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Understanding energy demand in Kuwaiti villas: Findings from a quantitative household survey

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ABSTRACT

Residential buildings in Kuwait account for almost 60% of the country's national electrical power generated, considerably greater than all other sectors or building types. This paper identifies key drivers of energy use in Kuwaiti villas based on a survey of 250 households undertaken throughout the six districts of Kuwait. The survey consists of a cross-sectional interviewer-administered questionnaire designed to gather detailed information about building physical characteristics, occupants' socio-demographic background and energy-use behaviours. Survey data is analysed using both statistical descriptive methods and multiple linear regression analysis to identify key determinants of energy consumption in a sample of Kuwaiti villas. Analysis indicates that an occupant driven cooling behaviour (air-conditioning thermostat temperature set points) is the major driver of energy use, followed by the number of rooms and the number of occupants. Together, such drivers significantly explain 32% of the variability in energy consumption Survey findings provide descriptive information about Kuwaiti households and insights into the key drivers of energy use to better inform further research and policy interventions in this field.

1. Introduction

The energy consumption of the Kuwaiti residential building sector is amongst the highest (per capita) in the world [1]. Residential energy use accounts for almost 60% of the country's national electrical power generated, considerably greater than all other sectors or building types [2]. The rapidly rising consumption associated with this sector is presenting serious energy security challenges for the Kuwaiti government, especially in light of the country's growing population and demand for housing [1,3,4]. In its latest National Development Plan (2015–2020), the Kuwaiti government announced plans to construct 45,000 new units - largely in the form of villas – by 2020 [5]. Although such ambitious housing projects are essential to meet the demands of a growing population they require significant additional production of electricity, especially as current installed capacity (14,702 MW) is very close to peak demand (11,220 MW) [2]. This is particularly challenging as power generation is primarily oil-based and rising electricity demand will increasingly undermine the country's hydrocarbon export capacity and national income [6].

Energy efficiency policy interventions to control wasteful residential consumption are therefore essential. To effectively plan and implement such interventions a thorough understanding of the factors that drive household energy use is needed [7–9]. In Kuwait however, despite the magnitude of residential energy use, there is very limited data and research available in regards to characteristics of the housing stock, its fabric, energy consuming equipment, the disaggregation of energy use, and occupants demand for services. No detailed household survey describing the composition of the national housing stock, dwelling sizes, form and fabric characteristics, building services and appliances used, thermal characteristics and energy use, has been published to date. Building census data from various government agencies provide only limited information regarding dwelling type, count and year of build. Similarly, although a mandatory Energy Conservation Code of Practice for Buildings has been enforced since 1983, there is very little evidence of its impact in practice [6,10].

To better assess the potential for efficiency improvements and demand reduction in Kuwaiti homes, a comprehensive household survey was undertaken in March 2015. The survey aimed to gather and analyse data describing physical and social characteristics of Kuwaiti homes and provide insight into key drivers of domestic energy use. Information about household socio-demographic characteristics, building form and fabric characteristics, space conditioning and water usage, lighting and electrical appliances, and electricity consumption was collected using a cross-sectional interviewer-administered questionnaire from a sample of 250 homeowners/household representatives throughout the six districts of Kuwait.

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Table 1
Number of residential buildings and units in Kuwait, 2013.

Villas		Flats		Courtyard houses	Palaces
Government	Private	Government	Private		
56,536 (19%)	49,228 (17%)	1088 (0.4%)	169,727 (57%)		
105,764 (36%)		170,815 (57%)		20,984 (7%)	47 (0%)

Source: [16]
Note: The percentage of the total stock for each dwelling type is reported in parentheses.

Table 2
Average energy use by flats and villas in Kuwait.

Kuwait					UK (2013)	
		Electricity use (2009)				
Dwelling type	Number of dwellings	Percentage of total residential energy use	Average kWh/dwelling/annum	Average kWh/m²/dwelling/annum	Average kWh/dwelling/annum	Average kWh/m²/dwelling/annum
Villas	105,764	88%	145,444	264	4170: electricity 14,829: gas Total: 18,999	209
Flats	170,815	12%	20,278	127		

Source: [17,18].
Note: Villas include both private villas and government villas. Average kWh/m²/dwelling for villas in Kuwait has been calculated based on an approximate floor area of 550 m², and for flats 160 m².Average kWh/m²/dwelling in the UK has been calculated based on an average dwelling size of 91m² [19].

