Using Social Technologies to Increase Sharing and Communication around Household Energy Consumption in Low-Income and Rental Communities

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ABSTRACT

The behavioral impacts of providing users with real-time energy use feedback—even at the aggregate level—can reduce energy use by 10-15%. Though comparison is a feedback method shown to encourage additional savings, home-energy research studies exploring social communication around feedback devices are limited. As a result, the relationship between feedback technologies and energy-conservation behaviors has become an increasingly important focus in the field of human-computer interaction. Furthermore, few studies explore this phenomenon among households, specifically, low-income households.

To bridge this gap, we conducted 26 photo-elicitation interviews with low-income tenant households across two locations, Pittsburgh, PA and eastern, NC. Our studies of low-income households show that comparison across households can have an important impact on how energy is used (or saved). These studies also reveal conflict between various internal and external stakeholders such as family members and landlords. To better understand this conflict, we re-analyzed data from the first study for specific landlord/tenant conflict and resolutions, held semi-structured interviews with landlords to understand their perspectives, and held a role-play exercise with tenants to understand ways to resolve the conflict between landlords and tenants. Finally, based on our qualitative study results, we developed an Android-based application called the Community Monitor that supports comparison and provides household energy-use information. After conducting a longitudinal energy use study with 15 collocated U.S. households in Pittsburgh, PA, we were able to better understand the impact of engagement around social sharing and community energy monitoring in residential communities, identify energy-related and personal concerns, and provide design implications for home-energy applications that share consumption data among community members.

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1 INTRODUCTION

Energy use and its impact on the environment is a topic of global concern. In countries like the U.S. with 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 (Gardner & Stern, 2009). 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 (Alcott, 2010). Results from research studies suggest, however, that the behavioral impacts of providing users with real-time energy use feedback--even at the aggregate level--can produce savings of 10-15% (Parker, Hoak, Meier, Brown, 2006; Fischer 2008; Darby 2006). There is also evidence that public commitment, comparison, and other forms of cross-household feedback may contribute to energy savings (Abrahamse, Steg, Vlek, Rothengatter, 2005; Darby 2006; Fischer 2008). Though comparison is a feedback method shown to encourage additional savings (Abrahamse, Steg, Vlek, Rothengatter, 2005; Darby 2006; Fischer 2008), home-energy research studies exploring social communication and comparison around feedback devices are limited (Froehlich, Findlater, Landay, 2010). As a result, the relationship between feedback technologies and energy-conservation behaviors has become an increasingly important focus in the field of human-computer interaction. Furthermore, few studies explore this phenomenon among households, and even fewer focus on low-income households.

The *majority* of American households have below-average incomes (Kentucky State Data Center, 2007), and 30% of households earn less than $30k *per* year (U.S. Census, 2009). Further, 30% of the U.S. population rent their homes (Current Housing Reports, 2009). Though median energy use for home heating and cooling is the same as that in more affluent households, low-income households must spend a greater percentage of their income on energy (Shui, 2002). After reviewing relevant literature from the CHI and Ubicomp communities regarding home energy consumption, we found that issues of class or income in the domain of home-energy consumption rarely surfaced, and few studies investigated energy consumption in rental households.

1.1 THESIS STATEMENT AND CONTRIBUTIONS

The primary focus of this thesis is to explore and respond to challenges faced by renters and low-income households around energy use. The following thesis statement guided our approach:

> Home energy-monitoring technologies should be effective for varying household types, regardless of payment responsibility, or the number and makeup of household members. However, today's energy monitoring technologies are not designed in an inclusive way and are not applicable to a large segment of the U.S. population, namely renters and low-income populations. Energy-monitoring technologies are not designed for these communities because there is limited home-energy research across these populations.
>
> To address this problem, we explored energy-related issues facing these communities and developed possible solutions. We then designed, implemented, and deployed a solution-based social energy application that was used by renters with varying income levels. This dissertation identifies population-specific challenges; provides more comprehensive guidelines for new energy-monitoring technologies; and details the results of a long-term deployment of a social energy application among rental and low-income communities.

Our thesis starts with an exploration of our target community, primarily low-income and rental households using ethnographical and participatory design inspired techniques such as photo-elicitation and role-play studies. Our first two studies were qualitative in nature: we designed and conducted the first study to understand energy consumption in low-income communities and the second study to understand conflict between various stakeholders such as family members and landlords. We then conducted a survey of eco-feedback devices and conducted a needs-validation study based on the results of our first two qualitative studies. Taking these results into consideration, we designed and implemented a social-energy application and concluded our work with a long-term deployment and evaluation of our application.

Our thesis statement contains a series of hypotheses that we describe in detail in the next sections.

1.1.1 Low-Income Households

A common belief may be that low-income households are not motivated to conserve electricity because economic hardships often force low-income households to make tradeoffs between necessities such as heat and electricity (Williams *et al.*, 2008). Contrary to the belief that low-income households may not be motivated to conserve electricity, research suggests that financial pressures may be less important than other motives (James & Sharpe, 2009). Consistent with this finding, our first hypothesis is this:

> Lower-income households do not have dissimilar motivations for energy conservation than higher-income individuals and households.

To test our hypothesis we explored energy-related issues facing these communities and developed possible solutions. We discuss this study in Chapter 3 and provide a summary of contributions next.

We contributed an exploratory/qualitative study of low-income households that:

- shows motivations for energy conservation to extend prior research in middle-class and affluent households;
- shows constraints that exist around energy consumption in low-income households;
- exposes (and extends) factors to behavior theories relevant to energy consumption in low-income households;
- provides design implications around basic assumptions: responsibility for bills, building ownership, and the relationships between household members that need to be reconsidered when designing Ubicomp technologies for saving energy.

1.1.2 Renter Households

Another common belief is that when landlords pay for electricity, renters may maximize their comfort by increasing their electricity consumption. One may assume that this will cause the person responsible for paying energy bills to be more conservative with his or her consumption than the person who is not responsible for paying energy bills. This leads to our second hypothesis:

> While payment responsibility may contribute to failed negotiations, it is not the sole reason for energy-related conflicts in renter environments. These conflicts may be caused by other factors such as a lack of communication between stakeholders such as landlords and tenants.

To test our hypothesis we explored energy-related issues facing landlords and tenants and developed possible solutions. We discuss this study in Chapter 4 and provide a summary of contributions next.

1.1.3 Improving Stakeholder Communication

Due to a lack of communication between stakeholders such as landlords and tenants, energy-related issues may go unresolved. This leads to our final hypothesis:

> A social application that allows individuals to compare their consumption with others and to actively engage around actions that affect energy consumption can encourage social interaction, raise awareness of energy conservation behaviors, help residents to identify and address energy-related issues, and reduce energy consumption.

To test our hypothesis, we conducted a concept-validation study to evaluate our concept and developed a set of design guidelines for social energy applications, which we describe in Chapter 5. We then designed, implemented, and deployed a solution-based social energy application that was used by renters with varying income-levels. We discuss the design of our application in Chapter 5 and the results of our deployment in Chapter 6.

We contribute a survey of eco-feedback technologies and results from a design exploration that builds upon our prior qualitative studies that:

- highlight the challenges and opportunities for the next generation of eco-feedback technologies

- provide design implications for social-energy applications that allow comparison and collaboration across households and multi-stakeholder environments and seek to engage internal and external stakeholders into home-energy consumption related issues

We then contribute a longitudinal deployment and the evaluation results of an interactive system for supporting comparison and collaboration across households that:

- demonstrates how renter households integrated our application into their existing routines and habits;
- shows how households identified and addressed energy-related issues discovered as a result of our application;
- demonstrates how trust plays a key role in stakeholder communication and environmental behavior.

1.2 THESIS SUMMARY AND OVERVIEW

To summarize, the goal of the dissertation is to provide a detailed understanding of energy consumption in renter households and to understand the factors that impact energy consumption in these communities. Further, the goal is to identify and understand conflict around energy consumption in rental environments and to identify ways to address issues between stakeholders, such as landlords and tenants. Based on our understanding of energy consumption in these communities and ways to address conflict that exists around energy, the goal of the dissertation was to design and develop an eco-feedback application for rental households. Finally, this dissertation evaluates the effectiveness of an interactive system that supports communication around energy consumption and comparison.

The next chapter describes current related work about feedback in the area of home-energy consumption. Chapters 3 and 4 provide an understanding of how related work and existing home-energy technologies fall short in low-income households. Specifically, Chapter 3 describes the dynamics of low-income households, the effects of these dynamics on energy consumption, and how low-income households differ from average-income households. Chapter 4 explores conflicts between landlords and tenants and how these conflicts impact energy consumption. The chapter also describes possible technical solutions to conflict between landlords and tenants. Chapter 5 provides a survey of existing eco-feedback devices and identifies challenges and opportunities within eco-feedback technologies. The chapter then goes on to describe the design and implementation of an application that could address the issues raised in our prior chapters, while taking advantage of opportunities that exist within eco-feedback technologies. Chapter 6 describes the results of our deployment to determine how household electricity monitoring devices, along with techniques suggested from related work, can work most effectively within the dynamics of low-income households and renters. We conclude with a contributions summary and concepts for future work.

2 RELATED WORK

Residential energy use accounts for 23% of the total consumption in the U.S. (EIA, 2010) and usage highly depends on the behaviors of occupants living or working in these settings (Parker, Hoak, Cummings, 2008). Further, public attitude and opinion research on climate change and energy conservation reports that a close majority of Americans feel that climate change is real, that reduced energy use is part of the solution, that human action and behaviors are contributors, and that personal actions can contribute to reducing climate change (Gardner and Stern, 2009). Understanding what drives these behaviors is critical to changing them, and we use this information to design and improve upon energy-conservation technologies. Therefore, this chapter lays out factors that drive behavior and does so along the dimensions of understanding conservation behavior, understanding factors that drive the behavior, and changing the behavior. After presentation of these factors, this chapter concludes with technologies, based on past research, that have been used to change consumption behaviors successfully.

