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Review analysis of economic and environmental benefits of improving energy efficiency for UAE building stock

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ABSTRACT

In the United Arab Emirates (UAE), buildings consume almost 90% of the total electricity used in the country. This paper provides a comprehensive overview of recent trends in energy consumption in the building sector as well as current efforts in promoting energy efficiency within UAE. Moreover, the paper explores available opportunities to improve energy efficiency of the UAE building sector. In particular, the impacts of three levels of energy retrofits are quantified based on results from existing literature and an optimization-based bottom-up analysis for residential, commercial, and governmental buildings. The analysis indicates that any level of energy retrofit for the existing building stock can be effective in reducing energy consumption and peak power demand as well as in lowering carbon emissions for UAE. It is estimated that a basic energy retrofit program applied to existing UAE building stock could achieve savings of 7550 GWh/year in electricity consumption, 1400 MW in peak electricity demand and reduce carbon emissions by 4.5 million tons/year per year. The program would have an average payback period of less than six months for the UAE government and would generate almost 9000 job-years.

1. Introduction

For several decades, United Arab Emirates (UAE), like most of its neighbors in the Gulf Cooperation Council (GCC), has one of the highest energy consumption per capita in the world. The main factors contributing to this high consumption include low energy prices, rapid economic growth, extreme climatic conditions, and improved standard of living. Over the last decade, UAE has initiated several initiatives to promote energy efficiency and renewable energy technologies to reduce its reliance of carbon-based energy resources and diversify its economy. In particular, most of all new buildings are now mandated to comply with specific energy efficiency requirements. Specifically, two rating systems have been established and applied since 2010 to ensure sustainable design and operation for all new buildings in Abu Dhabi using the Green building regulations [1] and in Dubai using Pearl rating system [2]. Moreover, and in order to improve energy efficiency of its existing building stock, Dubai has created Etihad Energy Services (EES) in 2013 using the energy performance contracting approach by initiating energy efficiency retrofit projects for more than 30,000 buildings. The target for EES is to achieve 1.7 TWh in energy savings from building retrofits by 2030. Recently, EES, the first performance contract company in the GCC region, has retrofitted several governmental buildings with over 50 energy conservation measures [3]. The retrofit projects have an estimated combined payback period of 6 years and have reduced annual energy consumption for the refurbished buildings by 31% representing 5.0 GWh of electricity use per year. Other retrofit projects specific to commercial buildings in Dubai have shown a reduction of 23% in annual energy consumption [4].

A recent study has outlined some economic and environmental benefits as well as common challenges for adopting renewable energy technologies in UAE [5]. In addition, consequences of global warming on energy consumption of UAE residential buildings have been evaluated and reported [6]. However, the impacts of implementing large-scale energy efficiency programs for the UAE building stock have not been analyzed in details. Only limited case studies outlining the benefits associated with specific energy efficiency technologies and measures of new and existing UAE buildings have been reported in the literature. For instance, addition of thermal insulation is found to reduce energy consumption up to 30% for a residential villa in Dubai [7]. More recently, passive building envelope systems have been estimated to reduce energy consumption of UAE residential buildings by up to 30% [8]. Advanced envelope systems including green roofs and climatic interactive façade systems have been also evaluated for specific buildings. It has been indicated that their implementation can reduce cooling

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thermal loads by 20% [9]. An analysis of common lighting retrofit options in governmental buildings has indicated that the installation of occupancy sensors can result in 10% energy use reduction, while, daylighting sensors with dimming controls can achieve 25% lighting electricity use savings [4]. Recently, the incentives and motives of occupants in adopting energy conservation measures have been assessed in a university campus in Abu Dhabi [10].

In recently published studies, social and environmental benefits of large-scale energy efficiency programs for the building sector have been assessed in addition to their economic impacts for select countries [11–13]. In particular, the cost-effectiveness of large-scale energy efficiency programs have been evaluated mostly in the US and Europe using a wide range of analysis approaches [14,15]. In this paper, the benefits of large-scale energy efficiency programs for both new and existing UAE building stocks are estimated based on a review of the exiting literature as well as a new optimization-based bottom-up analysis [16]. In particular, the economic, environmental, and social impacts of the energy-efficiency programs are quantified to inform decision makers on the effectiveness of various building energy efficiency programs. First, the paper describes the national energy consumption trends within UAE by building type and end-use. Then, the current UAE efforts to improve the energy efficiency of new and existing buildings are summarized. Finally, a comprehensive analysis of the benefits and impacts of large-scale energy retrofit programs of existing UAE building stock is presented.

2. Overview of energy demand and the buildings sector

2.1. Trends in electricity energy consumption

Over the last decade, the electricity consumption by UAE has increased significantly following a significant growth in its population as indicated in Fig. 1(a). It should be noted, however, that the per capita electricity consumption has actually decreased over the last few years most likely due to the significant increase in UAE population attributed to the influx of foreign workforce as clearly shown in Fig. 1(b) [17]. This growth in the population as well as in energy consumption has increased the requirements for electrical power to meet UAE national needs especially in the growing residential sector.

