A study into residential energy use in Adelaide metropolitan: determinants and effects on household's consumption

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Abstract
Energy consumption in residential buildings is a significant contributor to world energy use and related greenhouse gas emissions. Residential sector contributes to about one-fifth of global energy demand that stems from space heating, cooling, lighting and use of appliances in dwellings.
This paper builds on the existing literature on domestic energy use and examines the effects of various determinants on household energy consumption in Adelaide metropolitan area in Australia. Household characteristics, dwelling type and energy related behaviour are discussed as important drivers of household energy consumption.
Data collected from a survey of 300 households in 19 sample suburbs in Adelaide is used in this research. Sample suburbs consist of different types of development, dwelling type and demographic characteristics of residents. The results confirm the importance of these factors on residential consumption and it is expected that this study will lead to develop new policy guidelines towards cities become more sustainable.

Keywords: energy consumption, household characteristics, dwelling type, consumption behaviour

Introduction

Energy consumption is a significant element towards environmental policies addressing carbon reduction and global warming (Brounen, Kok, & Quigley, 2013). Roughly half of the world's populations live in cities and it is projected to reach 60% by 2030. As a consequence, the way cities manage energy consumption will be a key to a successful climate policy (Hallegatte & Corfee-Morlot, 2011). Since urban areas are currently the main energy consumers worldwide, energy consumption is an important element of strategies on urban environmental sustainability (Gu, Sun, & Wennersten, 2013).

Urban residential energy consumption is a significant contributor to world energy use and related greenhouse gas emissions, mainly because residential sector consume about one-fifth of global energy demand which stems from energy for space heating, cooling, lighting and running appliances in dwellings (Brounen, Kok, & Quigley, 2012).

Globally, household energy consumption grew by 20% between 1990 and 2006, accounting for almost 30% of total final consumption. Worldwide residential energy use is expected to increase by an average of 1.4% per year by 2030 (OECD, 2011).

Concerns about environmental impacts of residential energy consumption put household as the focus of policy agenda. So that study on household energy consumption and the way people use energy in their dwellings, offers an important opportunity for policy makers to develop the environmental and sustainable energy policies in order to conserve resources and to reduce carbon emissions.

Several studies have been undertaken in recent years documenting the determinants of energy consumption in various categories. Intergovernmental panel on climate change (IPCC, 2014) highlighted three arenas, namely behaviour, lifestyle and culture, technology and architecture, influencing household energy consumption. Ratti, Baker, and Steemers (2005) classified building energy consumption into four groups including urban geometry, building design, system efficiency, and occupant behaviour.

Kriström (2008) provided a review of the empirical literature on residential energy demand and categorised the variables influencing resident's energy use in two main groups: economic variables including income and energy price and non-economic variables including individual characteristics, household characteristics, information and weather. Kristrom (2008) found that income encompasses a large number of factors effecting energy consumption. For example, additional appliances which increase energy consumption are bought and used by higher income residents. A study by Australian Conservation Foundation (2007) argued however that, an increase in wealth could direct residents to buy higher quality and more environmental friendly products, in practice the opposite trend is observed.

In Australian cities, residential sector is an important component of total energy use as a result of fossil fuels based electricity generation, energy consumption in houses is one of the main contributor to national greenhouse gas emissions (ABS, 2010). Moreover, household energy use and related GHG emission has been increasing in recent years. A study undertaken by Kellet and Pullen (2012) has shown a significant growth in household annual energy use in past 30 years, particularly because of increasing floor area in new dwellings and increasing use of appliances by households. ABS (2015) findings demonstrated that household sector's net energy use increased 4.18% between 2008-09 and 2012-13. Energy use in this sector is projected to increase in the coming decade due to the increasing number of housing, increasing average floor space, declining number of people per household and use of more electrical appliances and equipment (ABS, 2010; Department of Infrastructure and Transport, 2010; Newton & Meyer, 2011).

