



# Nuclear electricity for sustainable development: Egypt a case study

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## ABSTRACT

Egypt is a fast growing country with 78.9 million population and annual per capita installed power 0.286 MW as of July 2008. Moderate to mature population and economic growth trends forecast population and annual per capita installed power to reach 111 millions and 0.63 MW, respectively by 2032; and 128 millions at per capita power of 1.02 MW by 2052. With these trends in consideration installed electricity generation capacity are forecasted at 70 GW by 2032 and 132 GW by 2052 as compared to the 2008 installed power of 22.6 GW. Meeting these demands is almost impossible using known limited national fossil fuel reserves. Current electricity generation policy exhausts about 65% of country's total fossil production. Crude oil reserves are expected to deplete by 2012, while gas reserves will be overstrained starting from 2030. A major policy shift towards the use of non-fossil resources is to be adopted. In the article Egypt's major primary energy resources are evaluated. Electricity generation plans till 2022 are presented and an electricity generation strategy based on gradual introduction of nuclear power starting from 2018 is outlined. A balanced generation mix based on 72.7% fossil, 13% nuclear and 14.3% renewables is targeted by 2052. The mix is supposed to meet Egypt's electricity needs by 2052 and to improve country's energy sustainability.

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## 1. Introduction

Energy is a major drive of modern economic development. With the increase of world population, more energy is required to satisfy rising human needs to maintain welfare. Improving of living standards and prolongation of human life itself depends, in the average, on the energy consumption per person. Moreover the demand for energy grows as more developing countries enter industrial and service stages of their development. In Egypt, as everywhere, energy plays a substantial role in country's economic development contributing to macroeconomic variables as gross domestic product (GDP), commodity exports and investments. On the other hand, Egypt as a developing fast growing country suffers from rapid annual population growth currently at a rate of 1.68%. As of July 2008, the population of Egypt was estimated as 78.9 millions [1]. According to the Cairo Demographic Centre, Egypt's population is expected to reach 110 millions by 2031 and 128 millions by 2051 [2]. Such a fast population growth along with other environmental challenges is overstraining the limited energy resources of the country. As is clear from Table 1, a carefully tailored energy policy is to be implemented to attain sustainable development.

## 2. Egypt energy profile

Primary sources of energy in Egypt include crude oil and natural gas, hydropower, in addition to the new and renewable energy represented in the solar and wind energy. The state had adopted plans to establish electronuclear stations that produce electricity through nuclear means [3,4].

### 2.1. Crude oil and natural gas

Crude oil reserves in Egypt mainly concentrate in the Gulf of Suez, the Sinai Peninsula and the Western Desert. Egypt's crude oil reserves stood at 3.7 billion barrels in 2007. Oil production in million barrels per day (Mb/d) was 0.61 in 1980, peaked at 0.93 in 1996, and has since been in decline reaching 0.66 in 2007. Production is expected to drop to 0.6 Mb/d in 2010 and to 0.5 Mb/d by 2030. In contrary, domestic demand for oil has been in steady increase from 0.26 Mb/d in 1980 to 0.65 Mb/d in 2007. With closing the gap between production and consumption, Egypt is expected to become a net oil importer in the very near future, even with the new discoveries. Most recent estimates figures net oil imports to reach 0.51 Mb/d by 2030 [5].

Natural gas reserves lie mainly in the Nile Delta, north of Western Desert and the Mediterranean. With natural gas (NG) the picture looks different. NG is distinguished to become a major primary energy resource in Egypt's energy profile. A steady increase has

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**Table 1**  
Egypt's population and electric power indicators (2007–2052).

	2007	2012	2017	2022	2027	2032	2037	2042	2047	2052
Population (million)	78.3	85.2	92.1	98.8	105.1	111.1	116.5	121.2	125.3	128.5
Per capita installed power (MW/c)	0.28	0.34	0.41	0.48	0.55	0.63	0.72	0.82	0.92	1.02
Total installed power (GW)	21.9	29.0	37.8	47.1	57.7	70.0	84.0	100	115	132
Installed power annual growth rate (%)	4.4	5.8	5.4	4.5	4.0	4.0	3.7	3.5	2.8	2.7

been observed during the period 1980–1999 rising from 0.03 trillion cubic feet (Tcf) in 1980 to 0.52 Tcf in 1999. A sharp increase in production took place during the period 1999–2006 due to extensive exploration activities with NG production at the level 1.86 Tcf in 2006. Production in 2007 stood at 7.5 billion cubic feet per day (Bcf/d) from 1.6 Bcf/d in 1991. Recent analysis estimates proven NG reserves at 66 Tcf, and probable – at 120–140 Tcf. Local NG consumption during 2006 accounted for ~68% of production. Major consumers were the thermal power plants accounting for ~65% of the total gas consumption [6]. Large industrial consumers have also been switching to gas including petrochemical, steel and fertilizer plants [7]. Table 2 summarizes data available on Egypt's oil/gas balance during the period 1997–2007.