2.1 UNDERSTANDING CONSERVATION BEHAVIOR AT HOME

Understanding the key drivers of electricity consumption at home is important as it provides us with target areas for energy reduction. Per Figure 1, the highest drivers of residential consumption are space heating and water heating (combined 63%), though other factors such as space cooling, lighting, cooking, and refrigeration (combined 27%) make up a large portion of consumption as well (US DOE, 2011). Past studies of home-energy consumption have included a majority of homeowners that have control over their environment (Woodruff, Augustin, and Foucault, 2007; Hasbrouck and Woodruff, 2008; Chetty, & Grinter, 2008; Carroll, Hatton, and Brown 2009; Pierce, Schiano, and Paulos, 2010); however, very few classes of households, such as renters and low-income, have been studied, or considered.

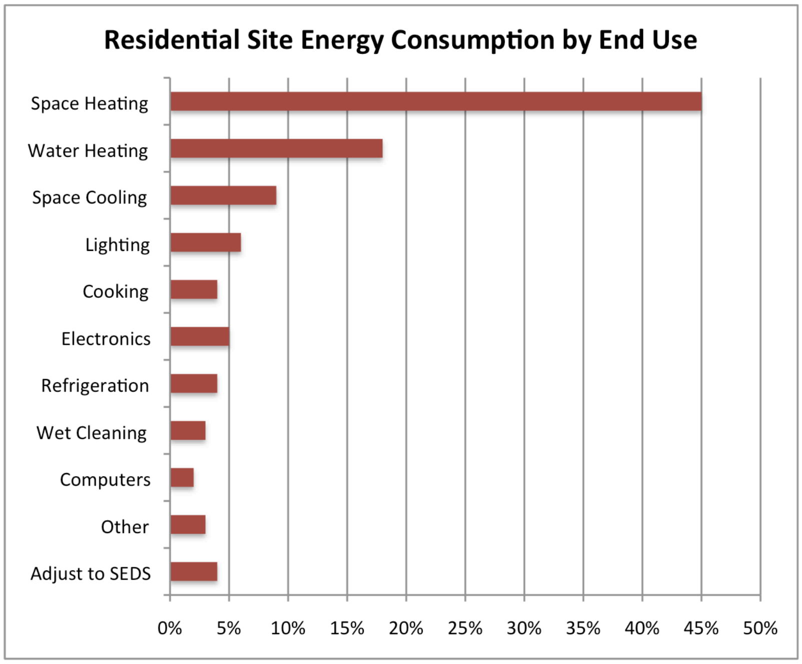


Figure 1 – Residential Consumption by End Use

(Adjust to SEDs is the Energy Information Administration's (EIA's measure to reconcile supply-side and end-user (*e.g.*, the *Residential Energy Consumption Survey* (RECS) estimates of energy use), (EIA, 2010))

Renters and low-income housing accounts for an important yet often ignored population within the subject of energy conservation. As mentioned earlier, 30% of households are considered low-income (U.S. Census, 2009), and 30% of the population rent their homes. Further, low-income households spend greater portions of their income on energy (Shui, 2002) because of costs such as transportation, food, and energy.

A good understanding of what happens around energy use in the home can allow us to build more effective eco-feedback technologies. Motivated by the focus on diverse (especially low-income and rental) users, this sub-section takes a broad look at what factors affect energy use in the home. These factors include personal factors, or "internal" challenges, and "external" factors such as dealing with multiple stakeholders.

2.1.1 INTERNAL CHALLENGES

Internal challenges, or personal factors such as comfort and convenience, or how well a household perceives the effect of energy consumption, plays a significant role in energy conservation behavior. Understanding these challenges is important because these are all challenges that can be overcome by individuals and individual behavior. Oftentimes, however, the solution lies with individual choice and knowledge but can be set back by external challenges. For example, though a person's comfort level may be improved with simple behaviors such as wardrobe selection (versus modifying the internal temperature), external factors such as poor infrastructure or poverty may prevent individuals from having this option. Similarly, learning more about how energy sources and our behavior negatively impact our environment, may positively affect our choices. However, external factors may prevent us from taking action. The next section discusses the internal challenges researchers exposed in their past work.

2.1.1.1 COMFORT AND CONVENIENCE

Understanding comfort and convenience is critical to understanding limits in motivating sustainable behavior change. The challenge in understanding comfort is in knowing, or being aware of the many ways in which people define, experience, and manage comfort. Participants in prior studies defined comfort in a variety of ways. For example, Chetty, *et al.*, defined comfort as *"the desire to have thermostats set to most preferred temperature settings over being energy efficient"* (2008, p. 245-246). For non-"green" households, researchers described comfort as that of convenience (Pierce and Paulos, 2010). In an Australian study that investigated ways to achieve efficiency to change household norms and expectations, the author linked comfort with cleanliness and associated the terms with maintaining body temperature and keeping our bodies clean (Strengers, 2008).

Interestingly, the ways participants *achieved* comfort also varied. In the case of "green" participants, some households adjusted and reconfigured blinds, solar panels, windows, and doors. The authors also gave an example of households opening lower floor windows and using skylights to create a "thermal chimney" effect to pull cool night air in through the windows and to push "stale air out through the skylights." Comfort was not limited to environmental settings but also was referred to in terms of noise levels, and how people felt in terms of their financial stability (*i.e.,* they no longer had to worry about energy costs, and environmental settings did not matter). In these cases, it is convenient to turn on the thermostat for comfort, or to leave the thermostat on while away.

In essence, comfort is more than cooling and space heating (Shove, 2003); it relates to our cultures, past experiences and expectations. For example, Shove refers to comfort as *"keeping oneself and one's clothes appropriately clean."* The frequency in which one bathes or washes clothes is driven by past experiences and/or social norms, or what others deem appropriate. This translates into energy consumption as U.S. householders primarily use washers and dryers to wash clothes, and showers, sinks, and bathtubs as a convenience for bathing. Cooling and space heating, however, account for a large percentage of household energy consumption. So, understanding individual and household boundaries for comfort is important for motivating sustainable behaviors, and knowing what may or may not lead to successful behavior modification.

2.1.1.2 "Invisibility" of Energy

If we could hear, see, and breathe the effects of climate change on a day-to-day basis, we would most likely change our behaviors. Having the ability to see the impact of our energy consumption on the climate and environment is likely to have the same effect. Unfortunately, our energy consumption, its effect on climate change, and the effect climate change will have on our future generations are all invisible. Further, many people have a hard time interpreting units of measurements such as the kilowatt-hour. Researchers from several of the studies we reviewed raised similar concerns (Chetty, Tran, and Grinter, 2008). They spoke of the challenge of "invisible" energy and highlighted the fact that energy is impossible to visualize as it is being consumed. In addition, the frequency of feedback (*i.e.,* receiving monthly electricity bills) is not sufficient and the units of measurement, *i.e., kWhs* do not connect to household behaviors (Chetty, Tran, and Grinter, 2008). As a solution for this disconnect, households desired real-time feedback and pricing information so that they could tie real-time feedback to behaviors and given costs (Chetty, Tran, and Grinter, 2008). Households also wished to use this information to identify household appliance inefficiencies and to better understand the benefits of consuming less (Chetty, Tran, and Grinter, 2008). On the other hand, many households, primarily those not responsible for paying electricity, have no idea about the costs of their electricity bills (Pierce, Schiano and Paulos, 2010).

2.1.2 External Challenges

External challenges, or economic, social, cultural, and institutional factors, are significant precursors of pro-environmental behavior (Kollmuss and Agyeman, 2002). Understanding these factors provides a comprehensive perspective of the components affecting home conservation behavior. These factors help create a broader picture for understanding new ways of motivating and encouraging home energy conservation. In this section, we discuss external challenges that occur at the household level, such as household type, who pays for electricity, income, and multiple-stakeholder issues.

2.1.2.1 HOUSEHOLD CONTROL AND PAYMENT RESPONSIBILITY

Certain households such as renters lack control over their environment and must negotiate with the landlord or building manager to address energy-related issues. Power imbalances between renters and landlords may prevent renters from having their issues resolved (Williams, B.E., 2008). In addition, investment in energy efficiency for rental housing may be lower because of the split-incentive problem – *i.e.* problems that occur based on who has control over the household space and who is responsible for paying electricity. The "landlord-tenant problem" is a classic example. In many cases, renters pay for their electricity in apartments, but landlords are responsible for initial purchases and upgrades (IEA, 2007). On the other hand, when landlords pay for electricity, renters may maximize comfort because they are not responsible for energy bills. As a result, one may assume that the person responsible for paying energy bills is likely to be more conservative with his or her consumption than a person who is not responsible for paying energy bills. In the case of master-metered apartments, university dormitories, and government-subsidized facilities such as public housing, for example, residents are often not responsible for their utility bills. According to an International Energy Agency (IEA) study, split-incentives are responsible for a significant fraction of energy use worldwide (2007).

This information is critical in understanding the nature of home-energy consumption. In addition, household income played a role in several qualitative studies (Woodruff, Hasbrouck and Augustin, 2008; Chetty, Tran and Grinter, 2008; Pierce, Schiano and Paulos, 2010) and could prevent or enable households to practice sustainable behaviors. We discuss this factor next.

