: wind farms: Dernah (60 MW); Al-Maqrun (120 MW); Western region wind farm (250 MW); Al-Maqrun, 2nd stage, (120 MW) Large scale PV plant grid connected in different locations about 5–10 MW; Expanding the use of PV technologies to feed remote areas about 2 MW; PV roof top systems to supply certain residential areas about 500 systems.

Wind Energy

It is reported [1] that wind is experiencing the strongest growth among the renewable energy sources with the decreasing generation cost. The wind power cost has dropped to 5 cents per kWh, and further reduction to about 2 cents is possible by 2010. The five top-growth markets for wind energy through 2010 will be the U.S.A., India, China, Germany, and Spain's of between 1,275 and 2,730 MW projected in each country. The wind power sources are clean, abundant, and do not need to be imported. However, they must be economical on their own merit. The new developments are meeting this challenge on the both sides, the initial capital cost and the cost per unit of electricity generated. Since the early 1980s, wind technology capital costs [1] have declined by 80 percent, operation and maintenance costs have dropped by 80 percent and availability factor of grid-connected plants has risen to 95 percent. For the wind plans at present, the capital cost has dropped below $800 per kW and the electricity cost to about 6 cents per kWh. The goal of current research programs is to bring the wind power cost below 4 cents per kWh by the year 2000. This is highly competitive with the cost of conventional power plant technologies. According to the National Renewable Energy Laboratory, several research partners are negotiating with U.S. electrical utilities to install additional 4,200 MW of wind capacity at a capital investment of about $2 billion throughout the nation during the next several years. This amounts to the capital cost of $476 per kW, which is comparable with the conventional power plant costs. According to the Electric Power Research Institute, the continuing technology developments and production economy would make the wind the least-cost energy within a decade.

The industry experts make this forecast based on the following ongoing research programs:

- more efficient airfoil and blade design and manufacturing.
- better understanding on the structure and foundation loads under turbulence, operating fatigue loads and their effect on life.
- computer prototyping by accurate system modeling and simulation.
- integrated electrical generators and power electronics to eliminate the mechanical gearbox.
- efficient low cost energy storage at large scale.
- better wind speed characterization, particularly within a large wind farm.

Successful design, development, and demonstration based on the results of these research programs are expected to increase the share of wind power in the U.S.A. from a fraction of 1 percent to more than 10 percent over the next two decades. The offshore wind potential is much greater than onshore due to good wind speed and the large area available for commercial installations. It is limited only by practical working depths and other maritime activities in the area of interest. Fishing, shipping routes, and military test grounds are some of the activities that may conflict with the wind farm. Water depth of 30 meters is practical. Taking only the water depth as a constraint, the accessible U.K. offshore wind resource is estimated to be 380 TWh per year. Taking other constraints also into account, this estimate is reduced to 120 TWh per year. A study commissioned by the European Union has suggested that the offshore wind farms in the coastal regions of Germany, Holland, and Denmark could meet all electricity demand in those countries. PowerGen Corporation of Britain plans to build 37 MW (25 towers, each rated 1.5 MW) of offshore wind capacity near Yarmouth, Norfolk, by 1999. Germany plans to install a large wind farm in the Baltic Sea, near Schleswig-Holstein. Denmark's ambitious offshore plan announced in the government's Energy-21 report published in 1997 aims to have at least 750 MW offshore capacity by 2005, 2,300 MW by 2015 and 4,000 MW by the year 2030. This will amount to about 50 percent of that country's electricity coming from wind. This would push the percentage limit to a practical maximum for any intermittent source of power. The first group of Denmark's offshore sites is shown in fig. 16–5 and 16–6. The offshore wind speed is generally higher, typically 8 to 10 m/s. However, due to lack of long term data, these estimates must account for the inherent variability in the estimate and the associated sensitivity to the cost of generated electricity. The onshore wind technology is applicable to the offshore installations. The major difference, however, is the hostile environment and the associated increase in the installation cost. The electrical loss in transmitting power to the shore needs to be accounted for. Overall, it is estimated that the offshore wind power plant cost can be at least 30 percent higher than the comparable inland plant. © 1999 by

