

Residential Electricity Consumption in the State of Kuwait

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Abstract

To mitigate climate change in Gulf Cooperation Council (GCC) countries, it is vital to understand how energy is being consumed in the different sectors. The GCC countries rely heavily on fossil fuel to meet the increasing demand for electricity especially from the residential sector. Consumption of fossil fuels has several impacts on the environment including the increase of carbon dioxide, a major contributor to climate change. Several measures exist to reduce electricity demand from the residential sector. These measures range from regulatory, technology, economic and information measures. To achieve successful adoption of these measures, a holistic understanding of the drivers and impacts of the growing trend of residential electricity consumption is required. This paper aims to understand the drivers and impacts resulting from the increase in the residential electricity consumption in Kuwait, one of the GCC countries. A Driving forces-Pressures-State-Impacts-Responses (DPSIR) framework is applied. Several indicators related to the socio-economic factors, energy consumption, energy intensity and carbon intensity are calculated using quantitative data for the period from 2000 to 2015. The results of analysis show that the increase in the residential electricity consumption is mainly driven by population growth and economic development. This has resulted in an increase in the fossil fuel consumption and the consequent CO₂ emissions. This paper recommends conducting a residential electricity consumption survey to provide data required to inform decision making on energy saving in Kuwait. This recommendation is also extended to other GCC countries where a regional database can be developed to share experiences related to reducing residential electricity consumption.

Keywords: DPSIR; GCC; Indicators; Residential energy consumption survey

Introduction

Climate change is strongly linked to the consumption of fossil fuel [1]. In 2015, the world produced 13.6 GT of oil equivalent (GTOE), 82% of which is fossil fuel. The amount of energy produced increased by 55% in 2015 compared to 1990; the share of fossil fuel remained unchanged, though (81% of total energy mix) [2]. In the Gulf Cooperation Council (GCC) countries, reliance on fossil fuel becomes considerably heavy. The GCC countries produce 23% of the world's total oil production and 11% of its total natural gas production. It also has a considerable share of the world's oil and natural gas reserves (39% and 21%, respectively) [3]. Fossil fuel is the main source used for electricity generation in the GCC countries. Electricity generated from renewable resources made only around 0.1% in 2015. The consumption of electricity in the GCC countries is relatively high when it comes to per capita consumption as it ranged between 6.6 MWh in Oman and 20.2 MWh in Bahrain in 2015 [2]. Moreover, the heavy reliance on fossil fuel for electricity generation has contributed to the relatively high per capita carbon emissions in the GCC countries. Five of the six GCC countries are in the top ten countries in the world in the per capita carbon emissions [4]. With commitments towards Paris Agreement signed and ratified by most of the GCC countries to reduce their carbon emissions, along with being committed to the achievement of the Sustainable Development Goals (SDGs), reducing electricity consumption in GCC countries becomes imperative.

Reducing electricity consumption from the residential sector appears promising for the GCC countries. The residential sector consumes considerable amount of electricity ranging between 27% in Bahrain and 64% in Kuwait of the total electricity generated in the GCC countries. This share exceeds that of the world (27%), OECD (31%) and non-OECD countries (23%) [2]. Literature cites several measures to reduce electricity consumption in the residential sector. These measures can be grouped into two main categories: demand side management measures and supply side management measures. Examples for measures from

the former category include electrical load management and use of renewable energy sources to produce electricity. On the other hand, measures from the latter aim to reduce electricity consumption from the end-users, meaning the residential sector in this case. Examples for this category include setting energy performance and efficiency standards, electricity tariff reforms, energy labelling, smart metering and behavioral change [1]. These sets of measures have been implemented widely in the world. Examples for implementation in the GCC countries also exist, including setting minimum energy efficiency standards for air conditioners in Bahrain, reforming electricity residential prices in Abu Dhabi and establishing an Energy Efficiency Center in Saudi Arabia in 2010. Nonetheless, measures to reduce electricity consumption in the GCC countries in general and in the residential sector in particular need to be carefully chosen in accordance with the socio-economic and political context of these countries. Furthermore, this should be done in response to the drivers to the high consumption in the first place. Accordingly, this paper aims to understand the drivers and impacts for electricity consumption in the residential sector in Kuwait, which is relatively a small country located in north-west Asia. The area of Kuwait is 17,817 km² with more than 4 million inhabitants. As other GCC countries, the economy of Kuwait relies heavily on revenues from oil exports. Results from this paper can be of use to inform selection of appropriate measures to reduce electricity consumption in the residential sector in Kuwait. Indicators calculated in this paper can be used to develop a national database that includes all relevant indicators

