

# Modeling and forecasting of electrical power demands for capacity planning

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## ABSTRACT

This paper describes the development of forecasting models to predict future generation and electrical power consumption in Jordan. This is critical to production cost since power is generated by burning expensive imported oil. Currently, the National Electric Power Company (NEPCO) is using regression models that only accounts for trend dynamics in their planning of loads and demand levels. The models are simplistic and are based on generated energy historical levels. They produce results on yearly bases and do not account for monthly variability in demand levels. The paper presents two models, one based on the generated energy data and the other is based on the consumed energy data. The models account for trend, monthly seasonality, and cycle dynamics. Both models are compared to NEPCO's model and indicate that NEPCO is producing energy at levels higher than needed (5.25%) thus increasing the loss in generated energy. The developed models also show a 13% difference between the generated energy and the consumed energy that is lost due to transmission line and in-house consumption.

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## 1. Introduction

Jordan is importing oil from neighboring countries to use for the production of power therefore the cost of production is high compared with similar cost in oil producing countries. This suggests that Jordan will remain as a net energy importing country, spending significant amount of its scarce hard currency resources on such imports. In 2005, oil and natural gas imports cost was approximately 58% of the total domestic commodities exports and about 24% of the gross domestic product. Primary energy resources consumed in Jordan include crude oil, natural gas and solar energy. However, imported crude oil and petroleum products constitute more than 97% of the annual rate of energy consumption in 2005. The domestic natural gas resource, which used to fuel  $5 \times 30$  MW gas turbines for electricity generation, satisfies less than 3% of the annual energy demand [1]. Recent energy forecasts show that primary energy demand will be about 8 and 10 million toe (tones of oil equivalent) in the years 2010 and 2015, respectively, reflecting a rapid trend of increase [1,2]. To meet this substantial growth in demand, large capital expenditures will be needed in all the energy sub-sectors.

Jordan will face major challenges in trying to meet the growing energy and especially electricity demands. While, concurrently, developing the energy sector in a way that ensures reducing the adverse impacts on the economy, the environment and social life.

### 1.1. Electricity generation and consumption sector

In 2005, the installed capacity was about 1906 MW. Of which 99.99% is thermal and the remaining small percentage represents renewable power generation systems. There are 21 power stations in Jordan: 15 plants belong to the power generation sub-sector and the remaining 6 plants are owned and operated by large industrial companies, e.g. fertilizers, cement, refinery and potash, with a total capacity of about 142 MW. Table 1 shows the operating power plants and their installed capacity belonging to the power sub-sector. About 54% and 37% of the installed capacity are conventional steam power plants and gas turbines, respectively.

The percentage of primary energy consumption that went for electricity generation, in 2005 was equivalent to  $2.37 \times 10^6$  toe compared with  $1.8 \times 10^6$  toe in year 2000 [1]. This is considered as the largest single consumer of primary energy in Jordan, of this about 93.6% was consumed in the Central Electricity Generation Co., power plants, which provide almost all the electric power to the national network. Table 2 shows a comparison of the types of fuel used in CEGCO's power plants for the years 2000 and 2005. Heavy fuel oil was the dominant fuel used before year 2003 because the two main, i.e. Aqaba and Hussein base load, power stations are conventional thermal plants employing Rankine steam cycle and were fuelled by inexpensive heavy fuel oil as the prime source of energy. But after the conversion of Aqaba thermal power plant to burn imported natural gas, heavy fuel oil consumption dropped significantly. In 2005, less than a quarter of the total electricity generated was produced using heavy fuel oil compared to about 87.9% at the beginning of this decade, which clearly

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**Table 1**  
Installed capacities (MW) of operating power plants in the year 2005