CRC Press LLC As of December 1997, Europe's wind capacity by country was shown in fig. 2–10. Germany and Denmark lead Europe in wind power. Both have achieved phenomenal wind energy growth through a guaranteed tariff based on the domestic electricity prices, perhaps a blueprint for the rest of the world to follow. Germany has a 35-fold increase between 1990 and 1996, a 70 percent annual rate of growth. With 2,000 MW installed, Germany is now the world leader. The former global leader, the U.S.A., has seen only a small increase during this period, from 1,500 MW in 1990 to 1,650 MW in 1996. In 1997, the European Wind Energy Association adopted an ambitious target of 40,000 MW of wind capacity in Europe by the year 2010 and 100,000 MW by 2020 (Table 16–3). Each European country would be obligated to meet its committed share of renewable electricity, including the wind energy obligation, towards the overall target of 12 percent of the primary energy by wind in Europe by the year 2010. In selected countries, the present wind capacity and future targets are listed in Table 16–4. The present and future targets for meeting the total electricity demand by wind capacity are listed in Table 16–5. Based on these targets, it is reasonable to expect that the wind may contribute 10 to 25 percent of the t total electricity demand in some countries by 2010.

There is a need in Libya to construct a standalone wind farm for generating a necessary amount of electric power by kinetic energy of wind. The interconnecting methods for the wind turbine/generators are essential in forming the wind farms are widely discussed in [3–6]. There was proposed a dc-link-type wind turbine generating system using a shaft generator system, which is widely used for power sources in a ship [6], and revealed the usefulness of the system. On the basis of the aforementioned system, a new interconnecting method for a group of wind turbine/generators is proposed. In this method, the outputs of each AC generator coupled with the wind turbine are rectified, and these rectified outputs are connected to DC bus via DC-DC power converters (and integrated in the).

Solar Energy

Libya has an important potential of solar but the role of this resource in the energy mix is negligible.

Functionally a solar cell is an electrical current source, driven by a flux of solar radiation. Photovoltaic's (PV) systems are solid state; therefore, they are rugged, simple in design and require very little maintenance. Perhaps the biggest advantage of solar PV systems is that they can be constructed as stand-alone systems to give outputs in ranges from microwatts to megawatts. That is why they have a vast array of applications, from calculators and watches to water pumping and remote lighting systems, satellites, space vehicles and even megawatt scale power plants. In today's energy and environment-conscious society the clean and seemingly inexhaustible source of energy from PV provides an attractive option. Once a very high priced technology, used exclusively for space applications, photovoltaic's is now well-known around the world and is finding rapidly expanding energy markets. Many hundreds of thousands of PV systems have been installed around the globe. For remote applications, utilities find PV-based systems more reliable and less expensive than their conventional options. There are generally four types of applications of photovoltaic power. One type is the grid-connected distributed power station which takes advantage of the high levels of solar radiation in an area to support the demand for electricity in the network.

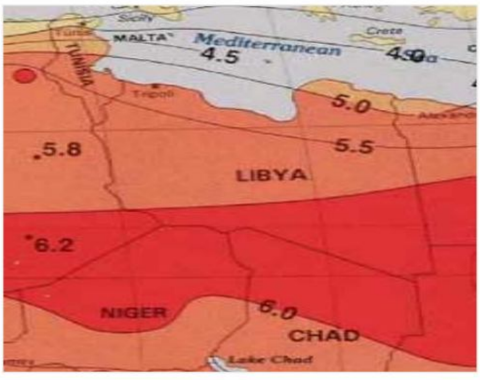

Fig. 6. A map of solar radiation in Libya

Solar energy production is a great interest for Libya which is in the heart of the sun belt (fig. 6). Solar radiation reaches(3000–3500) sunshine Hour/year.

