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Impact of oil prices, economic diversification policies and energy conservation programs on the electricity and water demands in Kuwait

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HIGHLIGHTS

- Kuwait-specific electricity and water demand model is presented.
- Strong association between oil income and electricity and water demands.
- Rate of change of electric load per US dollar oil price change is 0.13 GW.
- Rate of change of water demand per US dollar oil price change is 3.0 MIGD.
- By 2030, efficiency lowers electric load and water demand by 10 and 6%, respectively.

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ABSTRACT

This paper describes the influences of oil revenue and government's policies toward economic developments and energy efficiency on the electricity and water demands. A Kuwait-specific electricity and water demand model was developed based on historic data of oil income, gross domestic product (GDP), population and electric load and water demand over the past twelve years (1998–2010). Moreover, the model took into account the future mega projects, annual new connected loads and expected application of energy conservation programs. It was run under six circumstances representing the combinations of three oil income scenarios and two government action policies toward economic diversification and energy conservation. The first government policy is the status quo with respect to economic diversification and applying energy conservation programs. The second policy scenario is the proactive strategy of raising the production of the non-oil sector revenue and enforcing legislations toward energy demand side management and conservation. In the upcoming 20 years, the average rates of change of the electric load and water demand increase are 0.13 GW and 3.0 MIGD, respectively, per US dollar oil price increase. Moreover, through proactive policy, the rates of average load and water demand decrease are 0.13 GW and 2.9 MIGD per year, respectively.

1. Introduction

Decision-making, planning, and strategy development in the electricity and water production sectors are based on mid- to long-term demand forecast. In Kuwait, the main source of fresh water is desalination, which is a byproduct process of electricity generation, and hence, electricity and water are considered as one sector. The sector's production strategy is based on the demand analysis under different socio-economic, technological, and demographic development scenarios.

Abbreviations: A/C, air conditioning; BEF, building envelope factor; *D*, non-oil sector diversification factor; *E*, energy; EE, energy efficiency; *f*, fertility factor; F_{GDP}, GDP factor; GDP, gross domestic product; GW, giga watt; KPC, Kuwait Petroleum Corporation; *L*, loss factor; MEW, Ministry of Electricity and Water; MW, mega watt; MIGD, million imperial gallon per day; MSF, multi-stage flash; NEC, National Energy Council; N_{HK}, population of the non-Kuwaiti household labor force; N_K, Kuwaiti population; N_{nK}, non-Kuwaitis in independent households; *OP*, oil price; *P*, electricity power demand; P_{HP}, electricity power demand for the new housing project; P_{ICG}, industrial, commercial and governmental electricity power demand; P_{nKCap}, electricity power demand per capita for the non-Kuwaiti population; P_R, residential electricity power demand; P_{RK}, Kuwaiti residential electricity power demand; P_{RKCap}, Kuwaiti residential electricity power demand per capita; P_{RnK}, non-Kuwaiti residential electricity power demand; PR, power rating; *R*, reduction factor of non-Kuwaiti population; *Rf*, roof performance; RO, reverse osmosis; R_{Oil}, oil revenue; S_e, electricity saving in existing buildings; S_n, electricity saving in new buildings; S_R, residential electricity savings; S_{eW}, water saving in existing buildings; S_{nW}, water saving in new buildings; S_{RW}, residential water savings; *W*, water demand; W_{ICG}, maximum industrial, commercial and governmental water demand; *Wl*, wall performance; *Wn*, window performance; W_R, maximum residential water demand; W_{RnK}, non-Kuwaiti residential water demand; W_{RK}, Kuwaiti residential water demand; *Y*, year; *Z*, total annual water demand

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Table 1
Examples of macro-based demand modeling methods.

Method	Study	Drivers (Model inputs)	Historical data	Forecasted years
Artificial neural networks	Kankal et al. (2011)	GDP, population, import, export	1980–2007	2008–2014
	Alsayegh et al. (2007)	GNP, population, A/C system factor index, number of buildings, historic peak demand	1976–1999	2000–2025
Regression	Bianco et al. (2009)	Historical electricity consumption, GDP, GDP per capita, population	1970–2007	2008–2030
	Ediger and Akar (2007)	Consumption data for hard coal, lignite, asphaltite, wood, animal and plant remains, oil, natural gas, hydropower, geothermal heat and electricity, and solar	1950–2004	2005–2020
Regression-genetic programming	Lee et al. (1997)	GDP, population, historical demand	1961–1980	1980–1990
Linear and nonlinear models with Particle Swarm Optimization	Amjadi et al. (2010)	GDP, population, number of electricity consumers, ave. electricity price	1980–2000	2001–2006
Linear probabilistic model	Imtiaz et al. (2006)	GDP, population, electricity consumption per capita, number of electricity consumers, peak electricity demand	1993–2003	2004–2013

