

## Energy consumption and future potential of renewable energy in North Africa

M. Grein<sup>1\*</sup>, B. Nordell<sup>1</sup> and A. Al Mathnani<sup>2</sup>

<sup>1</sup> Architecture and Infrastructure, Luleå University of Technology,  
SE-97187 Luleå, Sweden

<sup>2</sup> Department of Environmental Studies, University of Sebha  
P.O. Box 68, Brack, Libya

**Abstract** - An overview of current and future energy consumption in North Africa, related to population growth and regional economy, is presented. Two scenarios are given; with and without the use of renewable energy. Current and potential use of renewable energy is described. Renewable can mainly be utilized by generating electricity and direct applications as space heating and/or cooling. Examples of utilization are discussed with emphasis on; (1) the region's potential and possible future export of renewable electricity; (2) Underground thermal energy storage (UTES) for seasonal and short term storage, is considered to play an important role in space heating and space cooling systems in the region.

### 1. THE REGION

North Africa is the area comprising of Morocco, Algeria, Tunisia, and Libya, with the Sahara desert to the south and the Mediterranean Sea to the north. The climate is dry and warm with annual mean temperatures from 15 °C to 25 °C, with a temperature difference of 20 °C between the coldest and warmest months. Heating is needed during the short winter and there is a large cooling demand during the long summer [1].

#### 1.1 Energy Situation

Oil is the most important source of energy in North Africa, A recent tendency in using natural gas can be observed. In 2004, oil was still the primary energy source with the exception of Algeria, where gas dominates. In 1997, Algeria's natural gas production exceeded its crude oil production for the first time [2]. **Table 1** shows the share of the total primary energy supply (TPES) in 2004.

**Table 1:** Total primary energy supply, 'TPES' in North Africa (2004)

	Alg. (%)	Lib. (%)	Mor. (%)	Tun. (%)
Oil	33.3	72.7	62.3	48.3
Gas	64.3	26.5	0.4	39.1
Coal	2.2	0	31.9	0
Hydro	0.1	0	1.2	0.2
Comb & Waste	0.2	0.8	4	12.4
Geo-Solar-Wind	0	0	0.2	0

In 2002, TPES was of 68.6 Mtoe (Million ton of oil equivalent), with 30.9 Mtoe for Algeria, 18.7 Mtoe, 10.75 Mtoe, and 8.28 Mtoe for Libya, Morocco, and Tunisia, respectively [3]. The TPES reached 72.2 Mtoe in 2004 [4]. Fossil fuel accounted for 87.4 % (Tunisia), 94.6 % (Morocco) Libya (99.2 %) and 99.8 % (Algeria) [5].

Since 1973, the TPES increased in all of the countries [4]. This growing energy consumption is a result of the urbanization process in the region, economic growth and industrialization. The TPES growth is directly related to the population growth. The total population increased from 36.2 millions in 1970 to 75.1 millions in 2000. The expected population growth [6] indicates

\* [grein@ltu.se](mailto:grein@ltu.se) \_ [bon@ltu.se](mailto:bon@ltu.se) \_ [almathnani2004@yahoo.com](mailto:almathnani2004@yahoo.com)

more pressure on the future energy supply, especially in the residential sector with its increasing cooling and heating demand.

The average economic growth 1995-1999 in the North Africa countries was 3.2 % for Algeria, 1.6 % for Libya, 3.6 % for Morocco, and 5.6 % for Tunisia. The corresponding values in 2005 were, 5.5 %, 8.5 %, 1.5 %, and 5 %. [7]. The increase in the OPEC countries Algeria and Libya, and the decrease in the Morocco and Tunisia, is a result of the sharp increase in oil and gas price [7]. OPEC countries will face an increase in demand as the economic growth will be reflected in, change in life style and increased energy consumption for e.g. space heating and cooling. For the non-oil producing countries, the pressure will be doubled. Governments will be forced to more efficient energy use to overcome the increasing energy cost. Alternatives like renewable energy and changed energy mix will be a challenge for the countries in the region.

In Algeria, the growing gas consumption of [8] is expected to continue as the government is encouraging the use of natural gas. Natural gas represented 63% of its total energy consumption in 2002 and is the main source for Algeria's electricity generation. The domestic consumption accounts for 26 % of the production in 2002. Algeria is the world's second largest producer of Liquefied Natural Gas (LNG) (after Indonesia) with 17 % of the total LNG production [8].