Therefore according to EAOL Med-Term Plan 2008–2012:

Construct a Solar Heaters Factory as a joint venture with local and foreign investors to satisfy local needs and export to international market.

Construct a PV Modules Factory as a joint venture with some investors.

Encourage and promote local & foreign investment in this field.

As it is well known solar radiation depends on the season and time of the day, which is shown on fig. 7.

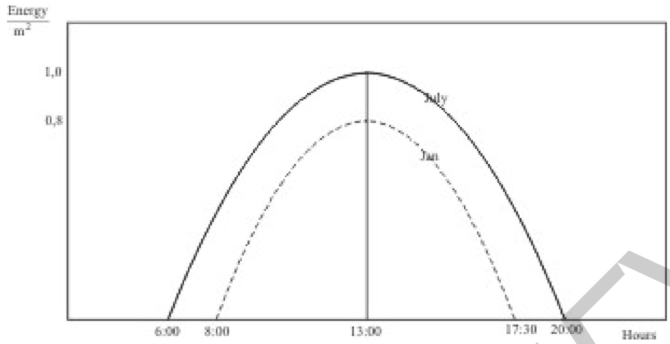

Fig. 7. Solar radiation during the day in January and July (in per unit)

Hybrid System

The certainty of meeting load demands at all times is greatly enhanced by the hybrid system using more than one power source. Wind is not predictable; PV is predictable but not available during night time, which makes the system is not predictable of meeting load demands at all times. Certainly there is a need of The Third one which will make the system reliable enough. So we came to Hybrid System.

Table 3. **Renewable energy potential in Libya**

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

Two power sources as it is seen from above is not enough.

At present and near past most hybrids use diesel generator with PV or wind, since diesel provides more predictable power on demand. In some hybrids, batteries are used in addition to the diesel generator. The batteries meet the daily load fluctuation, and the diesel generator takes care of the long-term fluctuations. For example, the diesel generator is used in the worst case weather condition, such as extended overcasts or windless days or weeks.

The power connection and control unit provides a central place to make organized connections of most system components like The Third one (diesel generator or fuel cell or biomass generator), the wind generator, the PV and the battery. In modern application super capacitors can be used as large amount of energy storage replacing The Third one as it is presented on fig. 8.

In addition, the unit houses the following components:

- battery charge and discharge regulators.
- transfer switches and protection circuit breakers.
- power flow meters.
- mode controller.

Hybrid with Fuel Cell. In stand-alone renewable power systems of hybrid designs (fig. 8), the fuel cell has the potential to replace the diesel engine in urban areas. In these applications, the diesel engine would be undesirables due to its environmental negatives.

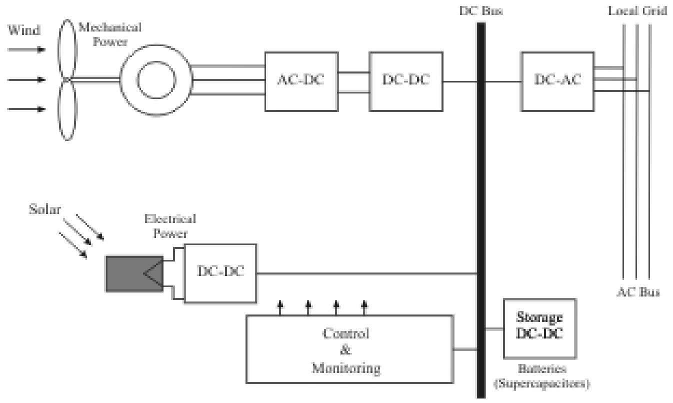

Fig. 8. Components of a renewable energy farm

The overall system must be designed for a wide performance range to accommodate the characteristics. As and when needed, switching to the desired mode of generation is done by the mode controller. Thus, the mode controller is the central monitor and controller of the hybrid systems.

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