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to help monitoring change in the trends of these indicators. The analysis results may also be generalized to other GCC countries as they share

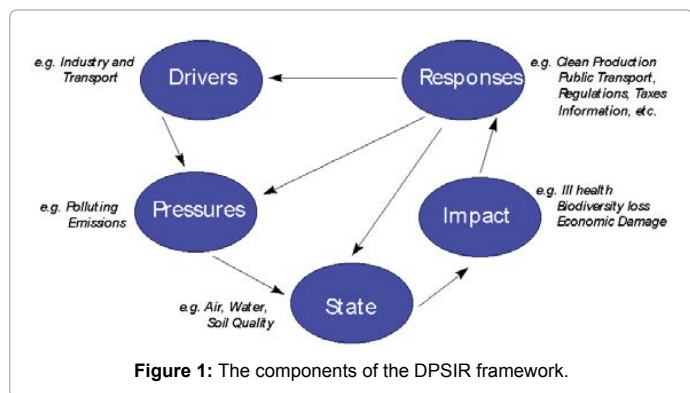


Figure 1: The components of the DPSIR framework.

many socio-economic and political characteristics. This paper consists of four sections. Having tackled the introduction, the second section sheds light on methodology used to achieve the aim of this paper. The results and discussion are presented in the third section, whereas the main conclusions are delivered in the final section.

Methodology

To provide a holistic picture on the increasing consumption of electricity in the residential sector in Kuwait, a Driving forces-Pressures-State-Impacts-Response (DPSIR) framework is applied. The DPSIR framework has originally been developed by the European Environment Agency (EEA) as a modified version of the Pressure-State-Response (PSR) model (Figure 1) [5,6]. The DPSIR framework is an analytical framework that is used for assessing environmental-related issues. It uses indicators to identify historical trends of drivers and impacts of a selected issue. The DPSIR framework shows the links of causes of

DPSIR component	Indicators	How indicators were calculated	Data used for calculation
Drivers and Pressures (D & P)	Population growth	$\text{Annual growth rate} = \frac{\text{Change of the population between 2000 and 2015}}{\text{Total population in 2000}} * 100$	Total population for the period from 2000 to 2015
	Economic growth	$\text{Annual growth rate} = \frac{\text{Change of the GDP number between 2000 and 2015}}{\text{GDP in 2000}} * 100$	The GDP (constant US\$) for the period 2000-2015
	Weather	$\text{Change in monthly average temperature} = \frac{\text{change of monthly average temperature between 2000 and 2014}}{\text{Monthly average temperature in 2000}}$	Average monthly temperature for 2000 and 2014.
	Subsidized electricity price	$\text{Percent of subsidized electricity} = \frac{\text{Cost of electricity production paid by the government}}{\text{Residential electricity tariff}} * 100$	Cost of electricity production and residential electricity tariff
State (S)	Share of residential electricity consumption of the total consumption	$\text{Share of residential electricity consumption} = \frac{\text{Residential electricity consumption}}{\text{Total electricity consumption}} * 100$	Total electricity consumption and residential electricity consumption during 2000-2015
	Residential electricity consumption	$\text{Per household residential electricity consumption} = \frac{\text{Total residential electricity consumption}}{\text{Total population}}$	Total residential electricity consumption for the period 2000-2015
	Per capita residential electricity consumption	$\text{Per household residential electricity consumption} = \frac{\text{Total residential electricity consumption}}{\text{Total population}}$	Total residential electricity consumption and total population in 2015
	Per household residential electricity consumption	$\text{Per household residential electricity consumption} = \frac{\text{Total residential electricity consumption}}{\text{Total number of households}}$	Total residential electricity consumption and number of households in 2015
Impacts (I)	Use of fossil fuel for electricity generation	$\text{Annual growth rate} = \frac{\text{Change of the fossil fuel used to generate electricity between 2000 and 2015}}{\text{Total fossil fuel used to generate electricity in 2000}} * 100$	Total fossil fuel used for electricity generation between 2000 and 2015
	Per capita CO ₂ emissions	$\text{Per capita CO}_2 \text{ emission} = \frac{\text{Total CO}_2 \text{ emissions in Kuwait}}{\text{Total population}}$	Total CO ₂ emissions and total population
	Energy intensity	$\text{Energy Intensity} = \frac{\text{Total primary energy in supply Kuwait}}{\text{GDP}}$	Total primary energy supply and the GDP
	Carbon intensity	$\text{Carbon Intensity} = \frac{\text{Total CO}_2 \text{ emission in Kuwait}}{\text{GDP}}$	Total CO ₂ emissions and the GDP
Responses (R)	Phase-out of indecent light bulbs Starting from the 1 st of August 2017		
	Energy awareness campaigns		
	Update of the Energy Conservation Program in 2014		
	Use of renewable energy to generate electricity		
	Set targets for renewable energy penetration		

