Communication Around Home-Energy Monitoring Devices: Connecting Stakeholders in Low-Income Communities

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ABSTRACT
Prior research results show that comparison as a feedback technique can encourage additional savings; however, a limited number of home-energy studies explore social communication around feedback devices. We will develop a system that supports comparison and cross-household communication, and provides energy-use information. We will then deploy our system across 50 mixed-income renters. Our expected contributions include an interactive system for supporting comparison and collaboration; a better understanding of the conditions that motivate or discourage energy conservative behaviors for individuals that pay and do not pay for their electricity; and design recommendations for visualizations that allow comparison and collaboration across households.

Author Keywords Home energy consumption, sensing, social computing, mobile/tablet displays.

ACM Classification Keywords H5.m.Information interfaces and presentation (*e.g.*, HCI): Miscellaneous.

General Terms Human Factors

INTRODUCTION

Energy use and its impact on the environment is a topic of global concern. In the U.S. alone, with its high *per-capita* energy use, households directly consume 21.7% of total U.S. energy and generate 21.1% of total U.S. carbon emissions [13]. Decades of research around home-energy consumption and conservation exist in the area of environmental psychology. Though the average annual cost of electricity is $1,000 *per* household, households often lack knowledge about the amount of electricity they consume or what factors influence consumption [1].

Energy-efficiency research results suggest that the behavioral impacts of providing users with real-time energy use feedback--even at the aggregate level--can produce savings of 10-15% [4]. There is also evidence that public commitment, comparison, and other forms of cross-household feedback may contribute to energy savings [1, 4]. Though comparison is a feedback method shown to encourage additional savings [1, 4], home-energy research studies exploring social communication and comparison around feedback devices are limited [12]. Furthermore, few studies explore this phenomenon among households, and even fewer focus on low-income households.

The *majority* of American households earn below-average incomes [13], and 30% of households earn less than $30k *per* year [18]. Low-income households, however, have the same median energy use for home heating and cooling as more affluent households, and as a result, they spend a greater percentage of their income on energy. Additionally, low-income populations include a broad range of household types (including one person, a family or extended family, roommates, long-term visitors, and so on) and ownership (including landlords/renters, government-run buildings, and homeowners). These varied stakeholders are typical of many American homes and have a significant impact on energy consumption.

As a result, communication is crucial to engaging multiple stakeholders (such as landlords and tenants) in decisions around the reduction of energy use. Because of the limited research exploring social communication and comparison around feedback devices and the limited research exploring home energy consumption in low-income communities, we chose to explore visualizations designed to allow individuals to compare their consumption with others.

Thesis Statement

We hypothesize that eco-visualizations designed to allow individuals to compare their consumption with others and to actively engage around actions that affect energy consumption will:

1) encourage social interaction;
2) raise awareness of energy-conservation behaviors;
3) help residents negotiate energy use issues with stakeholders (landlords, housemates, and community members); and
4) have an impact on awareness of energy conservative behaviors for individuals that do not pay for their electricity and those that do.

To address these questions and to either prove or disprove our thesis statement, we plan to build and deploy an interactive system that supports communication around energy consumption and comparison. We will conduct a study of the system's longitudinal use and impact. To better understand the effects of comparison and communication, we will deploy a real-time, energy-monitoring system among 50 collocated (mixed-income) households.

EXPECTED CONTRIBUTIONS

With the deployment of our tool and energy-monitoring devices, we plan to contribute the following:

1. An interactive system for supporting comparison and collaboration using results from studies that will:
   a. shed light on how such comparisons are used;
   b. help show how individuals collaborate around system information;
2. A better understanding of the conditions that motivate or discourage energy conservative behaviors for individuals that do not pay for their electricity and those who do;
3. Design recommendations for visualizations that allow comparison and collaboration across households.

RELATED WORK

Energy consumption has been a topic of global concern for decades, and there is extensive research in psychology about what factors affect conservation behavior. Attempting to bring about change is a challenge, however, given the vast number of factors affecting pro-environmental behavior [16]. Moreover, the vast number of factors makes testing them in various contexts difficult. Nevertheless, many techniques designed to promote energy-conservation behaviors exist, and some interventions leveraging these techniques have been successful.

For example, existing interventions/devices and techniques could work with a variety of household and income types; however, there are some limitations. For example, many of these devices are expensive, and low-income individuals may be reluctant to invest in these technologies. Tax-credit incentives for "green" home improvements, for instance, may not be helpful to households that pay too little (or none at all) in tax amounts that would allow them to claim credit.