In Libya, TPES has followed an escalating growth as in Algeria, though oil is the major contributor to its development. The regional distribution of fossil fuels is very uneven, particularly in respect to petroleum, as oil reserves in the region are mainly located in Libya (3900 Mt) and Algeria (1400 Mt). Algeria and Libya are expected to play a major role in oil and gas markets for years to come, especially for European countries [9]. A scenario for oil and gas production and export (2000/2005, 2010/2015 - 2020) developed for four South Mediterranean countries (SMCs) with hydrocarbon potential shows that the two countries will be able to increase their export of both oil and gas with handsome amounts to EU countries. This export is predicted to increase until the end of the scenario period (2020). The estimated export by Algeria and Libya to EU countries according to the developed scenario is shown in **Table 2** [9].

**Table 2:** Predicted oil and gas export

TPES	2010		2020	
	Oil (Mt)	Gas (BCU)	Oil (Mt)	Gas (BCU)
Algeria	104	85	123-143	120
Libya	116	10	156	27

According to January 2006 estimates by Journal of Oil and Gas (OGJ), Tunisia has proven oil reserves of 308 million barrels while Morocco has only 1.1 million barrels [10]. The natural gas reserve of the four countries amounts to 215,960 Billion Cubic feet (BCF) of which 74.3 % in Algeria, and 24.4 % in Libya [10]. Morocco is the largest energy importer in North Africa. Its annual cost of energy import increased from 1-1.5B\$ to B\$2 in 2005[10]. Coal is the second greatest share of Morocco's TPES (31.9 %). It is used for power generation in the country's two main electric power stations [11].

In 2004, the Total Final Consumption (TFC) of energy in the four North African countries was about 64.4 Mtoe or 19.5, 9.7, 9.3 and 6.4 Mtoe in Algeria, Libya, Morocco, and Tunisia, respectively. Fossil fuels made 100% of the total in Algeria and in Libya, while the corresponding values were 98.3 % for Morocco and 99.8 % in Tunisia.

Hydropower, accounted for only 1.7 % and 0.2 % of the total energy consumed that year [10]. Based on discussed facts, it is concluded that North African OPEC countries have a very weak energy mix, while Morocco and Tunisia have a modest weak mix.

A balanced, diversified, and environmental friendly energy system is the target for the whole world to curb problems associated with fossil fuel energy systems, which is the main cause of the worrying climate change. A change in the energy policies has to be implemented in all countries to reach the state of secured energy supply, even for countries with large sources of fossil fuels. North Africa must change to use renewable energy as a contribution to the international effort to reduce pollution. The region's climatic conditions are more favourable than in most other countries.

## 1.2 Electricity

The installed capacity of power generation has increased from 15.6 GW in 1999 to 19.4 GW in 2003; Algeria (6.8 GW), Morocco (4.9 GW), Libya (4.7 GW) and Tunisia (2.9 GW) [10, 14]. The installed capacity of Algeria was 5.93 GW in 2002 [8]. The growing power demand is also exemplified by Libya's annually increase of 6 – 8 %, with an estimated demand for 2010 of 5.8 GW and 8 GW for 2020 [13].

The residential sector is one of the main consumers of electricity. In 2004, 63.4 % of the electricity in Algeria was consumed by the residential sector while the corresponding values for Morocco, Tunisia and Libya were 32.3 %, 25.9 % and 87 %, respectively [2, 15]. The energy is mainly used space heating and cooling.

The consumption of electricity for heating and cooling, including commercial buildings (hotels, institutions, restaurants, governmental buildings, etc.) reaches 45.5 % and 45.9 % for Morocco and Tunisia. This is almost equal to the amount of electricity consumed by its industry, 47.5 % in Morocco and 46.8 % in Tunisia [2]. In Algeria and Libya, the power consumption of the industry was 34.8 % and 2 % in 2004[15].

The cost of electricity varies considerably in the different countries; from ~ 0.015 \$/kWh in Libya and Algeria (natural gas), to 0.056 \$/kWh in Tunisia where oil is used [14].