Table 1: Analysis of indicators related to causes, impacts and responses of the increasing residential electricity consumption in Kuwait using the DPSIR framework.

the issue and its impacts on the environment using correlations and indicators. The use of indicators helps monitoring change that occurs in relevant factors and how the implementation of specific measures contributes to changing the state. The use of indicators also contributes to benchmarking and conducting comparisons with the best practices. Results from the DPSIR inform decision makers on the quality of the environment and the consequences of policies implemented in the past [7]. In the DPSIR framework, the 'D' and 'P' refer to direct and indirect causes of an issue, which is the rapidly growing electricity consumption in the residential sector in Kuwait in this case. The 'D' and 'P' can be used separately as indicated in the original framework developed by the EEA, or they may be combined as they appear in the current literature. The 'S' in the DPSIR framework represents the current state of the selected issue, whereas the 'I' refers to impacts resulted from the current state. The impacts can include impacts on environment, economy or society. The last component of the DPSIR framework is the 'R' which represents actions and policies adopted in response to impacts, causes or state of the issue. In this paper, indicators used in the DPSIR framework were collected from relevant literature (Table 2) [2,8-10]. Data required to calculate these indicators was obtained from national sources including the Ministry of Electricity and Water, Central Statistical Bureau in addition to international organizations such as the World Bank and International Energy Agency. Time series data were collected for the period from 2000 to 2015.

Results and Discussion

Drivers and pressures

The analysis results indicate several drivers to the high electricity consumption in Kuwait. Firstly, the availability of fossil fuels has encouraged the increasing generation of electricity to meet demands without worrying about energy security or energy prices issues [11].

Being blessed with one of the largest oil and gas reserves in the world, Kuwait has no problem increasing the supply of electricity to meet the increasing demands from different sectors. Furthermore, the population growth and economic growth have both acted as drivers to the high demand on electricity ($r=0.95$ and 0.96 , respectively). Figure 2 shows the increase in the number of population and Gross Domestic Product (GDP) during the period from 2000 to 2015. The number of residential electricity consumers has increased as well by 5% in average per year between 2000 and 2015 reaching more than 500 thousand consumers. Another important factor that significantly affects the electricity demand is weather ($r=0.62$). The weather in Kuwait is hot and humid in summer, where the average temperature is around 38°C in August with a maximum of 50°C . The temperature drops in winter to 7°C in average in February with a minimum of 1°C . The average monthly temperature has increased by 1.9% between 2000 and 2014 [12]. Rainfall is relatively low in Kuwait with around 100 mm in winter (Figure 3). The harsh weather of Kuwait along with the population number growth and economic growth that attracted workers from outside the country is all factors that have contributed to the increase of the demand of the residential electricity consumption in Kuwait. Although the increase of the number of consumers contributes significantly to the increase of demand, the rapid increase was also due to the consumption pattern and lifestyle. The electricity tariff for the residential sector is highly subsidized in Kuwait. The government subsidizes around 95% of the electricity production cost [13]. This has directly influenced the dramatic per capita and per household consumption as illustrated next.