2.1.2.2 HOUSEHOLD INCOME

Income affects pro-environmental behavior (Clark, Kotchen and Moore, 2003; Pierce, Schiano and Paulos, 2010). There is research that finds that those with pro-environmental concerns are more likely to belong in higher-income populations (Balderjahn, 1988). However, an article in *Ecological Economics* stated that though some individuals wish to live more sustainable lifestyles, certain circumstances (*e.g.*, social norms) lock them into these lifestyles. "*Some of these circumstances are deliberately created by other interests, and a policy to limit consumption must look for adequate means over a large and varied field…*" (Sanne 2002, p. 273). Therefore, failing to account for economic factors such as income could lead to narrowly focused solutions and considerations when developing technologies to address home-energy consumption. Prior research shows that low-income households spend greater percentages of their income on energy consumption than do affluent households (Williams, 2008a). The increase in cost of home energy in recent years is greater than income gains for very low-income people (Williams, 2008a). This creates economic hardships, which often force low-income households to make tradeoffs between necessities such as heat and electricity (Williams, 2008a). Financial pressure may affect how and whether an individual saves energy. However, based on the charitable generosity of low-income households (James & Sharpe, 2009), financial pressures do not appear to be of prime importance to them. Additionally, low-income individuals often live in structurally inefficient households (*i.e.,* unsealed windows, poor insulation) with less efficient appliances due to income (Shui, 2002). An increase in the energy efficiency of low-income homes would significantly reduce energy use and carbon dioxide (CO_2) emissions (Williams, 2008b). Now that we have discussed how income plays a role in pro-environmental behavior, we discuss another key challenge that plays a factor across many situations – multiple stakeholders.

2.1.2.3 Managing Multiple Stakeholders

In their review of challenges in HCI, DiSalvo *et al.* argue that few HCI sustainable research studies target groups, or multiple stakeholders (2010). In fact, of the 157 relevant HCI papers reviewed, they found that 70% of them target individual consumers, not groups, or multiple stakeholders. One exception is the work by Woodruff, *et al.*, who concluded that, technologies must provide support for individuals and the collective in behavior change; this was as a result of the leadership their "green" participants assumed in sharing their success with others in the community as well as their willingness to serve as mentors to other community members by answering sustainability-related questions from community members. A second exception is the work by Chetty, *et al.*, who found that among non-green households, those that directly influence home-energy use include household members, utility companies, and policy-makers. For example, utility companies provide households with consumption information, which may influence consumption. Further, since policy governs everyone's consumption (Chetty *et al.*, 2008), it has a greater impact. Additional stakeholders such as landlords and maintenance may also affect household consumption. However, these stakeholders predominantly exist in rental environments. Given that 30% of U.S. households rent, studying the impact of multiple stakeholders on household energy consumption is increasingly important.

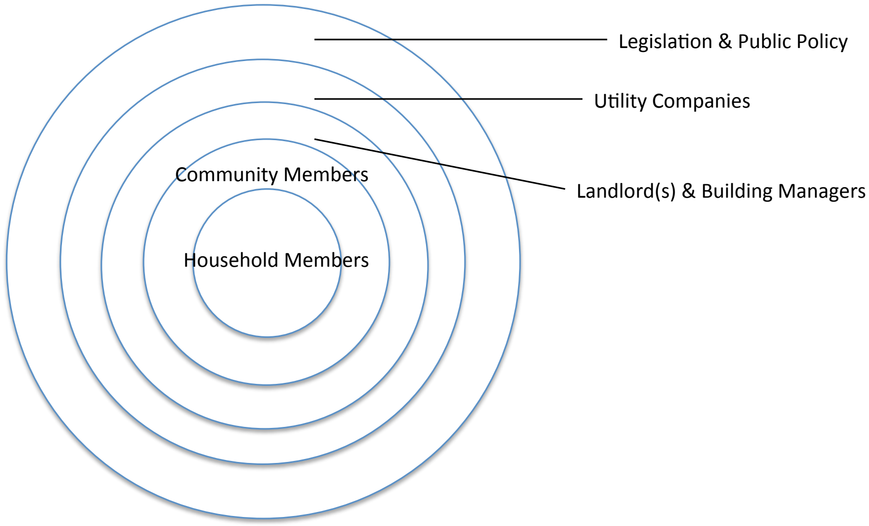


Figure 2 - Stakeholders affecting household energy consumption

2.1.3 SUMMARY

As we demonstrated in this section, understanding energy use in the home can allow us to broaden the scope of our considerations and focus when designing eco-feedback technologies. We have also discussed the various internal and external challenges householders face in reducing their home energy consumption. These challenges consist of several levels, including: 1) personal comfort and convenience; 2) the fact that energy cannot be seen and is difficult to measure, comprehend, and link to actual behaviors (internal factors); 3) the effect of external factors on consumption such as household control and payment responsibility, income, and multiple stakeholders on consumption. Now that we have a better understanding of home-energy consumption, a natural next step is to investigate methods of changing conservation behavior. We discuss this in the next section.

2.2 DETERMINANTS OF CONSERVATION BEHAVIOR

In the prior sections, we discussed everyday practices around energy use in the home and internal and external factors that affect these practices. In this section, we look to understand the factors, or influential determinants, of energy conservation behaviors. This section is particularly important to those wishing to design and develop technologies to promote conservation behavior change. Section 2.3 builds upon this work to extract techniques to be implemented into eco-feedback technologies and to effectively modify energy conservation behavior. Next, we describe the factors that affect conservation behaviors and present a model that effectively shows how these determinants influence behavior change. We conclude with challenges that exist to changing conservation behavior.

2.2.1 Factors Leading to Conservation Behavior

Many factors determine conservation behavior (Jackson, 2005; Cleveland, Kalamas and Laroche, M., 2005). These behaviors have been linked to reduced resource and energy consumption (Gardner and Stern, 2002), behaviors such as energy and water conservation, car use reduction, and to an extent, responsible waste disposal and recycling (Jansson, Marell and Nordlund, 2010). Understanding drivers of these behaviors is critical because they could have substantial positive effects on the environment. Factors that cause some discomfort or alter habits are likely to make behavioral change more difficult (Ritchie and McDougall, 1985), while those that require little or no personal or financial sacrifice are likely to bring about change more easily (Jansson, Marell and Nordlund, 2010). We discuss these factors next and separate them into three categories: routines and habits, intentions, and external factors.

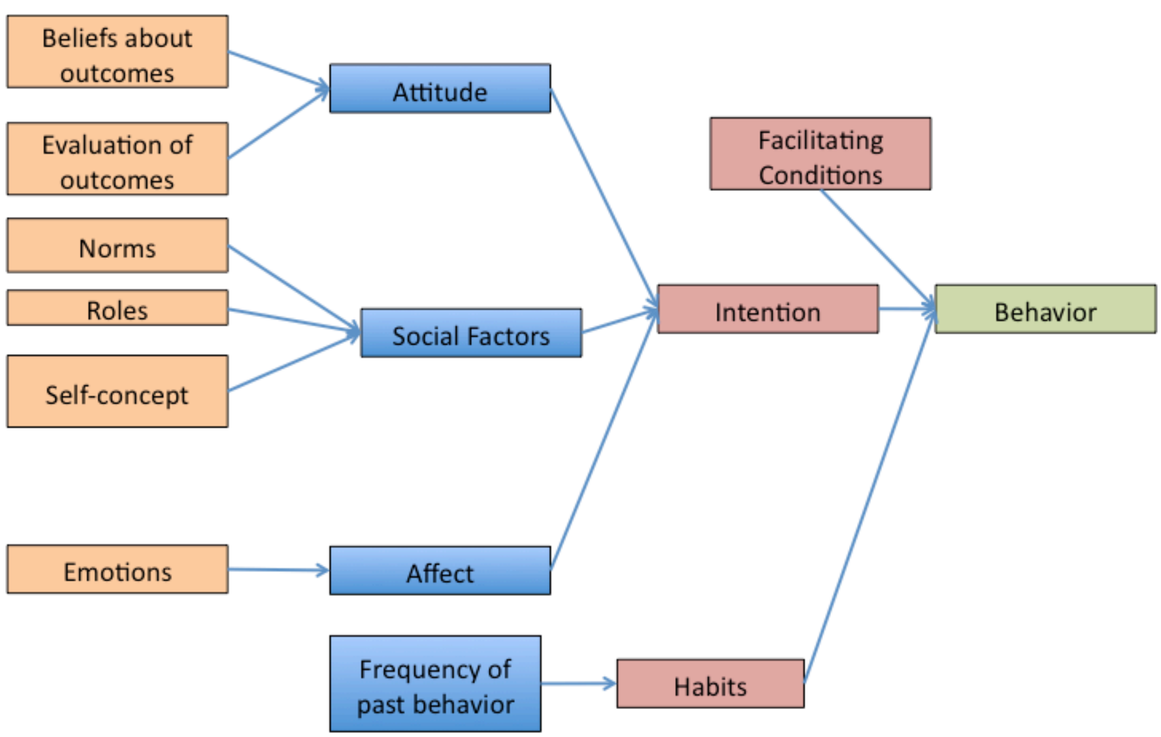


Figure 3 - Triandis' Theory of Planned Behavior (from Jackson, 2005)

Some models of behavior can help us to understand the psychological and social influences on pro-environmental consumer behavior (Jackson, 2005). These models account for four key internal and external elements to behavior change. These include: facilitating conditions, or situational factors (Stern, 2000; Triandis, 1977) such as the lack of access to certain resources, insufficient or unequal access; attitudinal factors (Stern, 2000; Triandis, 1977; Ajzen and Fishbein, 1977); habits or routines (Stern, 2000; Dahlstrand and Biel, 1997; Triandis, 1977), social influences (Giddens, 1984; Stern, 2000; Triandis, 1977; Ajzen and Fishbein, 1977), such as norms and roles; and personal capabilities (Triandis, 1977; Stern, 2000). Triandis' Theory of Interpersonal Behavior (see Figure 3) does a comprehensive job of laying out these factors.