Globally, in the baseline scenario (business as usual scenario), the power demand from 2003 till 2050 will grow rapidly. The demand of the residential sector is expected to grow by 80 % due to rapid population growth [3].

## 1.3 Emissions

The region's carbon dioxide emissions in 2000 were estimated to 84.4 Mt, 49.7 Mt, 33.7 Mt, and 21.3 Mt, for Algeria, Libya, Morocco, and Tunisia, respectively [10]. These numbers are expected to increase rapidly with the power consumption [3].

## 1.4 Energy scenarios

Regarding 'The Global Energy Future', several international institutions and multinational energy companies prepare independent studies on the development of the world energy market over the coming decades. Most projections have a horizon of 20 to 30 years. The most respected and frequently quoted studies are those produced by official energy organisations, such as the International Energy Agency (IEA), the US Environmental Information Adm. (EIA), and the European Commission Directorates General, responsible for EU energy policy (DG Research and DG Tren).

The most important studies along with their results are found on the internet (1) Annual EIA International Energy Outlook ([www.eia.doe.gov](http://www.eia.doe.gov)). (2) IEA World Energy Outlook on the prospective developments of world energy supply through 2030 ([www.worldenergy-outlook.org](http://www.worldenergy-outlook.org)). (3) Shell published three scenarios on world energy supply, under the title "Shell Global Scenarios 2025" ([www.shell.com](http://www.shell.com)).

Some differences occur because of the different methods used. For example, IEA predicts an annual 1.7% increase in global primary energy consumption from 2002 to 2030. EIA indicates a corresponding value of 2 % while EC suggests an annual increase of 1.8 %. These results relates to the business as usual scenario. Alternative scenarios, involving technology change, renewable energy, and changed energy policies, are also included [18].

No such regional studies have been performed on North Africa, though the trend will follow the reference case unless the region's energy policy is changed (e.g. more renewable energy). The only available study that deals with the energy future of the region is a study carried out for the EC Synergy Programme [9]. The study was on the Development of Energy Supplies to Europe from the Southern and Eastern Mediterranean Countries (SEMCs)]. Four countries of (SEMCs) where included; Libya, Algeria, Egypt and Syria. A scenario on oil and gas exports from (SEMCs) to (NEMCs) where developed. The potential and barriers for renewable energy in SEMCs were discussed in that study where Morocco, Tunisia and Algeria were included (see Renewables).

### 1.5 Water resources, cooling/heating demand, and climate change

Tina Tin *et al.* (2005) studied the impacts of a 2 °C global temperature rise, for two different emission scenarios, in the Mediterranean region using a newly developed climate model. Their results show that a global temperature rise of 2 °C is likely to lead to a corresponding warming of 1 to 3 °C in Mediterranean area. The largest increase in temperature is expected to take place in the summer in form of hot days and heat waves in North Africa. As a result of that, Heating Degree Days (HDD) and Cooling Degree Days (CDD) will see some changes. HDD will decrease substantially in the northern part and CDD will increase everywhere in Mediterranean, especially in the south. This change can potentially shift the peak in energy demand to the summer season with implications for the need for additional energy capacity and increased stress on water resources. The study concluded a very large rise in CDD, in North Africa and Syria, and a small drop in HDD. The energy demand for cooling is likely to rise as society become richer and the demand for comfort increases. Heat generated by cooling machines could rise temperatures even further and increase the demand for cooling [16].

By 2030, chronic water scarcity will affect more than three billion people in 52 countries if we carry on with the business as usual scenario of dealing with water scarcity issue. North Africa, with the exception of Morocco, is considered to suffer from water shortage at this time. The continuous growth of population will increase the water demand, with less available fresh water per capita. It is foreseen that North Africa will suffer from water scarcity by 2025 [17].

### 1.6 Renewable energy

Renewable energy (RE), wind, solar, geothermal etc., must play an important role in North Africa's future energy mix. Hydropower which is a RE is classified in a different category in most of the references (**Table 1**). RE could be used for power generation but most of all for replacing electricity in space heating and cooling.

As shown in **Table 1**, RE contributed to 0.2 % of Morocco's TPES in 2004, with no contribution at all for the other three countries. It is almost the same with the share in TFC when hydropower is excluded. IEA statistics show that Morocco has achieved a 9.4 % of electricity generation percentage from RE. Hydropower contributed to 8.4 %, while 1 % came from wind energy [2]. In Tunisia, only 0.3 % of electricity produced was generated from wind. Hydro made a contribution of 1.2 % of the total generated electricity. In Algeria, 0.8 % of the total came from hydro power [2, 4].

