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Fuel consumption efficiency for electricity and water production in Abu Dhabi

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A R T I C L E I N F O

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A B S T R A C T

Middle eastern countries are good examples of the strong link between energy and water. Indeed, most power plants are operated on a cogeneration mode and most of the water produced is a desalinated water. With growing economies and population, the demand for natural gas in the power and water sectors is increasing at sustained rates. Understanding the main drivers for the fuel consumption along with the associated (in)efficiencies is critical for designing policies aimed at rationalizing the use of natural gas. The Emirates of Abu Dhabi in the United Arab Emirates is used as a case study to quantify the effects of some key operational, economic and region specific gas consumption features on the gas requirements in the power and water sectors. A multilevel Divisia Index decomposition between 1990 and 2010 is used in this regard. We found that energy intensity has a major contribution to fuel requirements which indicates there is a room for potential efficiency improvements and fuel savings. The results show the contributions of power generation plants efficiency, annual demand profile and power requirements for water production (auxiliaries) to the fuel consumption. A monthly profile of the contributions of such factors shows the seasonality impact on the performance of the power and water production system.

1. Introduction

At the end of 2013, proved gas reserves in the Middle East are estimated at 80.3 trillion cubic meter (TBCM), around 43% of proven world reserves [1]. Gas exports from the GCC countries date back to the seventies; the first LNG plant in the GCC was built in UAE in 1977 for export to Japan. On the other hand, gas demand in the GCC countries has been increasing at sustained rates. Gas utilization for the electricity and water production, in the petrochemical and the aluminum industries, for injection into oil wells (Enhanced Oil Recovery) along with exports are the main demand segments. The increasing gas usage has translated into a looming gas shortage in the region. Kuwait and the emirate of Dubai in UAE are importing LNG and plans for new regasification facilities or expansion of existing ones are discussed. This new reality highlights the importance of consumption efficiency as a sustainability measure. Understanding the different factors driving gas consumption is important for policy analysis and decision.

In this article, we use a multilevel Divisia approach to analyze gas consumption in the electricity and water sectors in the 1990–2010 period. The aim is to quantify the effects of some key operational, economic and region specific gas consumption features on the gas requirements during the 1990–2010 period. Typical region specific features include the high seasonality due to high summer temperatures and humidity compared to the winter season. Consequently, water production costs are higher in the winter. This is because most of the water in the region is a desalinated water. The demand for water is in general less seasonal than electricity generation (Fig. 2) and since most of the power plants are operating on a cogeneration mode, there is not enough electricity demand (in the winter season) on the gas turbines in order to optimize the steam turbines output.

Decomposition techniques are widely used for the analysis of factors affecting changes in aggregate environmental and energy indicators. Liu et al. [2] proposed the general parametric Divisia method. Different methodologies based on the Divisia method are found in Refs. [3–5]. The multilevel Divisia decomposition was introduced in Ang [6]; it can be used to analyze "industrial energy consumption at two levels of sector disaggregation or more" for example. In our case, we use a multilevel Divisia decomposition to capture the effect of seasonality by considering months instead of sectors.

The Logarithmic Mean Divisia index (LMDI) method was proposed by Ang and Choi [7]. Multiplicative LMDI, proposed as the preferred index decomposition method, has been used extensively

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in energy and environmental analysis, Ang et al. [8–14]. In terms of applications, the Divisia Index methodology is used in energy intensity analysis and environmental emissions studies at a regional, country or on sectorial levels [16–18]. To our best knowledge, it has not been used to capture seasonality effects and the associated (in) efficiencies.

We use the LDMI type I [19] which is recommended for general use. Both annual and chain time series decompositions are used. Time series decompositions are useful to detect patterns and structural breaks and chain computation is recommended compared to period wise decomposition [15].

The remaining of this article is as follows: Section 2 gives a description of the electricity sector in Abu Dhabi. Section 3 is a description of the methodology to assess the evolvement of the fuel consumption in the electricity and water sectors. Section 4 is a discussion of the results then Section 5 concludes.

2. Electricity and water production and fuel consumption in Abu Dhabi

The economy of the United Arab Emirates (UAE) is the second largest in the Arab world after Saudi Arabia. Its gross domestic product (GDP) is estimated at $377 billion in 2012. Abu Dhabi, one of the seven emirates of the UAE has 95% of the UAE's proven oil reserves and 92% of UAE's gas reserves. Abu Dhabi GDP (constant 2007 $) has increased from 65 billion $ to 155 billion $ in the 1980–2010 period. During the same period, oil GDP has increased by 185% while non-oil GDP has increased by 337% [20]. The economic growth in Abu Dhabi was accompanied by a sustained increase fuel consumption for electricity production. Fig. 1 shows the annual electricity generation and the fuel consumption for the 1990–2010 period [21]. It should be highlighted that after 2005, Abu Dhabi started exporting electricity to Northern Emirates. As will be seen from the results of the decomposition, this export effect has impacted the fuel consumption positively.