## 2.2. Hydropower

Hydropower converts the energy of flowing water into electricity. It benefits from the potential energy difference between water levels before and after dams and barrages on River Nile and its branches and canals in driving turbines that generate electricity. Most of the available hydropower energy resources were exploited with the construction of plants at the Aswan Dam in 1960 and 1985, the Aswan High Dam in 1967, Isna Barrages in 1995, and Nag-Hammady barrages in 2008. Hydropower stations with installed capacity 615, 2100, 90 and 64 MW, respectively were installed and operated during the period 1961–2008. Now under construction is the Assuit Barrages and power station 40 MW expected to operate in 2009. Potential hydropower resources exist using other smaller barrages with total power ~36 MW [8]. This puts an upper bound of 2.945 GW for Egypt's hydropower resources. Table 3 summarizes status of hydropower electricity generating plants in Egypt.

## 2.3. Renewable energy

Promising renewable energy (RE) resources in Egypt include wind, solar and biomass with interest in applications going back to 1970. In early 1980s, a renewable energy strategy was formulated as an integral part of the national energy planning. The strategy has been revised in view of the projections for possible RE technologies/application options, available financing resources and investment opportunities. In 1986 New and Renewable Energy Authority (NREA) was established to act as the national focal point for expanding efforts to develop and introduce RE technologies to

Egypt. In April 2007, the Supreme Council for Energy adopted an ambitious plan which aims at covering 20% of the country's total electricity needs using RE by 2027 [9]. The plan opens the door for the private sector to play an active role in developing new and RE resources. The Egyptian electricity sector recently is drafting a new electricity act to encourage renewable energy utilization and private sector involvement in the process. According to new 2009 statistics of the Ministry of Electricity and Energy (MoEE), MoEE targets to satisfy 11.26% of the electric energy generation from RE sources (basically wind) by the year 2027 [10].

### 2.3.1. Wind energy

Coastal zones in Egypt enjoy high wind energy potential particularly at the Suez Canal and Red Sea coast. In 1988, a local wind farm with a capacity 400 kW was erected in Ras Ghareb. During the period 1992–1995 a pilot wind farm with total power 5.2 MW was erected in Hurgada, connected to the local city grid in 1993 and to the national electricity grid in 1998. A large scale wind farm started operation in 2000 with power 63 MW, connected to the national grid in 2001 and increased its power to 305 MW in 2007. A wind atlas for the Suez Canal – Red Sea zone and Egypt was issued in 2005 based on data collected during the period 1991–2001. The atlas shows the locations of most favorable areas for wind power generation. Favorable wind speeds of 9–11 m/s (at 50 m height) of sufficient strength and stability exist at Abu-Darag, Zaafarana, Ras Ghareb and El-Zeit Gulf. According

**Table 3**  
Hydropower electricity generating plants in Egypt.

Year	Installed power (MW)	Hydropower plant
1926	5.8 (abandoned)	Several mini plants in Fayoum Oasis
1960	345	Aswan-I
1967	2100	Aswan High Dam
1985	270	Aswan-II
1995	90	Esna
2008	64	Nag-Hammadi
2009	40	Assiut
Feasibility	20	Damietta branch
Feasibility	10	Rosetta branch
Feasibility	3.5	Zefta
Feasibility	2.5	Tawfiki head regulator
Total	2945	

**Table 2**  
Egypt's oil/gas balance.

	1997	1999	2001	2003	2005	2007
<i>Oil</i>						
Production (10 <sup>3</sup> barrels/d)	856	852	720	712	658	637
Consumption (10 <sup>3</sup> barrels/d)	531	563	544	561	604	680
Proved reserves (billion barrels)	3.70	3.50	2.95	3.70	3.70	3.70
<i>Natural gas</i>						
Production (B cubic feet)	477	518	867	1058	1501	7.5/d
Consumption (B cubic feet)	477	518	867	1046	1208	6.1
Proved reserves (T cubic feet)	20.36	31.50	35.18	58.5	58.5	66.0

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