The United Arab Emirates (UAE) is a federated country established in 1972. It consists of seven emirates: Abu Dhabi, Ajman, Al-Fujayrah, Dubai, Sharjah, Ummal Qaywayn and Ras Al Khaymah. The country's electricity sector underwent significant development during the 1990s, especially in Abu Dhabi, the state's largest emirate and holder of more than 90% of its oil reserves. In particular, Abu Dhabi Water and Electricity Authority (ADWEA) was created in 1998 to oversee and manage water and electricity generation and distribution. The power sector was divided into seven specialized electricity companies, including four generation companies (gencos), one transmission company (transco) and two distribution companies (discos). At the same time, the Abu Dhabi Water and Electricity Company (ADWEC) was established to maintain a monopoly over wholesale trading. It acts as a central buyer of all electricity and water produced, which it sells to the discos. In addition, the Regulation and Supervision Bureau (RSB), Abu Dhabi's regulatory body, was established to oversee technical regulations including grid codes, safety standards, technical and performance standards. Today, most of the electricity and water produced come from independent water and power providers (IWPPs) under long-term power and water purchase agreements (PWPAs). Even after the privatization of IWPPs, the government still retains full ownership of the monopoly businesses of procurement, transmission and distribution.

In addition to ADWEA, there are three other water and electricity authorities in the UAE, including DEWA serving mostly Dubai, FEWA (Federal Electricity and Water Authority) serving northern emirates Ajman, Al-Fujayrah, Ummal Qaywayn and Ras Al Khaymah, and SEWA for Sharjah. Most of the UAE's electricity is generated and consumed by

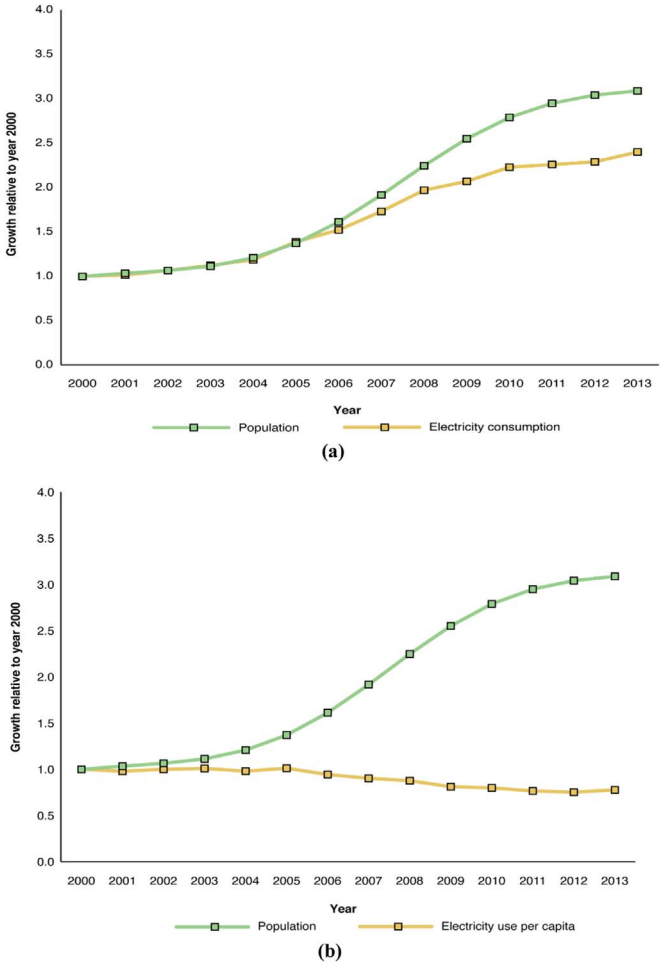

Fig. 1. Variation of (a) population and electricity consumption, and (b) population and per capita electricity consumption, 2000–2013.

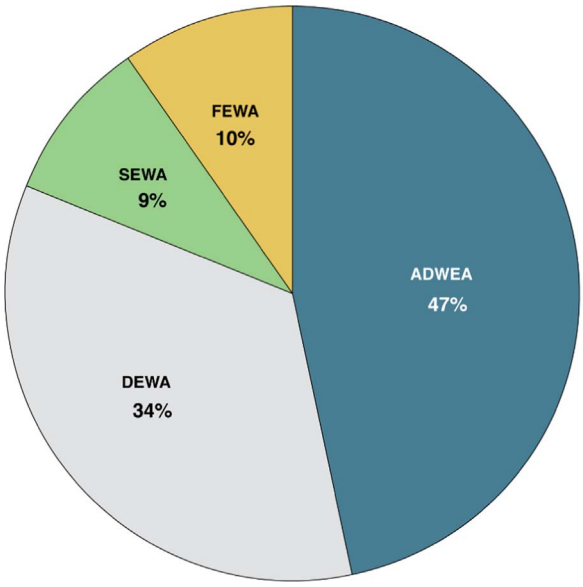

Fig. 2. Distribution by UAE authorities of the annual electrical consumption in 2013.

two authorities, Abu Dhabi's ADWEA and Dubai's DEWA. These two authorities account for more than 80% of the total annual electricity used in the country in 2013, as shown in Fig. 2 [18–20].

In 2013, the UAE had a combined generation capacity of