As you can see, Triandis' model categorizes attitudes, social factors and affect into *intention*, which has a direct impact on behavior, *habits*, or routines, and facilitating conditions, or *external factors*. After reviewing behavior models and theories, we saw that many of them converged on the notion that habits, intentions and external factors determine behavior as per Figure 4, which we discuss next.

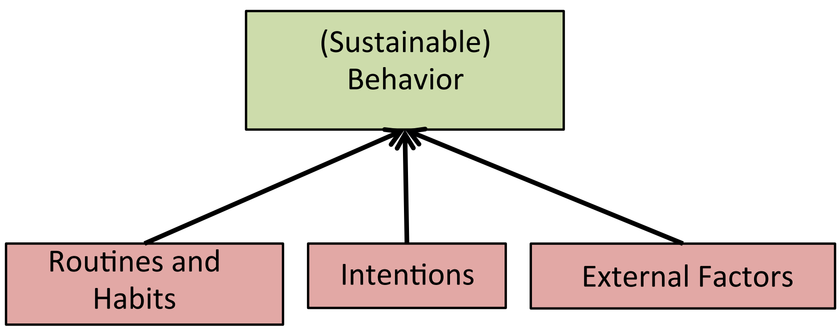


Figure 4- Simplified diagram of models of behavior change

2.2.1.1 ROUTINES AND HABITS

As shown in Figure 4, from a theoretical perspective, behavior is not always a conscious, or *intentional* decision. Thus, it is important to identify habitual behaviors that may prevent sustainable behaviors, and to explore ways to break these habits. According to Dahlstrand and Biel, changing behaviors often requires breaking existing habits and creating new ones (1997). There is agreement in habit research to three requiring factors for habits to evolve (Thøgersen and Ölander, 2006):

1. repetition of a behavior
2. the behavior must take place in a stable environment; and
3. rewards for the consequences of the behavior must be available

2.2.1.2 INTENTIONS

Much of the work in energy feedback is based on models of behavior change driven by *intentional* actions, which are in turn caused by a variety of factors such as attitude, or a person's overall positive or negative assessment of the behavior; perceived behavioral control, or the measure of how difficult or easy displaying the exhibiting behavior will be; and motivations and social factors, such as subjective norms (*e.g.*, see (Azjen, 1991; Jackson, 2005)). For example, a positive attitude about a behavior may or may not lead into an action because of social pressures.

2.2.1.3 EXTERNAL FACTORS

One external factor affecting behavior is institutional constraints (Stern, 2000; Triandis, 1977). Institutional constraints may include specific rules, or regulations that may pose as an obstacle to pro-environmental behavior. For example, legislation and public policy governs everyone's consumption (Chetty, Tran and Grinter, 2008) and therefore has a great impact on consumption. Another external, or situational factor includes whether or not an individual or household has access to certain resources. For example, for most renters, landlords and building managers responsible for the building infrastructure may influence consumption either directly or indirectly. They may provide access to recycling and/or an apartment building's total energy consumption. For homeowners, utility companies provide households with consumption information and may influence consumption based on the information collected (Chetty, Tran and Grinter, 2008). One way to reduce external or situational barriers could be to make additional resources available or known to individuals or communities.

2.2.1.4 CHALLENGES IN CHANGING CONSERVATION BEHAVIOR

In this section, we explained the factors that lead to conservation behavior based on several models of behavior. While these factors appear to be straightforward, bringing about behavior change is often difficult. First, individual behaviors are deeply embedded in social and institutional contexts (Jackson, 2005) that may be constantly changing. Second, factors such as individual habits, are often difficult to change. Modifying or eliminating habits, for example, can cause discomfort for some individuals, and factors such as social norms may be difficult to change at an individual level.

These factors vary from individual to individual, or from household to household. Third, certain pro-environmental behaviors may not result in overall environmental gains. For example, one may replace their non-programmable thermostat with a programmable one but then waste energy by using the programmable thermostat incorrectly. This is known as the rebound, or takeback effect. Finally, integrating these factors into programs and technologies is not a straightforward process and there are no guidelines or frameworks for this type of integration. In the next section, we list techniques that have either been shown to be effective, or have been hypothesized to be effective for changing behaviors. We outline how these techniques link back to the factors described in this section.

2.3 TECHNIQUES USED TO CHANGE CONSUMPTION BEHAVIORS

The previous section discussed what factors affect energy conservation behavior and the methods in which these factors drive behavior. Our next step was to explore which sustainable behavior change techniques have been successfully used, or highly recommended in the past. We then linked these techniques back to the behavioral model shown in Figure 4, which shows how these techniques worked. We also considered techniques used to address the following challenges mentioned in section 2.2.1.4:

1. Impacts social or institutional contexts
2. Modifies habits, or change comfort standards
3. Changes social norms
4. Informs individuals, or households of potential rebound effects
5. Makes consumption more visible

We specifically selected some of the *feedback* techniques used in: 1) Fischer's survey of 5 review studies and 21 individual studies (2008); 2) a report of utility-based approaches to address energy-use behavior at home (Carroll, Hatton and Brown, 2009); and 3) Froehich *et al.'s* review of eco-feedback technology (2010). Since each technique requires some form of feedback, we provide an overview of feedback next.

2.3.1.1 FEEDBACK

In a review of 51 "energy" related HCI publications, 70% of the corpus was related to *electricity consumption feedback* (Pierce and Paulos, 2012). There are two types of feedback and both have been shown to lead to energy reduction. Direct feedback includes real-time feedback displays that show consumption and cost data (Darby 2006) and can typically lead to a 5-15% savings in electricity consumption (Fischer, 2008). Indirect feedback includes energy-use information such as utility statements (Darby 2006) and typically leads to a 0-20% reduction depending on the quality of information given and the context (Fischer, 2008). Feedback is effective as it can affect individual attitudes and social norms, which impact one's intention to change behavior. Further, feedback has shown to be effective for helping to create new habits and abandon old ones (Fisher, 2008). Since direct feedback, or providing real-time customer data is perhaps the most effective form, we focus on understanding the effect techniques have when used with direct, real-time feedback in this section. We first discuss the effects of real-time feedback alone (*i.e.*, displays cost and consumption information only). We then discuss the effectiveness of techniques such as comparisons, social engagement, social sharing and goal setting.

2.3.1.2 Real-Time Feedback

There are positive and negative aspects to real-time feedback information. First, as we mentioned previously, real-time feedback information has been shown to lead to a 5-15% reduction in energy. However, one shortcoming of this figure is that a large portion of the supporting data is taken from countries outside of the United States (*e.g.,* Europe, UK, Japan, Australia). Households in these countries may have varying attitudes on energy conservation than U.S. households (Carroll, Hatton, Brown, 2009). On the positive side, real-time feedback does make energy consumption more visible, which was one of the challenges discussed in section 2.2. So, householders can see the impact their behaviors have on consumption. However, as of now, real-time feedback technologies may be limited to individuals with economical and/or environmental motivations (Thørgersen and Crompton, 2009).

Most real-time feedback displays include general information content such as real-time consumption and cost information, and marketers advertise these products as "green." However, according to an online survey of 50 early energy monitoring device adopters, only 9% were interested in carbon footprint data; 6% in cost and bill information, or prediction; 59% in real-time electricity consumption monitoring; and 26% of the respondents said that they were interested in education and energy-reducing tips (LaMarche, Sachs, and Roth, 2011).

Overall, real-time feedback addresses one of the challenges we presented earlier – making energy consumption visible. It also has the ability to address user attitudes, and depending on availability, it can help modify existing habits. We highlight the challenges that real-time feedback can address as well as reiterate the techniques real-time feedback uses to modify behavior in Table 1.

2.3.1.3 Comparisons

Comparison from an energy consumption perspective relates to historic comparison, or contrasting past and present consumption (Petkov, Köbler, Foth, Medland, Krcmar 2011; Grønhøj & Thøgersen, 2011). Social comparison differs in that individuals are contrasting their consumption with other households (Allcott, 2010; Petkov *et al.,* 2011). Grønhøj & Thøgersen also refer to this as normative comparisons, in which comparisons are made with "similar" households (Grønhøj & Thøgersen, 2011). Social comparison has been used successfully outside of the energy domain as a mechanism to increase contribution to communities (*i.e.,* Chen, Harper, Konstan and Li, 2010; Ayres, Raseman, Shih, 2009). Though historic comparison has been shown to be effective (Darby, 2006), assessment of social comparisons in environmental psychology is mixed (Froehlich *et al.*, 2010).

For example, social-comparison theory states that comparison with others reduces uncertainty and helps create standards of personal behavior (Festinger, 1954). In an energy-related workplace study (Siero, Bakker, Dekker, van den Burg, 1996), employees received feedback on their own conservation behavior. A second group followed the same procedure but with information about the performance of the first group. The results of the study showed that employees in the comparative feedback condition saved more energy than employees receiving information about their own performance only. A focus on a common group identity can lead to improved group member performance and cooperative behavior (McMakin, 2002).

However, householders have been skeptical of comparisons with "similar" households (Grønhøj & Thøgersen, 2011). In a study of energy consumption in military households, the result of social identity and social comparison as motivators was not as influential as expected (McMakin, 2002). It was thought that the military environment, which emphasizes competition and is more homogeneous than most civilian populations, would be particularly suited for social comparison and subsequent improved performance (McMakin, 2002). However, survey comments indicated that some residents were resentful of, and even hostile toward neighbors they perceived as wasting electricity. With up to half the respondents on post moving within a year, there may be little opportunity to build a group identity and even less motivation to make one's neighborhood perform better than everyone else's (McMakin, 2002). On the other hand, social comparison could provide insights on inefficiencies and promote collective action.

