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Effective or ephemeral? The role of energy information dashboards in changing occupant energy behaviors

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ABSTRACT

Building energy use research has largely been focused on technological performance despite growing evidence that human behavior has an equally significant role (Sovacool, 2014) [34]. This paper aims to address this by examining how the role of real-time information affects building occupant attitudes and behaviors toward energy use. Four buildings located on four different community college campuses in Illinois were outfitted with a centrally located graphic display of the building's real-time energy use (an energy dashboard) *and* implemented a 6-week energy behavior change campaign. Intervention efficacy was tested with an online survey that was distributed to each campus population before and after the intervention. Pre-post analysis, comparison between exposed and unexposed populations, and cross-campus comparisons were then conducted. Our findings show that although the interventions resulted in significant energy savings (7–10% in electricity and 50% decrease in natural gas), differences in student and faculty/staff energy attitudes or behaviors proved insignificant. Post-intervention longitudinal interviews with building facility managers, however, showed that energy dashboards improved their ability to detect system faults that led to their implementation of energy-saving building adjustments. While energy dashboards can be effective at improving facility management approaches, they are less useful for measurably affecting occupant attitudes and behaviors.

1. Introduction

Building energy conservation and efficiency have emerged as key factors in addressing climate related problems, and have thus been targeted as key components of many state energy programs, climate action plans, and other planning response strategies [1]. In the US, building energy use represents about 40% of the total energy and about 38% of total carbon dioxide (CO2) emissions [28,37]. Although construction type and building systems technologies play a major role in how much energy a building consumes, the people that both operate building systems and occupy building spaces are seldom considered. For instance, a review of publication trends from 1999 to 2013 in three leading energy policy journals showed an undervaluation of the human dimensions that impact energy use [34]. This is an alarming trend considering a recent Lawrence Berkeley Labs study suggests that up to 30–50% of total building energy use can be attributed to occupant behavior [36,39]. As technological improvements reduce the potential energy footprint of a building, these behavioral components become a greater percentage of its total energy use. A failure to recognize this human behavioral component can ultimately result in significantly higher energy consumption patterns, even in the presence of massive conservation efforts.

In the past, efforts to influence these types of behaviors typically focused on distributing information about energy consumption [8]. Although information-based campaigns can be effective, Darby [10] points out that many of these information-based strategies have led to short-term gains but have generally been less successful than theorized. According to Winter and Koger [40], this is because the approach typically fails to address elements that can influence human behavior over the long-term: the social norms, values, and perceived behavioral control of the actors [40]. In terms of energy conserving behavior, McKenzie-Mohr [25] asserts that an approach that is based on a deeper understanding of human behavior and the potential barriers to a desired behavior will dramatically increase the likelihood of behavior transition (e.g., forming new energy conservation habits such as turning off lights) [25].

In this exploratory study we test the question, "Can the presence of energy information dashboards affect the energy related social norms, values, and attitudes of building occupants?" In other

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words, are building energy dashboards an effective mechanism for affecting building occupant behavior regarding energy use? We use a quasi experiment of pre-post/comparative survey analysis to test if a combination of both information-based and social-norm based building energy conservation strategies will, in fact, alter reported energy attitudes and occupant behaviors. Follow-up longitudinal interviews were also conducted with facility managers.

Our study focused on four buildings located on four different community college campuses in Illinois. Each building initiated a behavior change campaign around the installation of a real-time energy information system (an energy dashboard) that provides objective building energy use and performance in real time. This technology makes energy spikes visible (in the form of a real-time graph) and was developed to help occupants see the effect of their consumption patterns and to help facility managers easily detect issues with the building operating system. The dashboard installation and campaign represent the study *intervention*. A survey tool based on theoretical frameworks from social and environmental psychology (outlined below) was developed and distributed to each of the four campuses before and after the intervention. Changes in energy attitudes and behaviors from different building users and occupants (i.e., students, faculty, administrative staff, and facility operators) were then statistically analyzed and compared with changes in the overall energy performance of the building.

In terms of performance, building energy consumption in the study buildings significantly decreased over the study period both in terms of natural gas (7–10% decrease) and electricity (approximately 53–60% decrease). This decrease was calculated from utility energy bills using standard energy use analysis techniques (i.e. controlling for weather variability, etc. – see Ghoreishi et al. [15] for a more detailed examination of the analysis). Our study suggests that the energy savings could largely be attributed to changes in building operator behavior. An increased awareness of the issues and ability to detect and correct building operational faults was reported by campaign managers to be an important benefit of the energy dashboards. In fact, the energy dashboards helped two of the four colleges detect significant heating, ventilation, and air conditioning (HVAC) system scheduling errors.