Many of today's electricity monitoring technologies show consumption in terms of CO_2, dollars saved and the number of kilowatt-hours consumed. These technologies limit their displays to individuals with economical and/or environmental motivations [3]. It has been argued that framing the decision to save energy as an economic one could de-motivate consumers due to small monetary savings. This is especially true if these interventions communicate savings on a day-to-day basis (*e.g.*, 3). While several techniques from behavioral psychology have been used in conjunction with home-energy conservation, two techniques that have remained relatively unexplored are comparisons and the use of feedback interventions to show comparisons [12]. These techniques can have a significant impact on consumption behaviors [2,4].

Comparison from an energy-consumption perspective relates to historic comparison, or contrasting one's consumption to one's consumption in the past [14]. Social comparison differs in that individuals contrast their consumption with other households [14]. Grønhøj & Thøgersen also refer to this as normative comparisons, where comparisons among 'similar' households are made [14]. Though historic comparison has been effective [4], the effectiveness of social comparisons in environmental psychology is mixed [12].

We propose investigating feedback interventions that focus on comparisons and new motivations, and our past work shows positive results for this direction.

RESEARCH PROGRESS

Our first two qualitative studies focused on low-income households and have been published in refereed conferences. Both of these studies partially confirm our hypothesis and inform our proposed work.

Energy Use in Low-Income Communities

In our first study, we explored energy consumption in low-income households [9]. We recruited participants from two locations: a small town in eastern NC and Pittsburgh, PA. Many participants lived in subsidized housing such as public housing and Section 8 apartments. Some participants had to pay for their electricity bills, while others received stipends, electricity allocations, or did not pay at all.

We gave participants disposable cameras and instructed them to "take pictures of objects and/or scenarios that make you think about personal energy use or anything that makes you think about energy." We gave participants one week to take photos and conducted photo-elicitation interviews shortly after.

We recorded and transcribed all interviews, and we conducted iterative coding of the interview data and photos. We extracted common themes from both sources that included motivations for saving energy, common energy-saving behaviors, and barriers to saving energy. We also collected information related to sharing and other social factors and approaches to monitoring energy use.

Some of our key findings revealed that financial concerns did not always drive individual motivations. Of course, not all participants were interested in saving energy, and some felt they were "doing enough already." However, many participants saved energy for reasons ranging from comfort, to the desire to protect the environment, and spirituality. We also found that landlords and other members of the community affect energy consumption. In fact, children, friends, guests, and other household members are often barriers to saving energy. Concerns about safety affected how participants used lights. Energy savings requiring infrastructure investments depend on landlord buy-in. Thus, energy use and feedback must situate itself within the context of a community of people who affect energy use. As a result, communication among multiple stakeholders could be a beneficial feature to add to today's energy monitoring devices.

Understanding Conflict Between Landlords and Tenants: Implications for Energy Sensing and Feedback

In our second study, we revisited our first-study data about landlord/tenant relations and contextualized it with data from tenant focus groups and landlord interviews [3]. Following the same methods as before, we used a website to recruit landlords of subsidized apartments.

We found that tenants are relatively powerless in the landlord/tenant relationship. To understand the tenant's perspective, we need to understand that tenants – particularly low-income tenants – who may feel lucky just having a place to live [19]. As a result, some tenants fail to report their needs to their landlord because of factors such as income and perceived status.

Our study showed that the tenants who were more knowledgeable about what could be expected were able to advocate for changes, particularly when they understood tenant rights and how to negotiate with their landlords.

Landlords also felt a level of powerlessness in the relationship. Most landlords we spoke with felt that tenants at times took advantage of them especially when tenants waste resources they did not pay for. For example, one of our landlords described a situation in which a tenant waited to notify him about a broken thermostat and instead opened his windows in the winter because he was too hot. This delay in notification meant paying for extra heat (until the tenant reported the issue, and then until the landlord found someone to address the issue).

One approach to resolving these differences is to share information across stakeholders. For example, one study participant described how high building-wide heating bills led to a group of tenants advocating for building improvements. Feedback technologies could help enable community action by making it easier to identify common issues, or improve landlord tenant communication about shared resources.

Many of the issues found in our second study resulted from differences not only in financial responsibility, but also in the availability of information. For example, the advocacy just described depended on tenants knowing that they *all* had high heating bills. Similarly, giving landlords better information about each apartment's energy use could address their dissatisfaction with tenant wastefulness. While the positives of sharing information in this way are clear, we must also consider the negatives. Information can affect the balance of power between parties [3], and this may lead to negative outcomes. For example, allowing a landlord to view each apartment's energy use may be a breach of privacy that could lead to censure or unexpected disclosures. Similarly, sharing among apartments might affect a person's sense of security (*e.g.*, people could guess when a neighbor comes home each day). Finding a way to support communication without creating negative outcomes is a challenge for designers of energy-feedback systems.