In McMakin's study, social comparison had a greater effect on parental rather than group behavior. For instance, parents modeled energy-efficiency behaviors in the home as a way for children to compare behaviors and develop good energy-use habits as a result (2002). This is consistent with research that shows that in terms of adopting environmentally friendly behaviors, children had a greater influence on their parents and spouses a greater influence on each other than does the influence of neighbors (Bratt, 1999).

OPower, a startup company that works with utility companies to provide data analysis on electricity, helps to improve information sent to customers regarding their electricity consumption. Motivated by a successful experiment to test the effect of normative messages on energy conservation (Schultz, Nolan, Cialdini, Goldstein and Griskevicius, 2007), OPower began using neighborhood comparison as a way to encourage energy conservation. Thus far, OPower has successfully used comparison techniques to help reduce consumption (~2-4%) (Allcott, 2010); however, it has not used this technique with real-time feedback. OPower uses paper bills to show how households compare with their neighbors; it is possible that integrating comparison techniques with real-time feedback could lead to more reductions.

Unfortunately, there have been very few studies that shed light on the integration of social comparisons with real-time feedback of energy use. Based on the results of prior research and the impact historical comparisons could have on consumption in comparison to social comparisons (see Table 1), social comparisons appear to be more advantageous than historical comparisons. Social comparisons have the potential of changing social norms, whereas historical comparisons do not. Further, social comparisons could cause households to raise questions about their consumption and possibly address external factors or facilitating conditions. Based on the success of social comparison and real-time feedback in prior studies, integrating comparisons with real-time feedback could have a significant impact on pro-environmental behavior and the reduction of energy consumption.

2.3.1.4 SOCIAL ENGAGEMENT

Human beings are social in nature (Jackson, 2005) and though we aim to be individuals, we model our behaviors on those around us (*ibid.*). People are more likely to make permanent changes in their energy behaviors when their neighbors and friends are changing their behaviors in similar ways (McMakin, Malone, and Lundgren, 2002). According to Jackson (2005), pro-environmental change must occur at a social level and cannot be conceived as an individual level process. While we showed examples of successful uses of comparison techniques across home energy, very few studies combine social engagement with real-time energy monitoring technologies for residential domains. Notable exceptions include Petkov, Köbler, Foth, and Kremer (2011) and Vande Moere, Tomitsch, Hoinskis, *et al.* (2011). Developers of *EnergyWiz,* a mobile application prototype, identified insights on comparative feedback designs *via* interviews (Petkov, Köbler, Foth, and Kremer, 2011). Other researchers found success by encouraging certain kinds of social involvement such as competition and peer pressure (Vande Moere, Tomitsch, Hoinskis, *et al.*, 2011).

We distinguish competition and peer pressure from social comparison used in these studies. In our view, competition implies some type of social reward or incentive, while peer pressure may suggest a negative outcome for noncompliance. These techniques were used in these studies as a form of social engagement. Neither of these studies, however, accounted for external factors (landlord conflicts, building issues, *etc.*) that could affect energy-related behavior, nor did they support or study discussion between or among stakeholders.

The addition of social engagement could affect social factors such as norms and roles, which could lead to some facilitating conditions being addressed; however, this depends entirely on the nature of the engagement. Social engagement around feedback information such as electricity costs and overall consumption may not be sufficient. Without some type of common goal or commitment, or special type of feedback display, households may not be interested in engaging around electricity alone. Perhaps households with multiple members or householders that share electricity bills may be more motivated to engage around this information.

2.3.1.5 PUBLIC COMMITMENT

Commitments are oral or written promises, or pledges to change behavior (Abrahamse, Steg, Vlek and Rothengatter, 2005) and have been successful in encouraging changes in electricity consumption (Katzev and Johnson, 1983; Pallack, Cook and Sullivan, 1980). The use of social websites, such as Facebook to support social issues (*e.g.*, sustainability) is possibly one of the most underexplored aspects of motivating behavior change (Froehlich, Findlater, and Landay, 2010). Social networking sites could motivate others to be energy efficient by providing accountability (Froehlich, Findlater, and Landay, 2010; Mankoff *et al.*, 2010). For example, it is probable that those who publicize their names or results may feel some type of pressure to further reduce consumption. In fact, in a field experiment conducted by Pallack *et al.* (1980) randomly assigned households were asked for their permission to publicize their names and results of their performance in the conservation study before the study began. According to the results, the group that publicized their results used 15% less natural gas and 20% less electricity than those that did not. None of the surveys we reviewed discussed communication between or among multiple stakeholders, so there is an opportunity to explore the use of social sharing as a technique that can be combined with real-time energy feedback in the future.

Adding the factor of accountability may lead to changes in social norms. Leveraging social media sites such as Facebook or Twitter could definitely have an effect on this factor; however, it is uncertain as to whether or not these effects would be positive or negative. Sharing information with others could lead to issues related to external factors, or facilitating conditions, such as poor infrastructure. Adding this social component could help to provide solutions to these types of situations.

2.3.1.6 Goal Setting

According to Ehrhardt-Martinez, *et al.*, feedback devices alone may not lead to the highest energy savings in the home; additional techniques such as integrating goal setting and engaging participants to take small steps to sustainable actions may be effective (2010). However, in a comparative review of 89 environmental psychology papers and 44 HCI papers, Froehlich, *et al.* found that goal setting had not been explored significantly in HCI environmental domains (2010). In one field study of goal-setting used with daily feedback of gas consumption, results showed a decrease of 12.3% (van Houwelingen and van Raaij, 1989). So, this is another technique that could effectively reduce energy consumption, and there are certainly opportunities for further exploration.

We have seen how goal setting could lead to positive outcomes. However, goal setting has disadvantages also. Depending on how difficult the goal is to accomplish, an individual or household could give up or lose interest because of their perceived difficulty in reaching the goal (Latham and Locke, 1991). In terms of challenges, goal setting primarily impacts attitudes and motivations but may have little impact on social norms or social roles if used as an isolated technique. Sharing the goal with others within a household or community is likely to become a public commitment, as discussed in the previous section, and affect factors such as social norms. As discussed earlier, this could have a positive or negative affect on behavior.

2.3.1.7 Summary

Feedback has played a key role in behavior change as it influences user attitudes and intentions; when integrated with other techniques such as comparison, social engagement, social sharing, and goal setting, feedback could be more effective. Table 1 below provides a summary of these techniques, which includes how the techniques use determinants of behavior as discussed in section 2.2 and address the challenges related to changing behaviors as identified in section 2.2.1.4. Based on our evaluations of these techniques, there many open opportunities to explore these techniques further. Future studies should further investigate the integration of these techniques into real-time feedback devices.

Table 1 - Real-time feedback methods used to change behavior and challenges addressed. The shaded green areas represent challenges described in section 2.2.1.4. X's represent which challenges each technique addresses, or which factors each technique uses to change behavior. ?'s indicate areas of uncertainty, or areas to be explored in the future. Note that the frequency of feedback affects the likelihood of breaking habits (*i.e.*, "repetitive prompts help to form new persistent habits" (Caroll, Hatton, Brown, 2009, p.12)

	Methods Used					Challenges Addressed	
		Modifies intention					
	Breaks habits/Creates new habits	Attitudes	Social Norms	Social Roles	Addresses facilitating conditions	Informs individuals, or households of potential rebound effects	Makes consumption more visible
real-time feedback (consumption/cost information only)	X	X					X
real-time feedback + historical comparisons	X	X					X
real-time feedback + social comparisons	X	X	X	?	?		X
real-time feedback + social engagement	X	X	?	?	?		X
real-time feedback + social sharing	X	X	X	?	?		X
real-time feedback + goal setting	X	X					X

2.4 SUMMARY

In this chapter, we sought to understand conservation behavior with the support of studies seeking to understand resource use at home; we then discussed factors that influence conservation behaviors and concluded with a review of techniques that could be used in combination with real-time feedback to change conservation behavior. We noted that many studies failed to account for certain groups, such as renters and low-income households. In Chapters 3 and 4, we explore the low-income and rental population, as well as the conflicts that exist in the landlord/tenant relationship.

3 It’s Not all About “Green”: Energy Use in Low-Income Communities

One of the most important socio-demographic factors that influence energy use and conservation is income (van Raajj & Verhallen, 1983). Thirty percent of U.S. households make less than $30K *per* year (U.S. Census, 2009). Yet, few details are available about the relationship between low-income households and energy, or how they manage their energy use. Without knowledge of the motivations and barriers affecting energy conservation, interventions will be less effective, and even programs that attempt to reach out to this community will fail to engage a large segment of the population.

The median energy consumption for heating and cooling for low-income households is almost as much as that of affluent households (Shui, 2002). Since low-income households tend to have smaller homes (Corcoran, 2001), it is important to understand the causes of their relatively high home energy emissions. Economic factors such as an inability to purchase energy efficient devices, and renting or owning homes in poor repair (*ibid.*), are likely to have a big impact.

As mentioned in the related work, some factors that affect energy use include external factors (*e.g.*, economic, social, cultural), internal factors (*e.g.*, awareness, values, attitudes, emotion), and demographic factors (Kollmus & Agyeman, 2002). In other words, our behaviors are functions of our personal selves (Gersick & Hackman, 1990) and our environmental conditions. However, prior living conditions, culture and other factors may all play a role in the energy use of low-income householders.