State

Electricity generation has been increasing by 5.1% on average per year over the period from 2000 to 2015. The per capita electricity consumption reached 14.2MWh in 2015 (Figure 4) [14]. This figure is close to many other GCC countries (such as United Arab Emirates

	Driving forces and Pressures	State	Impacts
	<ul style="list-style-type: none"> - Population growth - Economic growth - Weather - Subsidized electricity price 	<ul style="list-style-type: none"> - Share of residential electricity consumption of the country's total consumption - Residential electricity consumption - Per capita residential electricity consumption - Per household residential electricity consumption 	<ul style="list-style-type: none"> - Use of fossil fuel for electricity generation - Per capita CO₂ emissions - Energy intensity - Carbon intensity
Responses considered		<ul style="list-style-type: none"> [Technology] Phase-out of incandescent light bulbs [Information] Energy awareness campaigns [Regulatory] Update of the Energy Conservation Program 	<ul style="list-style-type: none"> [Technology] Use of renewable energy to generate electricity [Regulatory] Set targets for renewable energy penetration
Other potential policies	[Economic] Electricity tariff reforms for the residential sector	<ul style="list-style-type: none"> - [Information] Create a database for energy-relevant data - [Technology] Fix smart meters - [Information] Develop labeling system for electrical appliances - [Regulatory] Setting minimum energy efficiency requirements for electrical appliances - [Information] Develop building labeling system - [Other] Conduct energy survey for the residential sector 	

Table 2: Responses to causes and impacts of increasing electricity consumption in the residential sector in Kuwait.

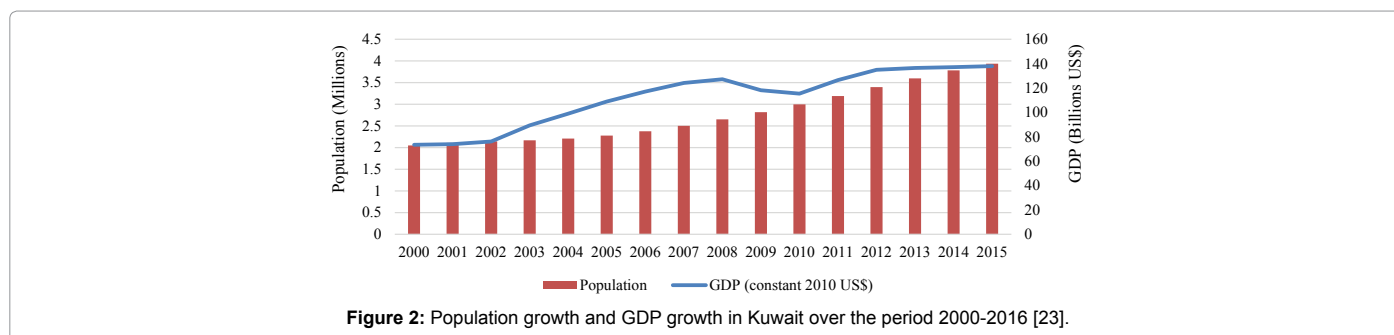


Figure 2: Population growth and GDP growth in Kuwait over the period 2000-2016 [23].

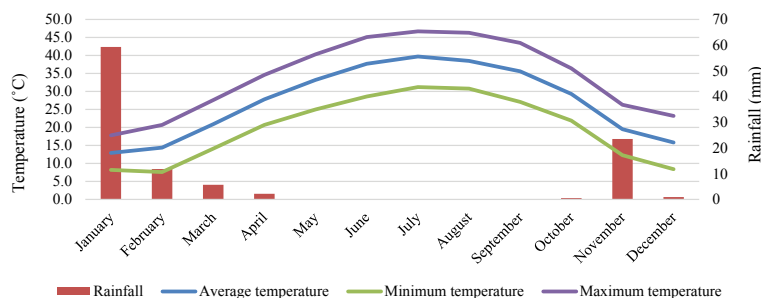


Figure 3: Temperature and rainfall in Kuwait in 2014 [12].