Given that there is an extensive academic literature exists on household energy consumption, this field of academia is still new in Australia. Lenzena et al. (2006) investigated the household energy requirement on sustainable household consumption from global perspective in five countries (Australia, Brazil, Denmark, India and Japan). The results proved that characteristics of energy consumption are unique to each country and depends on various factors (i.e., socio-cultural norms, behaviour, market conditions and policy measures). Consequently it is difficult to develop effective environmental policies using research studied being undertaken outside of Australia without sufficient information and analysis related to Australian cities. Moreover residential energy use reflects entrenched and complex attitudes to the energy consumption within a unique broader society (Randolph & Troy, 2007).

Randolph and Troy (2007) is one of the first systematic attempt to explore behavioural aspects of household energy consumption in Australia. They examined in two stages how socio-behavioural characteristics and dwelling types impact household energy use. The findings show that type of housing (high-rise or low-rise), tenure, socio-demographic profile of household and lifestyle position all have impact on household energy consumption. Newton and Myer (2011) adopted a comprehensive approach to investigate consumption behaviour in Australia. They found that determinants of consumption vary for different domains of consumption. Contextual (household, dwelling and location) factors have more influence on per capita resource consumption and recognized as a key environment shaping consumption behaviour. Consumption of small-higher income household is found to be much higher than others (Newton & Meyer, 2011, 2012).

This paper attempts to determine the effect of dwelling factors and household characteristics on household energy consumption in order to provide a greater insight into residential energy use in Australians cities.

Data and methods

Nineteen suburbs in Adelaide, capital city of South Australia, were selected as the case study areas. Sample suburbs were selected according to distance to CBD, degree of differences on neighbourhood form and design and demographic characteristics of residents; and as total those suburbs represent Adelaide which reflects variations in housing size, style, type, and age. Figure 1 illustrates the location of sample areas within Adelaide. According to number of dwelling unit in each suburb, the number of household for household survey was calculated.

A postal and web based mixed-mode survey was undertaken to capture data on the determinants of household energy consumption in Adelaide. The survey targeted a household member aged 18 and older. The survey was carried out simultaneously in sample suburbs, with a total sample size of 300, in the winter of 2015. Households were selected randomly using random numbers considering the percentages of building type in each suburb.

Figure 1: Location of sample suburbs in Adelaide city

The questionnaire was divided into four sections. The first section included questions on socio-demographic profile and environmental attitude of respondents and also demographic information of household. Section 2 included questions that aimed at exploring the neighbourhood characteristics and housing type. Third section was energy consumption of transport and is not included in this paper. Finally the questionnaire was concluded by collecting data based on type of energy using in house, expenditure on energy and use of domestic appliances and energy related behaviour and concerns. A summary of demographic information and dwelling type of the sample population is provided in table 1.

Table1: Demographic characteristic and housing type of sample population

Individual characteristics								
Sex		Age group				Educational qualification level		
F 46%	M 54%	18-30 8.5 %	31-50 28%	51-70 42%	>70 21.5%	High 42%	Average 48.8%	Low 9.2%
Household								
Annual income (Australian dollar)			Ownership status					
<$50k 43.3%	$50k-$100k 32.5%	>$100k 24.2%	Owner 54%	Owner-Commit to mortgage 24%		Tenant 22%		
Household type				Dwelling type				
Single HH 21.5%	Family HH 76.5%	Group HH 2%		Detached Semi-detached, row house Unit and apartment		68% 18% 14%		

In order to evaluate individual environmental attitude and individual energy consumption behaviour, respondents were asked to rank series of questions pertaining to energy use and environmental concerns. Figure 2 depicts majority of the sample population agreed that they can contribute to a better environment. However the willingness to make compromises to life style is 32% and willingness to spend extra money on energy efficient products is about 18%.

In relation to demographic factors, women respondents were defined to be more sensitive toward environmental issues and level of environmental concern. Moreover, the level of environmental concerns is higher in older age groups (51-70 years old) followed by middle age respondents (31-50 years old).

