

Medium-range planning economics of future electrical-power generation options

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Abstract

In their continuous planning for load growth, electricity utilities search for the most economic generation schemes. But this will be subject to a number of constraints, such as the type of fuel available and compliance with national environmental standards. In this paper, medium-range planning economics of using alternative fuels options for electrical-power generation systems in Jordan is discussed. Imported natural gas, heavy fuel oil, coal and local oil shale are compared. A net-present-value model was used to compare electricity generation cost for different types of thermal power plants. Sensitivity analysis was performed to determine the influence of the most important variables, such as unit capital and fuel prices, discount and inflation rates. It was found that imported natural gas, as a future primary fuel, to supply new combined cycle and/or upgraded existing gas turbine stations, in Jordan, represents the best option during the study period.

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1. Introduction

Electricity utilities usually require that power plants to be available for operation with simple control and low operation and maintenance costs. But, typically, electricity power stations require high capital investments and long construction time of 3–5 years. Usually, they have an average economic life of about 25 years. Therefore, careful planning should be adopted in order to select the most appropriate generation technology and type of fuel to be employed. According to recent studies, electricity demand in Jordan is predicted to grow at an average annual rate of about 6%. The annual rate of electricity demand will reach 13,500 GWh and the maximum peak demand will be approximately 2200 MW by the year 2015 (Jaber et al., 2001a; National Electrical Power Company, 2001). In the future, the dependence on imported energy, such as heavy fuel oil, natural gas or coal, for electricity generation will continue to increase because it is unlikely to have sufficient local natural gas and/or other fossil fuels that can satisfy the total national demand. In Jordan, heavy fuel oil is the prime fuel used to supply thermal power stations, in addition to limited amount of local natural

gas that fired directly in small and open cycle gas turbines. There is no experience, locally or within the neighbouring Arab countries, concerning other fossil fuels, such as coal, oil shale and natural gas to fuel conventional steam and/or combined cycles.

In this paper, imported heavy fuel oil, natural gas and coal, which are the most likely fuels that can be employed in Jordan for electricity generation, are compared using the net-present-value analysis. In order to exploit indigenous oil shale deposits, one-generation unit utilising oil shale as the prime fuel is scheduled to come on line during the study period. It is not the aim of the current analysis to discuss issues relating to fuels combustion and their storage or environmental impacts on the global scale. But preliminary and important indicators are derived to draw attention of those working in energy planning and decision-making to predict electricity unit generating costs and possible improvements.

2. National energy supply and demand

2.1. Indigenous energy resources and primary energy consumption

Jordan is a poor country in terms of commercial energy sources. This suggests that Jordan will remain as

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a net energy importing country, spending significant amount of its scarce hard currency resources on such imports. In 2000, oil imports cost was approximately 42% of the total domestic commodities exports and about 10% of the gross domestic product (Ministry of Energy and Mineral Resources, 2001a). Primary energy resources consumed in Jordan include crude oil, natural gas and solar energy. However, imported crude oil and petroleum products constitute more than 96% of the annual rate of energy consumption in 2000 (Ministry of Energy and Mineral Resources, 2001a, b). The domestic natural gas resource, which used to fuel 4×30 MW gas turbines for electricity generation, satisfies less than 4% of the annual energy demand (Ministry of Energy and Mineral Resources, 2000). On the other hand, there are vast oil shale deposits in Jordan. The proven reserves are exceeding 4×10^{10} tonnes, and these are yet to be exploited (Jaber and Probert, 1997; Natural Resources Authority, 2000; Mamlook et al., 2001). In a recent study, shale oil prepared by pyrolysis of Jordanian oil shale was characterised and compared to crude oil and some refined product (Akash and Jaber, 2002). It was shown that shale oil compared well to crude oil and its heavy fractions.

Based on the present and likely future annual energy consumption, these deposits could satisfy national energy demand for several hundred years, if developed and utilised wisely. Thus, such an indigenous resource could have a major role in reducing Jordan's dependence on imported crude oil, petroleum products and natural gas.

2.2. National energy policy in the 21st century

Energy forecasts show that primary energy demand will be about 6, 8 and 10 million toe in the years 2005, 2010 and 2015, respectively, reflecting a rapid trend of increase (Jaber et al., 2001a; National Electrical Power Company, 2001; Ministry of Energy and Mineral Resources, 2001a, b). To meet this substantial growth in demand, large capital expenditures will be needed in all the energy sub-sectors. The main highlights of the Jordanian energy sector, during the study period, includes:

- Demand and supply projections reveal that indigenous primary energy production will decrease in the future, and the share of imported energy will increase progressively.
- As a long-term strategy, it is planned to select imported natural gas as the future fuel for power generation, and this will be included in the energy-mix in 2005.
- In order to reduce the financial burden resulting from importing energy, it is expected that the government will pay more attention towards developing and

exploiting indigenous resources. These include the utilisation of oil shale and renewable sources to empower electrical-power plants.

- For planning purposes a capacity of about 100–130 MW could be imported as an additional reserve and considered to be available from the interconnection with Egypt and Syria.

In summary, 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.

2.3. Electricity generation and consumption

In 2000, the installed capacity was about 1660 MW. Of which 99.99% is thermal and the remaining small percentage represents hydropower and wind turbines. About 65% and 28% 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 2000, was equivalent to 1.8×10^6 toe compared with 1.75×10^6 toe during the previous year (National Electrical Power Company, 2001; Ministry of Energy and Mineral Resources, 2001a, b; Central Electricity Generation Company, 2001). Which is considered as the largest single consumer of primary energy in Jordan, of this about 93% was consumed in the Central Electricity Generation Co. power plants, which provide almost all the electric power to the national network. The latest annual consumption consists of 1478×10^3 tonnes of heavy fuel oil; 218×10^3 toe as natural gas; and 35×10^3 tonnes of diesel fuel. Heavy fuel oil is the dominant fuel used because the two main, i.e. Aqaba and Hussein base load, power stations are conventional thermal plants employing Rankine steam cycle and fuelled by inexpensive heavy fuel oil as the prime source of energy. In 2000, about 87.9% of the total electricity generated was produced using heavy fuel oil (Central Electricity Generation Company, 2001). Diesel fuel is used mainly to supply gas turbines, which are operated only to satisfy electricity demands during peak-load periods and emergencies: its share was 2% and 1.06% for electricity generated in 1999 and 2000, respectively (Central Electricity Generation Company, 2000, 2001). 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 2000 compared with 0.25% in the previous year. Thus, the dominant role of steam turbines and diesel-fuel fired gas-turbines is leading to increased dependence on imported oil: less than 11% of the electrical-power generation, at present in Jordan, arises

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