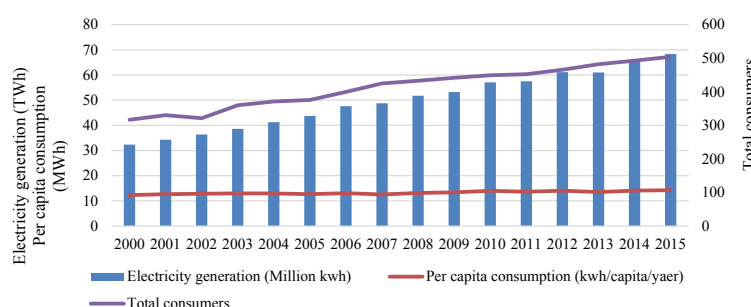


Figure 4: Electricity generation, per capita electricity consumption and number of consumers during 2000-2015 [14].

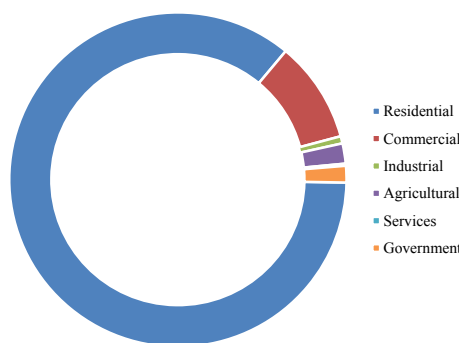


Figure 5: Percentage of electricity consumers in 2015 [14].

and Saudi Arabia); however, it is significantly high when compared to Oman (6.6 MWh/capita/year), for example. It is also significantly higher than the world's average (3 MWh/capita/year), OECD (8MWh/capita/year) and non-OECD countries (2 MWh/capita/year) [2]. The share of the residential electricity consumption has slightly decreased in 2015 reaching 64.5% compared to 66.8% in 2000. The residential electricity consumption amounted to 27 TWh in 2015 with residential electricity consumers making up around 86% of the total electricity consumers (Figures 5 and 6) [2,14]. The relatively high electricity consumption in the residential sector in Kuwait has reflected on the per household and per capita residential electricity consumption which amounted to 45 MWh and 7,000 KWh, respectively in 2015. These figures are considerably high when compared to a number of selected countries Figures 7 and 8. The Identification of indicators that illustrate the state of residential electricity consumption in Kuwait shows that although the increasing trend is in line with that found in other GCC countries, it is significantly greater than many of the world countries. This has impacts on the environment and economy as elaborated next.

Impacts

There are several impacts resulting from the rapid increase in the electricity consumption in general and that of the residential sector in Kuwait in particular. The first impact concerns the consumption of non-renewable fuel resources used for electricity generation including crude oil, oil products and natural gas. The consumption of fuel used in power plants has increased by an average of 4% between 2000 and 2015 (Figure 9). This has resulted in a growth of the country's total CO₂ emissions, per capita CO₂ emissions, carbon intensity and energy intensity (Figure 10); figures for the residential sector are not available, though. The impacts of the increasing electricity generation include loss of opportunity cost as well. Although figures for lost opportunity cost are not available for Kuwait yet, we believe that these would be relatively high. Lost opportunity costs include the opportunity to reduce electricity consumption and then benefit from revenues of exports of saved fossil fuel. Opportunity cost also includes cost of electricity generation as the actual cost of generating 1 KWh in Kuwait is around

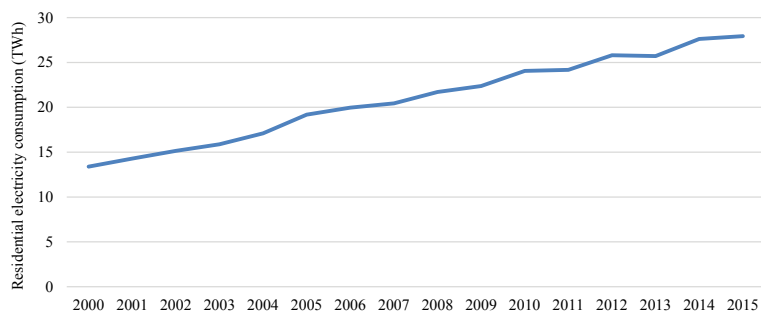


Figure 6: Residential electricity consumption in Kuwait between 2000 and 2015 [2].