We conducted a photo-elicitation study (Clark-IbáÑez, 2004) with residents in 26 low-income households across two states to explore their relationship to energy use. Photo-elicitation is a qualitative method where participants take their own photos, which are used to elicit information that may otherwise have been invisible to the interviewer. Our results demonstrate that these households are creatively engaged in energy conservation under a wide range of constraints. Participants described saving energy even when they did not pay for their own energy and were motivated by habit, spirituality and concern for future generations as much as by money and comfort. They reported more diverse and creative strategies for saving energy than either type of affluent householder. While they suffered from a lack of feedback about energy use, more severe barriers to saving energy included lack of control over other people and infrastructure, lack of money for up-front investments, and safety. Basic assumptions about responsibility for bills, building ownership, and the relationships between household members need to be reconsidered when designing Ubicomp technologies for saving energy. Designers may need to address issues such as unsupportive landlords or housemates.

In the rest of this chapter, we describe the methods we used to explore energy consumption in low-income households, discuss the results of our study and conclude with a discussion of our findings. This chapter is published in Ubicomp 2009 (Dillahunt, Mankoff, Paulos and Fussell, 2009).

3.1 METHODS

Our study took place in two locations: a small town in the Southern U.S. (*NC*) and a northerly metropolitan area (*PA*). We sought out members of households falling under the federal poverty line (this is dependent on household size and other factors). We advertised the study online (Craigslist), by posting flyers (*e.g.,* Figure 22), dropping flyers in random mailboxes, door-to-door visits, and in-person in central locations serving the low-income community. We varied the time and day of in-person recruiting, emphasizing times when many residents were likely to be available.

The goal of our study was to elicit participant viewpoints and practices surrounding energy management. We explored energy as broadly as possible to avoid introducing bias in the definition of energy or the set of practices under consideration. Our process involved a lightweight diary study with cameras followed by elicitation interviews (Clark-IbáÑez, 2004). The data included photos and transcriptions of interviews. Participants were paid $10/hour for interviewing.

3.1.1 Photo Diary & Elicitation Interviews

We interviewed 26 participants in the winter months between November 2008 and March 2009. We asked participants to “take pictures of objects and/or scenarios that make you think about personal energy use or anything that makes you think about energy.”

Participants were told to think of the camera as a personal diary and encouraged to take pictures inside and outside of the home. We required three starting photos: 1. The household thermostat, 2. a family member or close friend using energy, and 3. An energy source, *e.g.*, electrical wall outlet. Participants were assured that there were no right or wrong answers to the task and were given a minimum of a week to complete the task.

After developing the film, we conducted a photo-elicitation interview (Clark-IbáÑez, 2004) with each participant. These lasted 1-2 hours and focused on each participant’s thoughts and actions around energy. We discussed each photo the participant had taken and discussed community involvement and some participant-driven issues. We took extensive notes during each interview and all interviews were transcribed.

3.1.2 Approach Used for Analysis

At the end, we had 370 photos, ~24 hours of interview data, and a total of 216,494 words transcribed. We created physical posters containing case studies of each participant including photos, key facts from interviews, demographics and income. We hung all of these in a working space where we met as a group to explore this data. We also conducted iterative coding of the data. We created initial categories by organizing the photos into similar groups and discussing the case studies. This approach was influenced by the open and axial coding used in *grounded theory* (Glaser & Strauss, 1967). Based on this, one of the authors assigned low-level codes to the transcribed data in a grounded fashion using a text coding tool (TAMS Analyzer, 2009). We met multiple times as a group to refine and coalesce these codes into higher-level categories. These categories were also influenced by psychological theories of habit and motivation (described above). Finally, we used the case studies and the results of our coding to discuss and extract common themes.

3.1.3 Description of Participants

We recruited forty participants; fourteen dropped out, due primarily to the length of the study. Of the remaining twenty-six (see Table 2), five were interviewed without photos for technical or logistical reasons. Most participants were female (20). All but one were younger than sixty

Table 2 - Participants above the dotted line are from NC, below are from PA. *Housing*: (PH: Public Housing; S8: Section 8; O: Other). *Married?* (S: Single, separated or widowed, P: Married or living with a domestic partner). *: Smart Comfort. All names given are pseudonyms to protect participants' identity.

Name	Primary Motivation	Income	Housing	Gender	Age	Married?	# Adults	# Children	Bedrooms
Monica	What can I do?	<10k	PH	F	21-25	P	2	3	2
Candace	Protect environment	10-20k	PH	F	18-20	S	2	4	3
Geraldine	Waste not want not	<10k	O	F	41-50	S	1	2	3
Nicole	Secondary benefit	<10k	S8	F	21-25	P	1	1	2
Erica	Protect environment	10-20k	S8	F	31-40	S	1	2	3
Shannon	Secondary benefit	<10k	S8	F	31-40	S	1	1	3
Cheryl	Secondary benefit	<10k	S8	F	21-25	S	1	1	2
Paul	Protect environment	<10k	PH	M	21-25	S	4	2	3
Brian	Protect environment	<10k	PH	M	21-25	S	1	0	2
Michelle	Secondary benefit	<10k	S8	F	21-25	S	1	4	3
Jacqueline	Waste not want not	10-20k	PH	F	41-50	S	1	3	3
Catherine	Waste not want not	<10k	PH	F	51-60	S	1	2	3
Anita	Protect environment	<10k	PH	F	41-50	S	1	2	2
Veronica	Waste not want not	<10k	PH	F	51-60	P	2	0	2
Angela	What can I do?	?	O	F	31-40	P	3	2	4+
Charlie	Secondary benefit	<10k	PH	M	31-40	S	3	2	4+
Lauren	What can I do?	20-30k	S8	F	> 60	S	1	1	1
Kim	Secondary benefit	10-20k	PH	F	18-20	S	1	1	2
Dave	What can I do?	<10k	S8	M	21-25	S	3	5	4+
Claudia	Secondary benefit	<10k	PH	F	26-30	S	1	1	1
*Mary	Protect environment	<10k	O	F	41-50	S	1	1	1
*Eve	Protect environment	<10k	S8	F	31-40	S	1	4	2
Yasmine	What can I do?	10-20k	S8	F	26-30	S	1	3	2
Roy	Secondary benefit	<10k	O	M	51-60	S	5	0	4+
Diane	Waste not want not	<10k	PH	F	41-50	P	1	0	1
Justin	Waste not want not	20-30k	O	M	31-40	S	2	0	3

(twelve were younger than thirty). Most participants (22) were African American, including all in NC. Most participants (21) had one or more children living in the household (max: 5). Households consisted of nuclear families (2), single parents (18) and a mixture of parents and other adults or extended family members (5). Most participants (18) earned $10,000 or less, seven earned $10-30,000 and one unknown. The majority (10) were unemployed, eight worked part-time (cashier, administrator and, teacher's assistant, accountant, landscaping, house-keeping), two worked full-time (food service, clerk assistance), and six were self-employed or retired. Five were fulltime parents and six were students (sometimes in addition to other things). Over a third (9) of the participants had completed high school; twelve had some college courses, four had completed college, and one had taken graduate courses.

3.1.4 Description of Sites

We recruited from two complementary locations. Seventeen participants lived in a small town in eastern North Carolina, *NC* (population less than 30,000; median income ~$37,000 (NC City Data, 2009). Nine participants lived in a (relatively) large metropolitan area in Pennsylvania, *PA* (population ~311,000 (Population Finder, 2009) median income ~$32,000 (US Census Bureau Newsroom, 2009). For comparison, the national median income was $50,740 in 2007 (*ibid.*). Our interviews took place during the winter months of 2008 and 2009 (average low ~32ºF and ~22ºF, respectively (Weatherbase, 2009).

Publicly subsidized low-income housing falls into two primary categories: Large buildings with built in community centers commonly known as *Public Housing* (*e.g.,* see Figure 5, left), and scattered apartments commonly known as *Section 8 Housing*. Eligibility is defined by states and includes low-income families, the elderly and individuals with disabilities. Both types of housing may include high and low rise apartments and single-family homes. The primary difference between Section 8 and Public Housing is whether a resident has a choice about where to live (Section 8 may provide vouchers that can be used with any landlord that accepts Section 8 tenants, including but not limited to Public Housing units). Public housing in both cities in our study is 97% or greater African American. Women head most of these households.

Figure 5 - Public Housing Communities in a metropolitan area of PA **(left)** and a small town in NC **(right)**.

Nine participants live in the 218-unit, 29-building NC Public Housing, a complex built in 1941 and expanded in 1953. The facility is located on waterfront property, and borders downtown and historical sites. The neighborhood is unsafe, according to outsiders, and some participants mentioned gang violence, tagging (graffiti) and drug activity. Over 50% of residents we spoke with have washing machines, but the facilities are not wired for dryers (the housing authority provides clotheslines). HUD requires community service of residents who are not working, in school, or elderly/disabled and the housing authority provides opportunities for residents to complete this requirement. The community has a small, rarely used computer lab with broadband access (we only observed one or two people using the lab during a two month period). The community center holds workshops such as homeownership and money management. Participants described the community as tightly knit.

Five participants live in the 420-unit PA public housing, a complex built in 1940 and expanded in 1954. Churches and hospitals surround the neighborhood, which is severely depressed. We were told to recruit in the community center instead of door-to-door for safety reasons. Participants who live here are concerned about issues like safety, drugs and guns, teen pregnancies and youth violence. The community has a well-used computer lab with broadband access. The community center runs programs such as resume writing workshops and computer technology classes. Energy-efficient light bulbs are provided free, and programmable thermostats were being installed at the time of the study. Participants described the community as tightly knit.

An additional seven participants lived in scattered apartments and five lived in rented houses, mobile homes, or townhouses. One participant was a homeowner. These residences varied in their facilities. Most had no dishwasher; some had washer/dryer facilities; some had central air and heat; none had programmable thermostats.