Some on-going efforts to expand the role RE have to be mentioned. In Algeria, the government has committed it self to develop solar energy, to cover 5% of the national electricity needs by 2010 [2]. Morocco has set a target of 10 % RE in 2011 [10].

The region has a great potential to develop its RE resources especially solar and wind. In a study on Development of Energy Supplies to Europe from the Southern and Eastern Mediterranean Countries SEMCs, the current and future potential of renewable energy sources (RES) in five of SEMCs, Algeria, Morocco, Tunisia, Egypt and Turkey. This study underlines the present minor role of RES in the three North African countries. Excluding large Hydro power generation (in Morocco), the remaining RES based power generation reached 0.22 TWh for the three countries in 2000, Algeria with 0.01 TWh, Morocco with 0.18 TWh and Tunisia with 0.03 TWh[9].

Based on the planned projects announced by the countries, two scenarios were developed for RES by 2010. The modest scenario (*modRES scenario*) showed that, the contribution of RES in power generation of the three North African countries will reach 2.34 TWh in 2010. This is tenfold increase compared to the situation in 2000. Wind will take the lead (1.21 TWh) followed by Solar thermal (0.55 TW) [9].

**Table 3:** RES contribution in 2010 (TWh)

	Algeria	Morocco	Tunisia
PV	0.01	0.03	0.02
Solar Thermal	0.44	0.11	0.00
Wind	0.03	0.70	0.48

Small hydro	0.13	0.15	0.04
Biomass	0.00	0.20	0.00
Total	0.61	1.19	0.54

The high scenario (*highRES scenario*) focuses on the increase of RES (excluding large hydro) by allocating them a 10% share in power generation. This requires a very pro-active policy by the local governments and the international community. RES-based capacity will mainly be dominated by wind energy [9].

In North Africa, millions of km<sup>2</sup> fulfil the criteria of suitability for the construction of solar thermal power plants with respect to land slope and land cover [19]. The land slope should be less than 5 % and cultivated land areas are considered unsuitable for such plants. Concentrated Solar Power (CSP) technology requires locations with large fraction of direct solar radiation, and with free land available for collector arrays. Such site conditions are well fulfilled in deserts. Under the radiation conditions of North Africa (and of the Arabic Peninsula) CSP plants can annually generate 0.25 TWh/km<sup>2</sup> [19].

In co-generation of power by (CSP), multi-effect distillation (MED) plants waste heat can be employed for desalination with high efficiency. Waste heat from one kW power generation means that 0.04 m<sup>3</sup> of fresh water can be produced [19]. Desalination capacities of billions of cubic meters of fresh water can be achieved. Because of the strongly growing population, the demand for water and electricity will grow substantially in MENA (Middle East and North Africa) region. The up-coming need for desalination is tremendous [19].

Trans-Mediterranean Renewable Energy Cooperation (TREC) have come to a proposal where financial support from EU countries to NA/NE (North Africa and Near East) countries can benefit from that by taking advantage of their superior solar and wind potentials and generate clean electricity as a competitive industrial product for export to the European market [19]. As a by-product of solar power generation and export to Europe, huge amounts of sea water could be desalinated in cogeneration to overcome the expected shortage of fresh water in the NA/NE countries [19].

### 1.7 Underground thermal energy storage (UTES) technology

To reduce the increasing electricity demand for heating and cooling of buildings, underground thermal energy storage (UTES) systems should be used. UTES would improve the energy mix in the NA countries, and support the international efforts dealing with GHG emissions.

In UTES systems the underground is used for heating and cooling. Sometimes it is used directly for space heating and cooling but usually heat or cold is actively stored for later use. In UTES some kind of duct (pipe) system is used to inject or extract heat from the ground. Thermal energy is then stored and recovered by heating and cooling of the ground, while the ducts are the heat exchangers of the system.

