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Can social influence drive energy savings? Detecting the impact of social influence on the energy consumption behavior of networked users exposed to normative eco-feedback

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ABSTRACT

Eco-feedback systems provide a significant opportunity to reduce energy consumption. Previous studies have demonstrated a link between providing users with socially contextualized feedback on their energy consumption and reductions in energy use. Yet, the question—can social influence drive energy savings—remains unanswered. In this paper, we develop an algorithmic approach based on stochastic and social network test procedures to assess whether social influence impacts energy consumption behavior and apply the approach to an empirical data set of users exposed to unit-level socially contextualized feedback. We conducted a 47-day empirical experiment in a New York City midrise residential building occupied by students to capture energy consumption and user interaction data for participants in self-identified social networks. Social influence effects on peer network energy consumption were successfully characterized and isolated using adapted social network tests. These results indicate that future research should focus on how social influence and social networks can be leveraged to maximize savings in energy conservation programs.

1. Introduction

Rising energy costs and increased pressure to reduce carbon emissions have made energy efficiency a centerpiece of global policy debate. Because building energy usage accounts for over 40% of total consumption in the United States [1] and a significant portion of consumption in other countries, the built environment will play an important role in maximizing savings from efficiency measures. Efficiency measures in buildings have traditionally concentrated on physical improvements, but researchers have observed a phenomenon known as the "take back" effect where energy savings realized through physical improvements may be severely diminished by a corresponding increase in inefficient behavior by the consumer [2]. For example, if a consumer installs an energy efficient compact fluorescent light bulb but then leaves the bulb on longer than before, then the energy savings associated with the new light bulb may be diminished. Therefore, effective realization of sustained energy savings may require a coupling of infrastructural modifications with behavioral interventions.

Behavioral interventions that promote energy efficiency provide significant opportunities to reduce consumption and associated carbon emissions. Recent work has shown that behavioral interventions have the potential to reduce carbon emissions by 7.4% in the United States [3]. Accordingly, a recent article in *Science* calls for increased effort to understand the dynamics behind such behavior-based energy efficiency programs [4]. Past research has also demonstrated that providing users with eco-feedback—information regarding their current and historical energy consumption levels—can effectively motivate energy efficient behavior [5–7]. Several studies [8–12] have incorporated a normative comparison component within an eco-feedback system that allows users to compare their energy usage with their peers and neighbors. The success of normative eco-feedback relies on the premise that a user is influenced by actions of others in his/her social network.

While prior studies have found correlations between energy savings and normative comparisons, the inherent drivers motivating the observed energy conservation behaviors of eco-feedback system users are still unknown. To provide a foundation for better

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Table 1
Types of network effects, adapted from [31,32].

Network effect	Definition	Energy consumption example
Homophily	A user tends to create relationships with other users who share similar characteristics	A user creates a relationship with a user who also enjoys computer gaming causing them to use their computer the same amount and have similar energy consumption
Confounding factors	A user is exposed to similar external factors or stimuli as others in their social network	Two users in the same social network have the same work schedule causing them to adopt similar patterns of energy use and, as a result, to use similar amounts of energy
Social influence	A user's actions are triggered by the actions of another user in their social network	A user uses less energy because they observe his/her friend to be using less energy

understanding motivational drivers, it is thus necessary to investigate beyond correlative statistics and explore if social influence has a direct impact on energy conservation. In this paper, we establish a technique based on stochastic and social network test procedures to detect social influence in social networks of users exposed to eco-feedback and apply the technique to energy consumption and user interaction data collected from a 47 day empirical eco-feedback experiment.

2. Background

Thus far, studies [13,14] that have examined the impact of social influence on energy conservation have relied on user surveys as the primary data source. However, a recent field experiment [15] revealed that user surveys can be unreliable in determining the extent to which influence plays a role in conservation. The field experiment found that social effects engendered the greatest conservation behavior change despite respondents rating normative information as the least motivating factor for their conservation behavior. Therefore, research studying the role of influence needs to expand beyond user surveys and incorporate real energy consumption data in order to understand the underlying mechanisms driving conservation efforts. Eco-feedback provides a platform to capture such energy consumption data, but new innovative methods to analyze these data are required to gain a deeper understanding of the role of social influence in engendering energy conservation.

2.1. The impact of eco-feedback and normative comparison on energy consumption behavior

An early empirical residential eco-feedback study [16] was among the first to highlight the role that user behavior can play in energy consumption. Savings in this study were significant, ranging from 10.5% to 15.7%, and demonstrated that behavior change can play a major role in reducing consumption. Later empirical experiments [17–20] reinforced the observations of Seligman et al. [16] and provided insight into the effects that goal-setting and tailored eco-feedback have on energy use behavior. More recently, a large scale study [21] of 2000 households and a meta-analytical study [22] of utility eco-feedback programs concluded that users respond well to eco-feedback with reported energy savings of 15% and 7%, respectively.

Numerous studies [8,23,24] have expanded eco-feedback to include a normative comparison component that provides users with information regarding the energy consumption of their peers. The savings observed from these expanded studies have been as high as 55%. It should be noted that savings observed in this study's data-set are consistent with previous findings (users who utilized normative comparison reduced consumption by 5% from pre-study levels). A study [25] regarding user interface design of eco-feedback systems also suggests that normative comparison is an effective component in driving energy use reductions. Although these studies provide further evidence to support normative comparison as an eco-feedback tool for reducing consumption, they fall short of defining the impact of normative comparison on a per user level. Without this level of granularity, it is difficult to ascertain what specific factors are driving the success of normative eco-feedback systems in modifying user behavior.

The emergence and widespread use of online social networking provides researchers with new tools to explore the effects of normative comparison on an individual basis. Several studies [9,26,27] have successfully elicited energy savings by integrating online social networking tools with eco-feedback systems. In particular, a study by Peschiera et al. [10] combined social networking tools and eco-feedback into a single web interface. This interface allowed users to directly compare their energy consumption with others in their social network. The study revealed that normative feedback is more effective than purely historical feedback in yielding energy savings. A more recent study [11] expanded on this result by analyzing the network position of users in a social network relative to their energy consumption. The authors observed a correlation between the social position of a user in the network and the amount of energy they conserved, finding that the number of social connections of a user is positively correlated to the amount of energy the user conserves. While this correlation allows for the conclusion that social network effects impact consumption, it does not isolate the role of social influence (defined in Table 1) from other network effects. Observed correlations between energy use reductions and network position could be the result of other social network-related effects, such as homophily, that are described in detail in the next section of this paper. For this reason, this study expands upon previous work by investigating the time dependency of energy consumption on the level of an individual action to allow for the differentiation of social influence from other social network-related effects.

Additionally, recent building energy simulations [28–30] have been built based on these observed correlations and assume that when users interact they will inherently influence each other to change their consumption behavior. Yet, empirical evidence validating that users can influence each other's consumption behavior has not been clearly observed by researchers. New methods are therefore required to analyze energy consumption data to determine if social influence actually plays a role in the energy consumption of users. Without this deeper understanding of what is motivating users to conserve energy, researchers and policy makers will be limited in their ability to effectively optimize energy policies and eco-feedback systems to reduce consumption.

2.2. Social network effects

Social network effects have been studied by researchers in computer science and social science extensively. The three main types of network effects—homophily, confounding factors, and social