Power plant	Steam	Combined cycle	Gas turbines		Diesel engines	Wind turbines	Hydro units	Bio gas	Total
			Diesel fuel	Natural gas					
<b>CEGCO</b>	<b>1013</b>	<b>97</b>	<b>453</b>	<b>150</b>	<b>35</b>	<b>1.4</b>	<b>6</b>	<b>–</b>	<b>1755.4</b>
Aqaba	5 × 130						6		656
Hussein	3 × 33		1 × 14						396
Rehab	4 × 66		1 × 19						60
Rehab/combined cycle		1 × 97	2 × 30						297
Risha			2 × 100	5 × 30					150
Marka			4 × 20		20				100
Amman South			2 × 30						60
Karak			1 × 20		4.5				24.5
Aqaba central					10.5				10.5
Ibrahimiyyeh						4 × 0.08			0.32
Hofa						5 × 0.225			1.125
<i>Other organizations</i>	<b>27</b>	<b>–</b>	<b>100</b>	<b>–</b>	<b>17</b>	<b>–</b>	<b>6</b>	<b>1</b>	<b>151</b>
Samra power station			100						100
King Talal dam							6		6
Jordan bio gas company								1	1
Other	27				17				44
<b>Total</b>	<b>1040</b>	<b>97</b>	<b>553</b>	<b>150</b>	<b>52</b>	<b>1.4</b>	<b>12</b>	<b>1</b>	<b>1906.4</b>

**Table 2**  
Annual fuel consumption in CEGCO's power plants for the years 2000 and 2005

Fuel type	Energy consumed (in toe) for the year	
	2000	2005
Fuel oil	1478 × 103	0.655 × 103
Natural gas	218 × 103	1231.2 × 103
Diesel fuel	35 × 103	244 × 103

demonstrates that natural gas is becoming the prime fuel for the power generation sub-sector [3]. Diesel fuel is used mainly to supply gas turbines, which are operated only to satisfy electricity demands during peak-load periods and emergencies. Electricity harnessed via renewable sources, such as hydropower and wind, accounted for only a very small percentage. This was about 0.5% of the total electricity generated in 2005. Thus, the dominant role of steam turbines and natural gas fired gas turbines is leading to increased dependence on imported oil and natural gas.

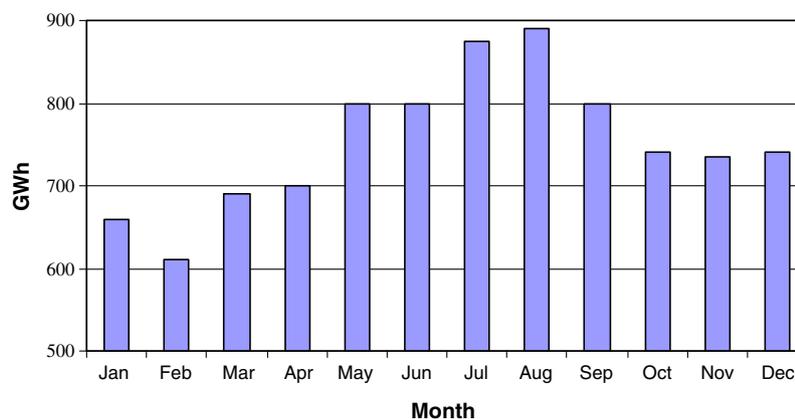
The system's peak load, in 2005, was 1751 MW compared with 1238 MW and about 440 MW in 2000 and 1985, respectively [4]. This represents an average annual growth of approximately 10%. The peak load always occurs late in the summer. This is due to the excessive use of air-conditioning and ventilation systems be-

cause of the dry climate and high temperatures, as well as being the holiday season for tourists and many returning Jordanians, who normally work abroad.

The total generated electricity in 2005 was 9653 GW h and about 983 GW h was imported from Egypt and Syria. The monthly-generated electricity is shown in Fig. 1, from which it can be seen that electricity demand is higher during the summer season.

During the year 2005, electricity consumption was 8712 GW h compared with 6133 GW h in 2000, with an average annual growth rate of approximately 10%. Fig. 2 shows the consumption of electricity by different sectors. It can be seen that the household and industrial sectors are the largest consumers with a joint share of 64.84%. The average annual consumption per capita was 1939 kW h compared with 1464 kW h in 2000 and approximately 950 kW h in 1985 [4].

The electrical power sector was recently privatised and as a result augmented into several companies, some of which is responsible for the generation of electricity, others for its transmission. There are six electricity generation-and-distribution companies in Jordan, but the Electricity Regulatory Commission and Ministry of Energy and Mineral Resources have ultimate authority over them. These are:



**Fig. 1.** Monthly electrical energy productions of CEGCO's power plants in 2005.

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