This exploratory study faced the typical challenges of any quasi-experiment that is conducted in a natural setting, including an indeterminate mix of users and activities, lack of control over the interventions at each study building, poor response rates, and lack of control over weather that may impact occupant behavior. In spite of these difficulties and a general lack of (0.05) statistical significance, the data indicates positive responses to dashboards and energy use education at all but one setting.

This study contributes to the literature both in terms of methodology and research questions addressed. Sovacool [34] reports a significant lack of energy academic literature that utilizes human-centered research methods such as surveys and interviews (i.e., only 12.6% of total studies published in *The Energy Journal*, *Energy Policy*, and *Electricity Journal* from 1999 to 2013). This study employs both a survey and longitudinal interviews to capture the human dimensions of energy use and offers suggestions on how to improve these methods in the future. Sovacool [34] also reported a need for research questions addressing "the barriers to technologies. . .and uncover[ing] possible resistance to changing levels of energy consumption." Our key research question addresses this point by assessing a new technology (energy dashboards) and its ability to affect change in attitudes toward energy consumption.

In the following section, we outline the environment-behavior theories and measures used to develop our survey instrument and highlight the existing literature surrounding real-time energy information. We then present a description of our study and our results, followed by a discussion and concluding thoughts on the planning ramifications of this work and suggestions for future research.

2. Environment-behavior theories

Social, behavioral, and cognitive psychological theories have shown that a wide variety of factors can influence pro-environmental behavior. According to Kollmuss and Agyeman [21], pro-environmental behavior is defined as "behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world (e.g., minimize resource and energy consumption)"[1] [21,p. 240]. Two theories that have arguably generated the most empirical support for identifying the underlying human causes of direct and indirect pro-environmental behaviors are the Values Beliefs Norms Theory [35] and the Theory of Planned Behavior [2]. We use elements of these theories to construct a framework for our study.

The Values Beliefs Norms theory generally states that a causal chain of (i) personal *values*, (ii) personal *beliefs* (which includes a combination of ecological worldview, adverse consequences for valued objects, and perceived ability to reduce threat), and (iii) personal *norms* lead to a given pro-environmental behavior [35]. This theoretical framework is depicted schematically in Fig. 1.

The Theory of Planned Behavior, states that an individual's *intention* to behave a certain way is the best predictor of pro-environmental behavior. Behavioral intentions are thought to be a function of three elements – attitude, subjective norms, and perceived control [2] (see Fig. 2). This theory is more focused on the individual's rational choice, while the Values Beliefs Norms theory emphasizes morals and values. Both, however, support research that has shown that environmental knowledge *alone* is not a strong predictor of pro-environmental behavior, a common misconception in environmental education and policy [20,21].

Both theories have proven to exhibit high explanatory power. Kaiser et al. [19] found the intentions predicted by the Theory of Planned Behavior accounted for 95% of conservation behaviors while the Values Beliefs Norms theory accounted for 64% [19]. It is notable that both models include similarities in causal domains, including cultural/social (e.g., social norms), personal (e.g, habits, values, beliefs, attitudes, knowledge of issues/action strategies, verbal commitment), and environmental (e.g., locus of control) factors [18,24]. These factors are therefore used within the theoretical framework that was employed by our study and are discussed in more detail below.

2.1. Elements of pro-environmental behavior

Many factors have been shown to influence pro-environmental behavior, including habits [25], environmental awareness [21], emotional involvement [7], and values [35], among others. The factors that constitute the Theory of Planned Behavior (beliefs, attitudes, social norms, and perceived behavioral control), however, are generally considered the most significant in studying energy-related human behaviors and are therefore used in this study [19]. The Theory of Planned Behavior theoretical framework identifies beliefs as affecting a person's attitudes, social norms, and perceived behavior control, which then impact their intention and behavior [2].

2.1.1. Beliefs and attitudes

In the most general sense, a belief is considered an understanding whereas an attitude is considered more of an enduring feeling

[1] We contend that building occupant energy related behaviors fit this definition.