3.2 Results

Interesting and common themes that arose included motivations for saving energy, common energy saving behaviors and reasons for missed opportunities to save energy. Additional themes included sharing and other social factors, *e.g.*, impact of a person’s past on his/her behavior, and approaches to monitoring use. We discuss the results in the remaining sections.

3.2.1 Motivations for Saving Energy

As discussed earlier, households that identify as green are influenced by cultural trends, such as bio-centric activism or trend-focused utopian optimism, that fall outside of more mainstream motivations (Woodruff, Hasbrouck and Augustin, 2008). Spirituality and the health of future generations are also important in green households (*ibid.*). In contrast, “typical” households are motivated by saving money, comfort, and to a lesser degree, environmentalism (Chetty, Tran and Grinter, 2008). We found some similar sources of motivation in the low-income community.

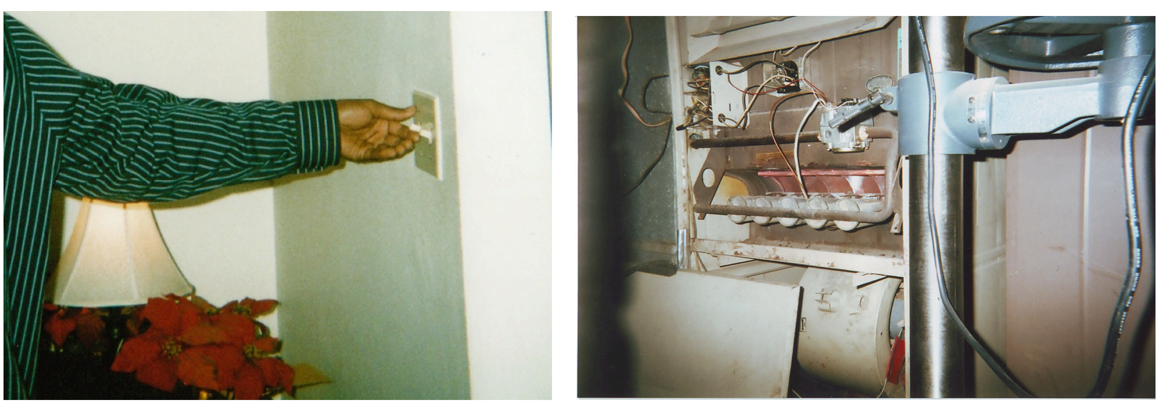


Figure 6 - (left) Candace’s TV, electronic devices and lights can all be controlled by one switch. **(right)** Roy troubleshoots a furnace. **Figure 6** and subsequent images in this chapter were taken by participants as part of the study.

Some of our participants were financially motivated. However, because of public subsidies, only four participants paid their own energy bill. Nine participants only paid when they exceeded a set allocation of kilowatt-hours *per* month. Eight received stipends (for part of the rent and/or utilities). Five had access to free, unlimited energy. Interestingly, these differences had little effect: not paying for energy did not stop participants from saving it. Spirituality, protecting the environment for future generations, and prior training/habits were the primary reasons most participants saved energy. A smaller number of participants reported saving energy for financial reasons.

3.2.1.1 PROTECTING THE ENVIRONMENT FOR FUTURE GENERATIONS

Although only two participants used the word "green" in their interviews, concern for the environment for the sake of future generations was prominent among seven – "[for our daughter], and her children and grand children," – Brian (from NC). This form of environmentalism was also found in affluent green families (Woodruff, Hasbrouck and Augustin, 2008), but other motivations mentioned by Woodruff *et al.* (2008) such as those focused on the earth/climate or inward on the person (*e.g.*, self-reliance) were not discussed by our participants.

Many of the participants' concerns for future generations extended beyond the environment. For example, Eve, who cared for four children at home, volunteered for a sustainable garden program, volunteered for Head Start, and helped to run a neighborhood crime prevention event.

In Figure 6 (left), Candace, (from NC) who learned to be environmentally conscious because of her mother and a teacher, is illustrating how her TV, electronic devices and lights are all connected to one switch so that they can all be turned off at once. Candace uses this switch to enforce her rules regarding energy use on other members of her household:

Candace: When you hit the switch, the TV and everything else goes off, and my daughter doesn't know that, so when I'm not in there, I will hit the switch on the wall, and if she tries to turn the TV on, it won't turn on.

3.2.1.2 WASTE NOT, WANT NOT/LIVE WITHIN YOUR MEANS

A moral aversion to waste, driven by a deep connection to God, motivated six of our participants. For example, Roy commented, If you love your house, you'll fix things up…. If your faucets is leaking, fix them. In Figure 6 (right), he is fixing the furnace to help his landlord, and also to help residents in all of the apartments to save energy. Like many of the participants who wanted to avoid waste, this ethic came from his connection to God: "My motivation is really focused on God..." Similarly, Jacqueline (from NC), who accidentally wasted energy during Thanksgiving, commented "And I need to break out of that, because I'm wasting."

*Our results do not explain the prevalence of or reasons that spirituality and environmentalism are linked, but it is not unique to our population: In more affluent green households, this also occurred (*Woodruff *et al., 2007).*

3.2.2 SECONDARY BENEFIT: MONEY OR PERSONAL PREFERENCES

For nine other participants, the two main causes of energy saving behaviors included: the need for money and personal preferences. Saving money was the focus of five of these participants. Even modest cost savings can have a big impact on small budgets, and many participants who reported different primary motivations were also concerned about money.

Candace: I notice a lot of people out here that tend to leave the porch light on… and they have no [idea] it goes to the house electricity bill. … so I don't mess around with the porch light, unless I'm outside, and I always make sure I turn it off.

Although Candace was primarily an environmentalist, she reported removing bulbs from her chandelier for comfort reasons (Figure 7, left).

Figure 7 - (left) Candace removes bulbs from the chandelier for comfort. **(right)** Catherine enjoys line drying her clothes.

Candace: I like to go to lower watts, which just seems to have actually a little yellow tint to it, and it actually keeps the light just light enough, not disturbing you, or, you know, when you're watching TV, it's not a glare... It's very comfortable.

Even a behavior that many view as a burden such as drying clothing on a line can be driven by for personal preference:

Catherine: I don't like dryers…. in the North you don't have lines to hang on. You have a laundry room and a dryer… But to get back and put them on the line and just-- ooh, that felt so great. I really love it. I love it.

3.2.2.1 WHAT CAN I DO?

Similar to some of the participants in Chetty's study of "typical" households (2008) a few participants (5) either didn't care, or felt they were already doing enough. For example, Lauren, an elderly woman from PA who lives alone in a small one-bedroom Section 8 apartment stated:

Lauren: There's nothing else that can be done. I mean I do laundry once a week. I do dishes once a day. I watch television so many hours a day. I'm not home for a lot of hours a day. Then I'm in bed for the rest of the hours of the day. I'm doing it.

3.2.3 SAVING ENERGY—TRENDS AND PROBLEMS

A recent survey of 2,000 Americans found that changing to energy efficient light bulbs and turning the thermostat down in the winter and up in the summer are common energy saving behaviors (Leiserowitz, Maibach, Roser-Renouf, 2008). Recent interviews with residents of 15 "typical" households found similar behaviors, as well as installing a programmable thermostat, turning lights off, and unplugging devices (Chetty, Tran and Grinter, 2008). Participants in our study mentioned similar behaviors although up-front costs, negotiations with housemates, and structural inefficiencies sometimes stood in their way (as described below). Participants also mentioned many other ways of saving energy:

- …continually complain to management to repair kitchen door seal and cork holes in wall. (Catherine)

- Decorate your house with candles and light those… (Nicole)

- I make the clothes, because I cannot afford to pay the light and buy clothes. So I make that. That's energy saving whether you think it is or not. It is. (Lauren)

- Another thing I save in energy is your timing. When you get up in the morning, everybody get up at the same hour. You line up, you go to the bathroom. Take your turn.… Turn the light on and everybody through, turn that light back out. (Lauren again, on managing 7 kids)

- …take that same bucket, wash them walls, wash them dressers... Clean all the dirt around the house, then you mop your floor. That's saving on your hot water. (Lauren)

- …we plant things, and you can actually use things like food stamps to buy seeds. That is one way to save energy, is to grow your own food instead of incurring all the fuel and environmental [costs]. (Eve)

- I love to fish. Matter of fact, went yesterday. (Charlie)

3.2.3.1 Barriers to Saving Energy

Extrinsic constraints that affect environmental responsibility among affluent green homeowners include the quality of public transportation and the availability of environmentally friendly products (Woodruff, Hasbrouck and Augustin, 2008). In contrast, the primary barriers identified by our participants

Figure 8 - Barriers to saving energy

(left) Brian keeps a sheet under the door to prevent air from coming inside. **(right)** An energy inefficient light bulb. Brian commented that this is all he can afford (and had in "real-life").

were financial issues and structural inefficiencies. Availability of products, habit, the choices of other household members, and safety were also important.

Financial issues were especially problematic when saving energy had an up front cost. For example, Angela, who lived in an NC household with three adults and two kids, could not afford to refill her "gas tank" (cost was $600-$1200). Instead, she placed space heaters around her home, saying "if I had, you know, the gas on, then the electricity wouldn't be so high because I wouldn't have to use the space heaters."

Participants spent a great deal of effort making up for the structural inefficiencies of living spaces. For instance, Brian, a participant living in an old and drafty NC Public Housing apartment (shown in Figure 8, left):

Brian: I keep a sheet up in the door, so the most of the air won't come in, but it's still-- that's on the bottom of the door, but the air still comes in from the side.