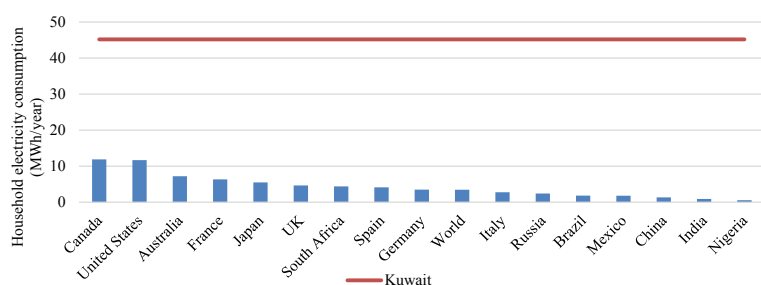


Figure 7: Residential electricity consumption per household in selected countries compared to Kuwait [15].

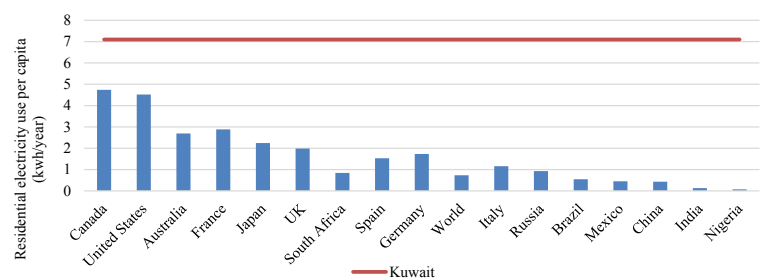


Figure 8: Residential electricity consumption per capita per year in selected countries compared to Kuwait [2].

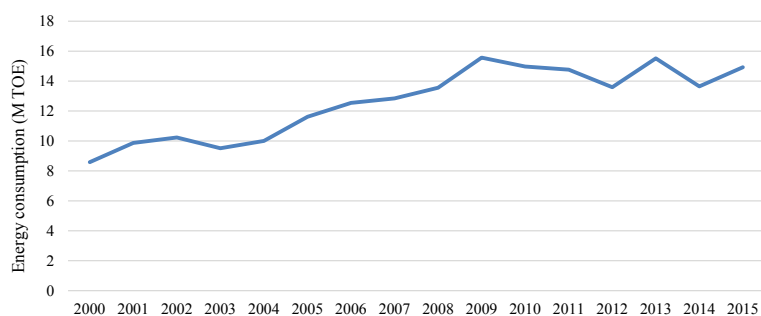


Figure 9: Energy consumption of power stations (million TOE) [2].

40 fils whereas residential electricity tariff is only 2 fils/KWh only as shown in the next sub-section.

Responses

In response to the increasing demand on electricity, several actions were taken based on the drivers, state and impacts of this

issue. Table 2 shows how these responses align to the different components of the DPSIR framework. The responses range from regulatory policies, to economic and technology policies. For instance, a ban on the imports of the incandescent light bulbs was enacted starting from August 2017 to reduce residential electricity consumption. Additionally, the Ministry of Electricity and Water in

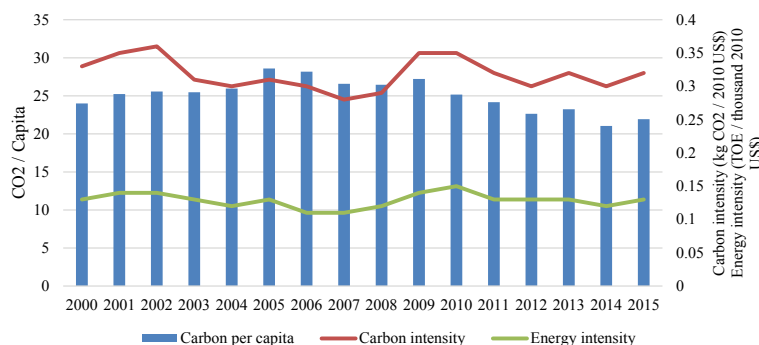


Figure 10: CO₂ emissions per capita, carbon intensity and energy intensity in Kuwait between 2000-2015 [2].

