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Estimating potential saving with energy consumption behaviour model in higher education institutions

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ABSTRACT

Towards sustainable Higher Education Institutions (HEIs), energy consumption behaviour is one of several issues that require an attention by facilities manager. Information from the behavioural aspect would be useful for facilities manager on managing the energy and determining potential energy saving. A lack of information negatively affects this aim. Hence, this paper proposes a methodology for assessing the energy consumption behaviour with the objective determining potential energy saving. The method used energy culture framework as basis and joined with centrographic approach and multiple-regression analysis. A self-administrated survey carried out involving 1400 respondents in selected HEIs. There are four types of energy use among students in HEIs namely, 'high', 'low', 'medium' and 'conserve' determined from the centrographic analysis. The energy consumption behaviour model was developed and tested against the holdout sample. Through the model's application, there is a vast potential for energy savings with over 55 kWh daily among the students.

1. Introduction

In facilities management (FM), energy must be managed properly without wasting organizational resources [1]. An increase of energy usage and lifestyle factors among students in Higher Education Institutions (HEIs) are the main factors for assessment of energy consumption behaviour patterns [2,3]. This is to ensure that the university budget for energy is not exceeded and to create a benchmark of energy use. However, there is a lack of knowledge and systematic approaches of assessing energy consumption behaviour pattern among HEIs.

This paper proposes a methodology of "energy culture" framework. The concept was analysed using centrographic approach through standard deviation ellipse (SDE) calculation and multiple-regression analysis (MRA). Hence, the three main objectives in this paper were set. First was determining an energy consumption pattern, second was developing an energy consumption behaviour model (ECBM), and finally determining the potential energy saving among Malaysian HEIs students.

2. Literature review

Energy must be defined in terms of the ways in which it manifests itself [4]. It is variously classified as heat, light, sound, radio, radar, TV, electricity, magnetism, mechanical energy, growth, and even "matter". It has been difficult for the layman to accept that this range represents different manifestations of the same thing. Hence, to do justice to the concept of energy, it requires treating each of its manifestations as it is treated by experts in that particular field.

Energy consumption behaviour can be defined as the total energy use of the occupant from both human and physical characteristics. The statement is consistent with previous studies which state:

> "*Buildings per se do not consume energy; rather people living and working in building use energy*" – Stafford [5]

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"*Human attitudes, income and intentions do not directly consume electricity. Rather they influence how the physical devices are operated*" – Cramer et al. [6]

These early statements strongly agree that user behaviour is the key in explaining energy consumption. It has to combine the physical elements (e.g., the building's characteristics, appliances, etc.) and the human variables (e.g., beliefs, demographic, lifestyle, etc.) in order to measure the energy consumption behaviour. Other researchers also view energy consumption behaviour as demand which serves to explain the needs and preferences of individuals in terms of their energy use [7–10].

It further needs to explain energy consumption behaviour. Although it has been studied since 70s, when the popularity of the topic was rising, many unexplained elements still exist. Lately, the trend in energy studies has shifted towards a conservation focus. A high level of awareness among researchers regarding global warming problem means that energy consumption behaviour research is again taking place, where an assessment of the micro aspects of behaviour is required in order to develop strategic policy and programs for reducing energy demand. However, as reported in the literature, model development was found to be lacking, especially in terms of determining exact figures, which are not provided by the conceptual model which is generally used in relation to this topic.

2.1. Lifestyle

People's lifestyle affects energy consumption in a significant way, due to both cultural and social variables [10]. 'Lifestyle' is originally a sociological term that has developed many meanings. Lifestyle is defined as "distinctive modes of existence that are accomplished by persons and groups through socially sanctioned and culturally intelligible pattern of action" [11,12]. The concept is famous in marketing studies and has long been used in consumer research and advertising. In energy research, it refers to the combination of culture, social class, consumer choices, behaviour, historical trends, and marketing that determine energy end-use [12]. The relevance of lifestyle to energy consumption is illustrated by findings that similarly structured households with identical physical shells are associated with widely varying energy usage [11].

Lifestyle is usually conceptualized as a consumption pattern influenced by decisions at various points across the lifespan, such as what profession to engage in, where to live, when (or whether) to marry and have kids, and more proximal choices regarding what types of electrical appliances to buy, and how and when to consume the energy [13,14]. Thus, this concept suggests that analysis of lifestyle and energy consumption needs to encompass not only the traditional demographic segmentation elements, but also the information about types of appliances the individual owns and how they use them [12]. Furthermore, through understanding lifestyles, better public policy can be designed in relation to energy [15].

2.2. Energy culture framework

The energy aspect of lifestyle has generated much attention from researchers. One of the intentions is the greater number of research of the integrating models. Aims of the integrating models are to seek the driver of behaviour, and show relationship between drivers. Early studies can be found examined household energy use in term of their energy behaviour [8]. The aims were to model the energy use from the residence towards energy conservation. These include their socio-demographic factors, family life-style; energy prices; energy related behaviour; cost benefit trade-offs; effectiveness and responsibility; feedback; information and home characteristic discussed in term of ventilation and temperature perspective.

The impetus for this research came from the idea of an 'Energy Culture', first introduced for household energy consumption [16]. The cultural model was based on four dimensions of energy consumption: engineering, economic, psychology and anthropology.

Energy culture as drawn by previous researcher is only a concept [16]. Other researcher draws on a wide range of literature on energy behaviour and attempts to use a system perspective [17]. While the approach acknowledges an important sociological influence from practice theory, it also has strong links to lifestyle research in marketing and the first that attempts to realize the idea of energy culture empirically [17].

"Culture" here refers to the diversity of values, beliefs, knowledge, practice, technology and other cultural determinants that exist within any given society [17]. The 'Energy Cultures' approach developed has some interesting parallels to all these approaches [17]. Different integrated patterns of behaviour – similar to 'lifestyles' – should be identifiable based on the differences in material culture, cognitive norms and everyday practices. In this approach, behaviour is seen as an amalgam of those three principal components which interact together to produce a self-reinforcing system that are characterized by strong habits.

It has been argued that there is no single analytical approach in the previous studies that provides a framework for analysing more than a small portion of behaviour, or providing reliably successful interventions [17]. The analysis overlooks the importance of influences beyond the consumer, which includes "producers, vendors, installers, regulators, financiers, a long-lived built environment and technology stock, and a range of ideas and motivations" [18]. Thus, the aims of the Energy Cultures framework is to centre on the behaviour of individuals within the system, to explore outwards from the aspects of the system that most strongly influence behaviour, and from there to consider what interventions might be successful in achieving behavioural change.

The framework in Fig. 1 suggests that consumer energy behaviour can be understood at its fundamental level by examining the interactions between cognitive norms, material culture and energy practice [17].

In this paper, the framework designed was used as a basis to assess energy consumption behaviour among Malaysian HEI students. Previous research only focuses on demographics from a cognitive-norm aspect, a device and setting in material aspect and household activity in energy practice. This paper proposes an expansion of the "energy culture" framework for assessing energy consumption behaviour among Malaysian HEI students. The variables include environmental concern, social aspiration, comfort and education for cognitive norm aspect, device and building regulations from material aspect, and finally activities and social marketing of energy practice aspect (see Fig. 1).

2.3. Centrographic approach

The concept of the centrographic approach is used in this paper to assess energy consumption patterns. It is usually applied in geographical and mathematic fields. It comprises a set of measures and indices for thread cription and analysis (point areas located in a spatial system), equivalent to similar measures and indices in other branches of statistics dealing with non-geographic sets of data [19]. The centrographic's unique approach is that it represents a multi-dimensional structure presented in the simplest form as a map and location information

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