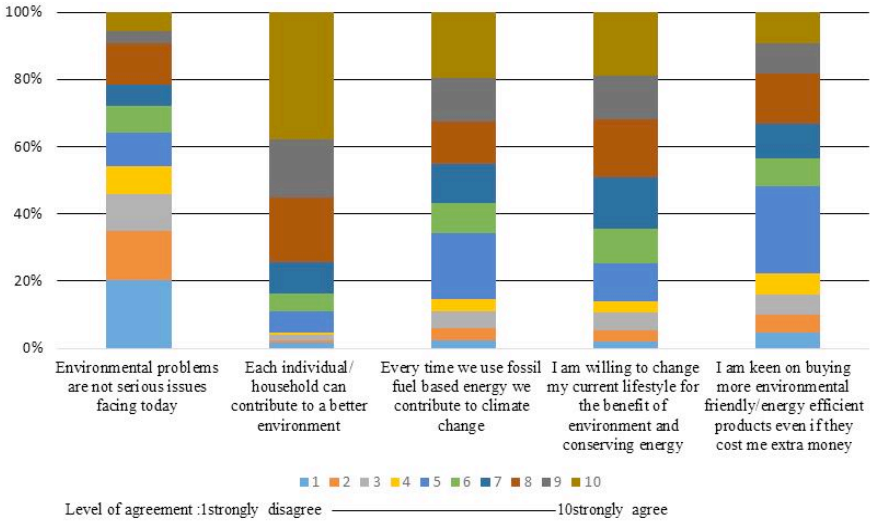

Figure 2: Environmental attitudes

It is be seen from Figure 3, the majority of respondents were involved in energy conserving behaviour in most categories. Compared to male, female participants

behaved more in energy saving matters. However there were no significant differences in engaging in conservation behaviour among all age groups of respondents.

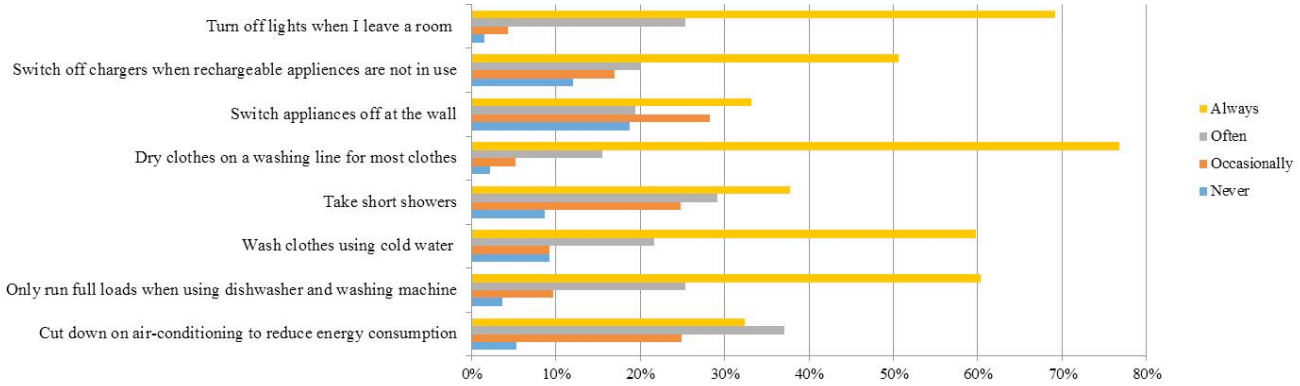

Figure 3: Energy conserving behaviour

Results and discussions

Data on types of energy used in house (including electricity and gas and presence of solar photovoltaic panels) were collected through survey. Respondents were asked to provide the expenditure on electricity and gas according to their latest billing cycle. In South Australia, households receive energy bills in three months cycle. Electricity was used by 100% of the sample population, whereas about 76% of sample households had natural gas connection. In this paper only in-home energy use, including energy for space heating, cooling, operating appliances are included in analysis.