As in all GCC countries, demand for electricity in Abu Dhabi is highly seasonal because of high summer temperatures and humidity compared to the winter season. This seasonality along with the fact that production of water in a cogeneration mode with electricity, affect the performance of the producing plants. Indeed, since water production is less seasonal than electricity generation (Fig. 2), there is not enough electricity demand on the gas turbines (in the winter season) in order to optimize steam generation for the thermal desalination system. This leads to production inefficiencies and higher water costs productions.

3. Data and methodology

We use a multilevel Divisia Index approach (LMDI type I) to assess past contributions of some identified factors to the total fuel consumption for the production of electricity and water in Abu Dhabi.

All the data (fuel consumption, generation) used is published on the Abu Dhabi Water and Electricity Annual Statistical Report [21]. GDP values are from the Abu Dhabi Statistical Centre [20].

To use the multilevel Divisia approach, we first start by defining the identity linking the fuel consumption to the variables that we want to use for the explanation of the variation of such a consumption. In our case, we decompose the annual fuel consumption using the identity as in (Eq. (1)).

$$f = \sum_{i=1}^{12} \frac{fi}{Gi} \frac{Gi}{Ni} \frac{Ni}{N} \frac{N}{GDP} GDP, month \quad \mathrm{i} = 1 \ldots 12 \tag{1}$$

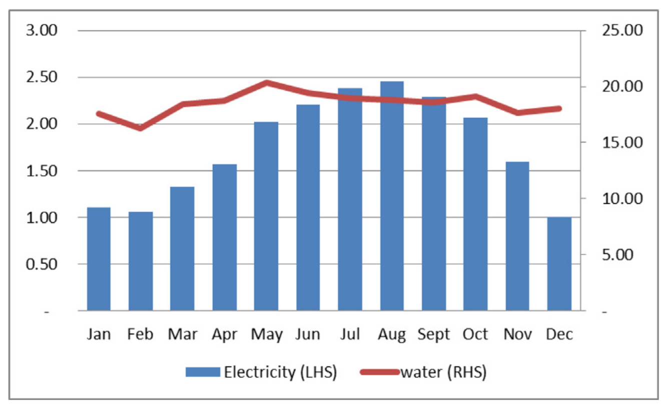

Fig. 2. Typical electricity generation (TWh) and water production (billion gallon day) profiles (2010 data).

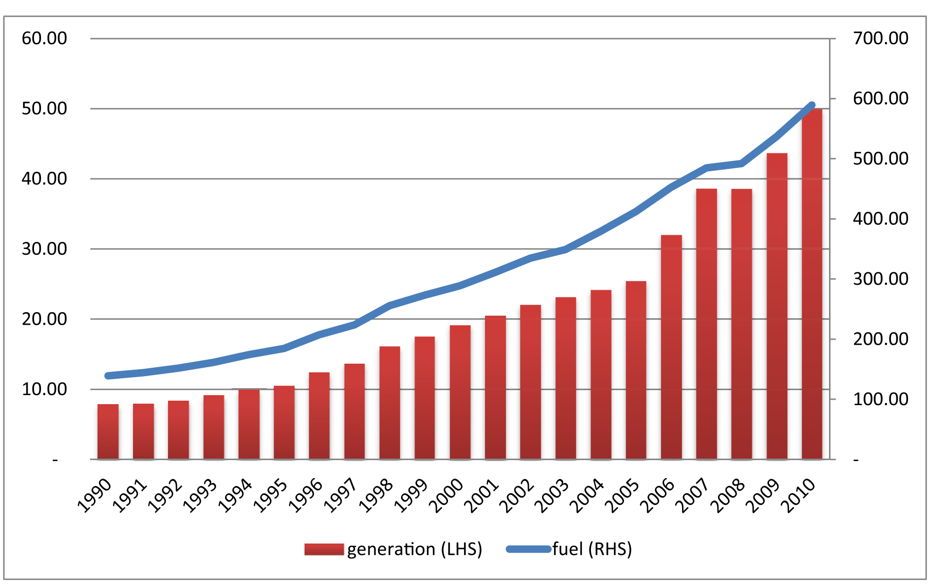

Fig. 1. Electricity generation (TWh) and fuel consumption (Trillion Btu).