Period	Consumer type, fils/kwh
Up to 30 September 1953	All consumers: 27
From 1/10/1953 to 31/3/1955	All consumers: 18
From 1/1/1961 to 30/4/1961	Up to 200 units: 7.5 , 2000 to 4000 units: 6 , In excess of 4000 units: 4.5
From 1/5/1961 to 31/3/1964	Ordinary consumers: 6 Industrial and Agricultural consumers: 4
From 1/4/1964 to 31/5/1965	Ordinary consumers: 5 Industrial and Agricultural consumers: 4
From 1/6/1965 to 31/5/1966	Ordinary consumers: 3 Limited income groups: 2
From 1/6/1966	Ordinary consumers: 2 Industrial companies: 1
Until 16/5/2016	State facilities: 2 Supported industrial companies:1 Chalets: 10
From 16/5/2016 (different start dates for the sectors)	Investment properties: Up to 1000: 5, 1001-2000: 10, In excess of 2000: 15 State facilities and Commercial consumers: 25 Industrial consumers: 10 Agricultural consumers: 10 Other consumers: 20 Reactive power: 3 fils/kvarh

Table 3: Development of electricity tariff in Kuwait [18,19].

Kuwait has organized several campaigns to raise awareness towards energy saving in different governorates of Kuwait. Moreover, several policies were introduced in attempt to reduce electricity consumption in the building sector in general in Kuwait. These policies include the update of the Energy Conservation Program in 2014, the use of renewable energy to generate electricity and the setting of renewable energy penetration targets. However, there are other policies that can be considered to reduce residential electricity consumption in Kuwait (Table 2). The review of literature on climate change mitigation shows a considerable number of measures that can be considered to reduce residential electricity consumption. The first recommended measure is related to reforming electricity tariff for the residential sector to encourage rational use of electricity. The historical development of the electricity tariff shows a decreasing trend for the tariff since 1953 (Table 3). In 2016, the tariff was revised for all consumers; however, it remained unchanged for the residential sector. The highly subsidized residential electricity tariff (95%) encourages unsustainable consumption patterns [16]. Thus, revising the residential electricity tariff is highly recommended for Kuwait. Other recommended measures include provision of information that helps consumers to

make green purchase behavior through energy labelling. Fixing smart meters would also be useful in addition to conducting residential electricity consumption surveys to identify opportunities for energy savings and provide data required to inform decision making on energy saving in Kuwait. Kuwait's Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC) suggests additional measures including fixing building-integrated PV systems, developing building rating system, providing incentives for renewable energy, and adopting appliance efficiency standards. The same report has also assessed the effectiveness of two measures to reduce the electricity consumption from the building sector in general. These options are adopting the green buildings concept that can achieve a 10% reduction in the electricity consumption by 2020 and using a district cooling system that can reduce electricity consumption by 4,000 GWh by 2018 [17]. Although the above-mentioned measures can contribute to reducing the residential electricity consumption in Kuwait, it is imperative to understand consumption pattern related to residential electricity use. In specific, it is worthy to understand consumer behavior related to the purchase of electric appliances. This contributes to prioritizing electric appliance for setting energy efficiency standards and labeling. It also helps simulating electricity consumption in the residential sector in Kuwait. Understanding the consumption patterns also offers the opportunity to consider setting variable electricity tariff rates for the residential sector where a higher rate is charged for peak times and a lower rate for the off-peak times. It would also be beneficial to conduct a residential electricity consumption survey in Kuwait. Such surveys are conducted in many countries including some Arab countries such as Saudi Arabia, Palestine and Jordan [20-22]. This is to have a full understanding of the sector prior to having any energy-relevant policies set in place. Sharing experiences with other Arab countries allows for policy learning and facilitates adoption of similar surveys in the GCC countries.

Conclusion

This paper shed light on the residential electricity consumption in Kuwait using the DPSIR framework. Results showed the potential for implementing several measures and policies to reduce the electricity consumption in the residential sector in Kuwait. For future studies, this paper recommends investigating the electric appliances ownership, the resident energy consumption behavior and how these are correlated with the socio-economic factors of the residents. This study also recommends the collaboration between the GCC countries with regard to conducting residential electricity consumption surveys and assessment of potential measures.

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