REMAINING RESEARCH AND METHODOLOGICAL APPROACH

Our first two studies shed light on the dynamics of low-income households in terms of energy consumption and how community sharing affects conflict among stakeholders in a given location. The primary goal of this dissertation is to understand the dynamics of low-income households in terms of energy consumption; to understand how the data from real-time electricity monitoring with a visualization providing information about the community enable household and community sharing; and how this data affects conflict among stakeholders in a given location.

To understand the impact of real-time electricity monitoring and a visualization designed to show how community information affects households and communities, our main approach is to implement and deploy an intervention for mixed-income individuals for six to nine months. To identify how our technology affects individuals with varying payment schemes, we will also divide our participants into groups consisting of those who pay for electricity and those who do not.

We will install 50 real-time energy-monitoring devices (donated by Google) across mixed-income households in Pittsburgh, PA. We are collaborating with an organization that helps provide affordable housing to populations with physical, developmental and/or income limitations. This organization has provided two locations for us to deploy real-time energy monitors that meet our hypothesis-testing requirements. Both locations include all-electric households. In the first, individuals paying market value for their apartments are responsible for paying electricity bills, while low-income individuals are not. The second location consists of all low-income households that do not pay for their electricity bills.

We are currently considering our interface's design and will base subsequent iterations on feedback from our pilot deployment (see Table 1). We will deploy Android-based tablets to show our display, and we envision our participants engaging with our display as they would a picture frame. We have conducted "speed-dating" sessions [6] to identify core design features and plan to review our designs with our target population to help select which one to pilot. Our core feature allows one household to compare their consumption to the rest of the neighborhood (while avoiding privacy issues). The application will also receive alerts based on community status (*e.g., "*10 community members are now hang drying their clothes"), allow participants to post information in a "Twitter-like" or "Facebook-like" way, and allow households to receive tips on ways to save as well as provide their own tips for their community. During our one-month pilot deployment, we plan to use our participants as "consultants" to help evaluate our features, test our system, and provide feedback on our intervention, test our surveys, and to help us test our interview processes.

For the official deployment, we plan to measure the following to prove or disprove my thesis:

Social interaction - the number of system posts per household and overall use of application features, (pre/post) social interaction among household members, neighbors, and landlords, and frequency and span of household discussions around intervention data;

Raised awareness - (pre/post) survey and interview results of environmental attitudes [7] and awareness [7,10], *e.g*., whether information from the intervention was used in landlord discussions;

Negotiation - (pre/post) landlord/tenant happiness, issues reported and addressed over time;

Impact of pay and no pay – we will use the same measures as above but we will compare results from each location.

Project	Duration	Start	End
Pilot Development	~2 months	Jun 2011	Aug 2010
Pilot Deployment & Study	~1 month	Aug 2011	Sep 2010
Updates	~1 months	Sep 2011	Oct 2011
Longitudinal Deployment & Study	~9 months	Oct 2011	Jul 2012
Data Analysis	~10 months	Oct 2011	Aug 2012
Dissertation Writing	~6 months	Dec 2011	Oct 2012

Table 1. Plan for completion. Estimated schedule for remaining research. Timeline includes planning, development, deployment, and data analysis.

CONCLUSION

We hypothesize that comparison and communication across households will help residents negotiate with multiple stakeholders (*e.g.,* landlords, roommates); interpret and act on data about their own energy use; encourage discussion; and aid in overall reduction of energy use. My plan to prove or disprove my hypothesis is to develop an interactive system for supporting comparison across households and to deploy this system across 50 mixed-income households in Pittsburgh, PA. Our remaining research builds on our preliminary studies that show positive results towards the hypothesis and will ground our work in a real-world design context.

BIOGRAPHICAL SKETCH

Tawanna Dillahunt is advised by Dr. Jennifer Mankoff at Carnegie Mellon University's Human Computer Interaction Institute (HCII). Her research focuses on improving the behavior of individuals using ubiquitous and social technologies particularly in the domain of environmental sustainability. She has published work exploring the use of ambient positive rewards on mobile phones to encourage positive transportation behaviors, tailoring websites to increase contributions to online communities, and exploring energy use in low-income communities. Tawanna entered the Ph.D. program in the Fall of 2007 and expects to complete her dissertation work at the end of 2012.

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