The survey has made two important contributions to the residential energy demand research field in Kuwait:

1. It represents a novel attempt to develop a comprehensive information base about the physical and social characteristics of Kuwaiti villas at a national level (about which published data is virtually non-existent.)
2. It provides insight into potential drivers of energy use in Kuwaiti villas to better inform future research and policy developments in this field.

2. Literature review

2.1. Residential energy consumption in Kuwait: causes, concerns and interventions

Following the discovery of oil in Kuwait in 1938, the state entered an exceptional period of economic development and wealth that significantly impacted the residential building sector and its energy use [11]. Today the residential building stock consists primarily of large villas and smaller flats in mid-high rise apartment buildings (Table 1). More than 80% of Kuwaiti nationals live in villas [12] of which there are two main types: government and private. Government villas are designed and built by the Public Authority for Housing Welfare (PAHW – the agency responsible for setting and implementing national housing policies), while private villas are often partly financed by the PHAW but commissioned by the homeowner. Mid-high rise apartment buildings mainly house the expatriate population, which reside in Kuwait on a temporary basis and are not normally allowed to own property. This study focuses on villas as they account for a significantly greater portion of electricity use compared to flats (Table 2), are the main housing type for Kuwaiti nationals, and constitute the bulk of future PAHW housing projects.

A number of factors have contributed to the high electricity consumption by residential villas in Kuwait. These include the government's generous welfare and energy subsidy program, a rapid growth in the population (with an average annual growth rate of 3.1% [5]), municipality building codes progressively allowing for an increase in dwelling sizes (in 1996, 2002, and 2012), and the country's harsh summer climatic conditions (with average temperatures of 38 °C, and maximum temperatures reaching higher than 50 °C) [6,11,13,14]. The energy subsidy programme facilitates high energy use consumer behaviour and the air conditioning of large homes designed with little consideration of energy efficiency [4,13,14]. The Energy Subsidy Programme was established in 1962, and currently subsidises 95% of the cost of energy to the final consumer. Residential consumers are charged a rate of KD 0.002/kWh (equivalent to $0.01 at the time of writing) of the electricity generation cost of KD 0.047/kWh (equivalent to $0.16); a rate that has remained unchanged for over 50 years [6].

Recognizing the need to improve energy efficiency, the Kuwait Ministry of Electricity and Water (MEW) has, since 1983, enforced a mandatory Energy Conservation Code applicable to all new and renovated buildings [15]. This code, developed by the Kuwait Institute for Scientific Research (KISR) for the MEW, set minimum thermal insulation requirements for walls, roof, columns and glazing as well as peak power guidelines for air-conditioning units [15]. Although researchers at KISR estimate that a building constructed in full compliance with the 1983 code requires 40% less cooling [10], such estimations are based on modelling-based studies and little evidence of the code's impact exists in practice [6,10,11]. Similarly, despite changes in design and construction technology, and developments in building simulation software, the 1983 code was only updated in 2010 and again in 2014 to allow for more stringent guidelines.

Little organised, coherent, and accessible household-level data is available about the Kuwaiti residential building stock and its energy use. No national survey describing stock composition, dwelling sizes, form and fabric characteristics, building services, appliance ownership, thermal characteristics and performance, and energy billing data has been published to date. Only basic information about dwelling type, count, and year of build can be gathered from national statistics data published by the Public Authority for Civil Information (PACI) and building archival records from Kuwait's Central Statistical Bureau (CSB).

2.2. Drivers of residential energy use

A number of studies have been undertaken internationally in the field of residential energy demand, especially following the oil price adjustments that took place in the 1970s. Such studies have, through various methods, attempted to better understand the sector's energy use profile and the drivers that may influence this. Researchers have examined and established the impact of build-