Multiple regression analysis was performed to investigate the influence of various factors on per capita energy consumption of sample households. In this model the basic equation is as follows:

$$\text{Per capita energy use} = \beta_0 + \beta_1 X_1 + \beta_2 X_1 + \ldots + \beta_n X_n + \varepsilon$$

Where: β_0 =addictive constant; β_1 to β_n = regression coefficient for input variable;
X_1 to X_n = all independent variables.

During the analysis insignificant variables were excluded from the model. The model enables to assess relative effects of variables on household energy use. The analysis confirms that household energy consumption is a function of household characteristics and dwelling factors. Table 2 presents the regression model for the sample population.

The model explains 35% of variance in per capita energy use. Obviously there are other significant factors like consumption behaviour suggested by other researchers (e. g., Fielding, Louis, Warren, & Thompson, 2011; OECD, 2008, 2011; Randolph & Troy, 2007; Wyatt, 2013) are not included in this model.

The most statistically significant factors associated with household energy at 1% significant level are number of occupants (household size), size of dwelling, age of dwelling, availability of solar panels and electricity for space heating and water heating. Coefficient for solar panel and household size are remarkable and negative. Smaller households account for larger amount of per capita energy use and it is significant at 5% significance level for single household type. Also household annual income and running pool and spa have positive effect at 5% level and use of top rated energy efficient appliances has negative coefficient and significant at 5% level.

Table2: Regression analysis for Energy consumption

	Coefficient	t	Sig.
Constant	49.673		
Household characteristics			
HH size	-37.745 ***	-4.142	0.000
Owner commit to mortgage	-5.644	-0.350	0.727
Household annual income	9.360 **	2.387	0.018
Presence of children	-17.855	-0.786	0.432
HH type: Single household	59.487**	1.960	0.050
Couple without children	25.755	1.226	0.221
Dwelling characteristics			
Dwelling type: Detached house	15.410	1.204	0.230
Building size	20.337 ***	2.615	0.009
Age of house	16.553***	3.414	0.001
Wall material: Double brick	-10.015	-0.557	0.580
Brick veneer	10.632	0.638	0.524
Thermal insulation of roof/walls	35.687 *	1.587	0.098
Availability of solar panels	-45.397 ***	-3.375	0.001
Electricity: Water heating	47.315***	3.440	0.001
Space heating	38.234 ***	2.458	0.009
Appliances: using top rated energy efficient appliances	-30.267 **	-1.923	0.055
Running pool and spa	54.231 **	2.098	0.037
F 5.68 ***			
***P<0.01, **P<0.05, *P<0.1			
Dependent variable: Per capita energy consumption			

Since the majority of respondents reported brick veneer and double brick as outside wall material, wall material is not defined as significant predictor for energy in this study.

Conclusion

This study reports the findings of the household energy survey of a representative sample of 300 households in Adelaide city. First the level of environmental concerns and energy consumption attributes of individual respondents was investigated. Then, the effect of various factors on per capita household energy consumption was examined. The findings of this study reveal that in-home energy use varies between households and dwelling factors and household characteristics play a significant role on the per capita energy use of households.

Household size is one of the remarkable variables and has a strong negative effect on energy consumption, so that single person households consume higher amount of energy. Household annual income is also a significant determinant which leads to greater use of energy.

The model outcome shows that there is an association between the level of energy use and dwelling characteristics. Five variables relating to housing characteristics namely building size, age of house, installed solar panels on roof, electricity use for space heating and water heating and type of appliances utilized in home, are recognized as dominant factors for energy use.

The model explained about 35% of total variance of the domestic energy use. Further investigation is required to include set of other related indicators like household behaviour in this model. Understanding the actual occupant behaviour toward energy use will give us a better insight on determinant factors of residential energy consumption.

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