The duct system could be placed horizontally or vertically (e.g. in boreholes) in the ground [20]. In many cases heat pumps or cooling machines are included in the systems but in favourable cases, such as in the North African climate, the ground can be used directly for heating and cooling. Then, only a circulation pump is used to pump water through the underground duct system with high efficiencies. Such systems can also be used for thermal energy storage, during shorter periods (diurnal) or even between the seasons.

Sweden has considerable experience in ground coupled systems, theoretically and practically, and there are presently more than 300,000 systems in operation in Sweden, mainly for heating. Most of these are small-scale heating systems for single-family houses but during the last decade several hundred large-scale systems have been built for heating and cooling of commercial buildings. Approximately 20% of the total Swedish heating demand (100 TWh) is extracted from such UTES systems.

In 2005 Sebha University and Luleå University of Technology started a Libyan-Swedish collaboration to develop and implement such systems for the North African climate.

## 2 SUMMARY AND CONCLUSIONS

There is an increasing demand for energy of the NA region, related to the growth of the economy and population. Despite the fact that, the region has a great potential for RE its present contribution is very low. Some promising efforts (Governmental plans) have been made to make the use of renewable energy a standard practice. Producing and exporting clean electricity out of the abundant resources of the region is an achievable vision. UTES technology is expected to play an important role in the future energy system by reducing the power demand for space heating and cooling in the region. UTES is expected to enable a large scale RE utilization and a well balanced diversified energy mix of the countries of the region.

## REFERENCES

- [1] Encyclopaedia Britannica, North Africa, 2006. [www.eb.com](http://www.eb.com)
- [2] EIA 2006. [www.iea.org/statistics](http://www.iea.org/statistics)
- [3] IEA, [www.wbcsd.org](http://www.wbcsd.org)
- [4] IEA 2006, [www.iea.org/statistics/index.htm](http://www.iea.org/statistics/index.htm)
- [5] IEA 2006, [www.iea.org/statistics/index.htm](http://www.iea.org/statistics/index.htm)
- [6] Cedare, Centre for Environment and Development for the Arab Region and Europe, Water for 21<sup>st</sup> Century: Vision to Action, Framework for Action for North Africa (FFA).
- [7] Middle East and North Africa, Economic Developments and Prospects 2006, Financial Markets in a New Age of Oil, Middle East and North Africa Region, Office of the Chief Economist.
- [8] EIA March 2005, Country Analysis Briefs, [www.eia.doe.gov/emeu/cabs/Algeria.html](http://www.eia.doe.gov/emeu/cabs/Algeria.html)
- [9] MEDSUPPLY, Development of Energy Supplies from the Southern and Eastern Mediterranean Countries, final report, 2003.
- [10] EIA, April 2006, Country Analysis Briefs, [www.eia.doe.gov/emeu/cabs/Maghreb.html](http://www.eia.doe.gov/emeu/cabs/Maghreb.html)
- [11] Library of Congress - Federal Research Division, Country Profile: Morocco, April 2005.
- [12] C. Kauffmann, 'Energy and Poverty in Africa', OECD Development Centre, [www.oecd.org/dev/insights](http://www.oecd.org/dev/insights)
- [13] Library of Congress- Federal Research Division, Country Profile: Libya, April 2005.
- [14] M. Badawi, 'Electricity Landscape and Market Globalization: Options and Challenges for the Arab World', Arab Fund for Social and Economic Development, Kuwait. World Energy Council, 18<sup>th</sup> Congress, Buenos Aires, pp. 1 – 18, October 2001.
- [15] General Electric Company of Libya (GECOL), Annual Report, 2005.
- [16] T. Tin, C. Giannakopoulos and M. Bindi, 'Climate Change impact in the Mediterranean Resulting from a 2 °C Global Temperature Rise', A Report for WWF, July 2005.
- [17] J. Margat and D. Valle, 'Mediterranean Vision on Water, Population, and the Environment for 21<sup>st</sup> Century', 2000.
- [18] M. Geyer, Report on the SolarPACES START, Mission to Algeria, September 2003.
- [19] G. Knies, 'Trans-Mediterranean Renewable Energy Cooperation TREC', Paper for Arab Thought Forum and Club of Rome, Amman, Jordan, 2003.
- [20] B. Nordell and M.A. Grein, 'UTES for Space Heating and Cooling in North Africa', Paper presented at the Second International Conference on Energy and Environment, Tripoli, Libya, 2006.