Demand forecasts are attained through the simulation of a model that is run under various scenarios. The model systematically relates the specific electric load and water demands to the corresponding social, economic, and technological factors that affect these demands. There are various demand forecasting methods with different approach and demand drivers. Depending on the availability of data, time era, socio-political, economic and technological aspects of a country or region, a specific model is developed. In general, there are two main approaches which are the micro and macro demand models (Bhattacharyya and Timilsina, 2009; Fu and Nguyen, 2003). The micro approach, which is also known as the bottom-up or end-use approach, is represented by economic-engineering models in which technology indicator drivers are utilized for the demand model development. This approach attempts to capture the impact of energy usage patterns of various devices and systems. The micro models for electricity demand focus on various uses in the residential, commercial, industrial, and agriculture sectors of the economy.

The macro modeling approach, which is also known as the top-down approach, follows an aggregated view of the influence of the economic, demographic and social behavior on the demand. It relies on econometric modeling techniques utilizing linear, non-linear, regression (linear and non-linear) or artificial neural networks method. Table 1 cites examples of macro-based demand modeling studies.

It is observed that the drivers (or model inputs) differ from one study to another. The main reason for this diversity is that each study was carried out for a specific country (or region) within a particular time frame era. Hence, the driver variables were selected based on their influence on the demand within specific locations and time frames. Some studies included the historic demand as an input to embed a “memory” in the model for the demand trend profile. Such models are utilized in countries in which the demand development has been steady (i.e., no unexpected or prompt changes). Some studies have used additional or redundant economic parameters, such as, GDP per capita, import and export, in addition to GDP. Although the import and export are embedded within the GDP, their influence on the demand, in some countries, is more intense. Air conditioning systems require, relatively, high energy, and some studies, carried out in countries with hot climates where A/C systems are widely used, included A/C system parameters in the modeling procedure. In countries where the cost of electricity is not subsidized (or has low subsidy), the electricity tariff is considered an important driver affecting the demand. In many regions, the cost of the imported primary fuel (oil and gas) has a direct effect on the cost of the electricity, and hence, on the demand. Some studies included the number of buildings as a driver since a building space requires cooling/heating services and other energy-consuming equipments.

Long-term demand modeling and forecasting is a challenging procedure with respect to the precision of the forecast demand values. Unprecedented factors (wars, financial crisis, political changes, etc.) that may take place within a country, region, or/and the world can radically affect the demand drivers and, hence, influence the demand. Therefore, demand modeling must be carried out periodically to account for such changes. Demand drivers must be reviewed annually for the purpose of retrofitting, adding, or/and eliminating these drivers. Consequently, the demand model structure might further be developed to accommodate such changes.

A number of energy and electricity demand modeling studies were carried for Kuwait. Each study used a distinctive set of socioeconomic drivers which were justified to serve the study's goal. Marzouk (1979) conducted a study to model and forecast energy demand from 1980 to 1990. The analysis focused on the relation between subsidy in all energy forms, i.e., electricity, gas, gasoline, etc. Results showed that the demand was influenced by the overall growth of the economy and not by the short-term price variations. Burney et al. (1993) carried out a study of which one of the aims was to model and forecast electricity and water demand up to the year 2005. The forecasting was carried out for the residential, industrial, commercial, and government sectors. A sector-specific demand econometric regression model was developed. It was found that electricity and water consumption were highly correlated with the household income. Al-Enezi et al. (2004) estimated the total, per capita, and peak load demands for electricity in Kuwait for up to 2010. The aim of the study was to define the relationship between the demand, from one side, and the electricity tariff, tariff collection rate, immigration policies, building codes cases, and economic performance. Hajeeh et al. (2006) developed an energy demand model for Kuwait to forecast the energy demand up to 2015. The main analysis was focused on the influence of the energy tariff on the demand.

This paper presents an electricity and water demand model (macro-based model) that forecasts the demand up to 2030 and analyses the influence of oil prices, economic diversification, and energy conservation policies on the demand. The proposed model was developed in a project to outline a strategy to exploit renewable energy sources in Kuwait (Alsayegh et al., 2012). The model was only utilized to forecast the demand up to 2030. The model takes into account political and economical changes that were not considered in earlier studies and have direct and strong influence on the demand. Such political and economical changes include:

- The rise of oil prices after 2005. The nominal oil prices between 1992 and 2005 ranged between US ($) 20 and 40. After 2005 the oil prices soared and reached about $135 in 2008.