Monica (NC Public Housing) had similar concerns. Other participants overcompensated for air leaks by turning up the heat:

Catherine: Our windows….ooh baby, air blows right around up in them just like it do this door. We can't feel the little heat until we blast it to 80, which we're uncomfortable with…but we don't want to get real sick.

Some energy saving products were unavailable. As shown in Figure 8, (right), Brian uses inefficient light bulbs because they are inexpensive, but when asked if he knew what the differences in costs were he said… "I never really did the research or went out to the stores. I haven't seen one in real life. I've seen it on TV…"

Similarly, Claudia (PA public housing) complained that she could not recycle because it was not available. Eve, one of two participants who had received a free energy audit, energy education, and some home improvements, such as weather stripping, was frustrated by her inability to implement improvements she was told would help:

Claudia: This is a Section 8 rental apartment. They told us to go get rid of the really old refrigerator that we had, that it's a big power hog. They went through and strongly hinted to the landlord that she should replace the stove. That didn't work, but we modified our behavior…. They had a lot [of suggestions], but unfortunately, a lot of those things are out of my control….

Participants noted that some waste was the product of routine or accident. For example, out of habit Monica, an NC Public Housing resident slept with her fan on every night, even in the cold winter months.

More than one participant mentioned that other household members caused excess consumption:

Candace: The most savings from here would be basically the television…Well, things that I think of, things like the television and games, stuff that actually pulls a lot of energy from the home. My boyfriend uses it [television] when he plays the game.

Erica also mentioned her daughter's use of the television and Nicole discussed her boyfriend's need to go to sleep with the television on. Angela, a mother of two, mentioned:

Angela: …the kids leaving all the lights on all the time, I’ll think about it, you know, how much electricity we’re using and I’ll go through and I’ll turn things off.

In addition to excess consumption, the actions of other residents sometimes led to reduced opportunities to save. In particular, participants reported concerns about safety and destructive actions directed at their activities. For example, Claudia volunteered for a garden program that was later cancelled because:

Claudia: We buried the flower bulbs and every time people go and trash it and throw trash in there and they destroy it because they used to grow flowers, pumpkins, watermelons and now it's just destroyed and we can't do it no more because they shut the program off.

When asked if she continues to garden, she said “No. Because there's nowhere to grow or do gardening.... Usually people, they just walk on the grass anyway. They don't care.”

Lack of safety also affected participant behavior. Brian, a NC public housing resident who had to hang his clothes outside to dry, complained “Some of it is a bad thing [hang drying clothes], because people will steal clothes off clotheslines these days.” Claudia described leaving the lights on to … just let people know that I'm in the house [when] I'm not in the house. Balancing conflicting concerns such as safety, saving money, and saving energy is a difficult task.

Although safety is much more of a day-to-day concern among our participants, residents in more affluent homes also mentioned the use of light to increase safety, along with the importance of a way to call for help (“a line to the outside world”) (Haines, Mitchell, Cooper and Maguire, 2007).

The barriers to saving energy we observed were at some level all caused by lack of control: Services (*e.g.*, recycling), control over the home itself, other household members, and members of the broader community.

3.2.4 SHARING AND OTHER SOCIAL FACTORS

Participants from NC reported sharing information with their friends, family, and/or neighbors about energy bills and strategies for saving energy. This was true even outside of the tightly knit Public Housing community. For instance, Cheryl, a Section 8 resident from NC was well aware of some of her family members’ energy bills:

Cheryl: Now, my cousin, I can tell you her bill was 400 and some change. My friend down there, her bill was 300 and some change. My aunt's light bill was three and some change. I guess it's just because we could, because you know what I'm saying, we compare stuff…

Geraldine, also from NC, describes a situation in which one of her neighbors consulted with her about her energy bill and asked for advice on how to lower her bill:

Geraldine: There was one time when one of the young ladies came to me and she told me her electric bill was almost $300 because of the windows and everything because, you know, and mines was like $171, so I said well look-- so I told her about it [small space heater] and I even took her to the store and I showed her which ones to get, and I said "You don't have to put them [small space heaters] on high because the rooms are small. You can put it on low, and once it gets to a temperature you feel comfortable, you set it there and that way it will automatically do just the same thing."

In contrast, participants from PA typically did not discuss their electricity consumption and/or behaviors with neighbors. One participant from PA, Yasmine, felt as if she were being intrusive by asking for this information about how much her neighbors paid in electricity bills:

Yasmine: I guess 'cause people think you are in their business. Or if you're not paying their money- if you're not paying their bill then you don't need to know.

People living in rural areas have a higher level of social trust than those who live in cities, though it's unclear if any causal connection exists (Taylor, Funk and Clark, 2006). Increased social trust may help to explain the difference in sharing in PA *vs.* NC.

Sharing also took place in other ways. Participants described trying to educate members of their own households and also their broader social network. For example, Kim, who saves energy even though she does not pay for it at her current PA residence, told us:

Kim: [My friends] know that I used to pay light, so just turn it off when you leave. That's it. Sometimes they get mad, but now the ones that are closest to me that know me, they know to do that. But other people I still have to explain to them that I just don't leave my lights on all the time.

3.2.4.1 Impact of an Person's Past on His/Her Behavior

Woodruff *et al.* discuss the fact that green household members fully maintain habits formed during previous phases of their environmental challenges (2007). Our results show that this finding is also valid in low-income communities. Participants' past experience and habits have a strong impact on behavior. Lauren (from PA) describes learning many energy conservation behaviors as a child:

Lauren: I learned how to make my own clothes by hand. We didn’t have machines when I grew up. Everything was done by hand. I learned to cook on the outside, not inside the house. In the summertime I did most of my cooking on the outside because it's better for you anyways, much healthier for you. And I learned this in Rome, Georgia. All this in Rome, Georgia when I was a little girl growing up.

Similarly, Candace talked about how her mother was strict growing up and enforced energy saving behaviors at home:

Candace: Yeah, and also my mother was always the type to say, “That light better be off.” And when I began to move out, and pay my own electricity bill, I see what she meant, from my first apartment, when I got the light bill.

This effect was strong even when participants were not responsible for paying electricity bills. For example, as mentioned earlier, Kim pays no electricity. Here, she describes why she still turns things off:

Kim: Yeah, like when I used to stay with my grandmother she had to pay light and gas and stuff like that, so she was really into us turning the TV off and the lights and stuff. If you're not using the TV unplug it and things like that. Like I said, it's just stuck with me. Now it's like a habit that I can't break I guess.

3.2.5 MONITORING ENERGY USE

Despite the known benefits of providing end users with data about their own energy use (Abrahamse, Steg, Vlek and Rothengatter, 2005), participants in the study received little or no feedback about it. Participants with unlimited electricity, for example, received no feedback. Those with a set allocation received none unless they exceeded the allocation. Those who received bills felt they contained too little information too late. Perhaps as a result, they did not describe tracking energy use in the detailed fashion that green participants did (Woodruff, Hasbrouck and Augustin, 2008). Despite the lack of feedback, some participants monitored what they could out of necessity.

Participants had creative suggestions for how to provide real time feedback, and they also learned to use what little feedback they had. Erica, who paid for some of her own electricity and made $10-20k *per* year, used her thermostat as a means of gauging how much her electricity bill would be each month: *"I think of, okay, if I keep this [thermostat] on between 72 and 75, I'm going to*

Figure 9 - Energy monitors (left) Geraldine uses her energy meter as a monitoring device to let her know how much energy she is using. **(right)** An "Energy Saver" device that Jacqueline uses to help determine how much energy she's using. For Jacqueline, the device specifies three colors: Yellow = "Caution", Green = "green light is fine" and Red = "You're getting a light bill"

have a low light bill."

Angela, whose light bill ran anywhere between $350 - $500 *per* month learned to read her energy meter: "The faster it spins [energy meter], the more it costs. The more energy you're using, the higher your bill is."

Geraldine, who paid for energy despite making less than $10k *per* year, showed the same idea in Figure 9 (left):

Geraldine: That's where you find out how much energy you use in your apartment…. that lets you know how much energy you're using in your house, and it can give you, if you care, then you'll look at it and see it. If it's higher than what you think it should be, then you can make adjustments in your house to slow it down, you know. [If it's] going real fast you can make adjustments to slow it down and save energy.

Interestingly, Jacqueline, a public housing resident from NC who made $10-20k *per* year, had a more sophisticated meter in the kitchen of her apartment (see Figure 9, right). She was the only participant to mention such a device:

Jacqueline: This is what they call, in our apartments, our energy savers…. The yellow light comes on and lets us know that we're just about to exceed over our energy. The green light is fine, it's fine. The red light *is what you worry about when that comes on in your apartment. That means you're getting a light bill because you are over. <laughs> If you are over. And it [the device] helps a lot. It helps a lot.*

Although children are not responsible for paying the energy bills in the home and are largely unaware of the exact usage and cost, Justin (from PA) suggested having children pay part of the electricity bill with their allowance:

Justin: When that bill comes, go in their pockets and say, "You're half on this." ….They aren't going to want to be giving their money up to pay these bills, so they've got to turn them lights off, open them blinds.

3.3 Discussion

Our results illustrate a community that includes individuals strongly engaged in energy-saving behaviors. As summarized in Table 3, low-income householders had a surprisingly broad range of motivations that went beyond money. Our comparison shows that many of the motivations present in affluent households are also valid in low-income communities.

Energy-saving behaviors occurred whether participants were or were not responsible for paying their energy bills. Approaches to saving energy could be characterized as more creative and diverse among low-income households than affluent households. All types of households shared a wish to monitor energy use, though access differed across groups. Our participants resembled typical households most in the barriers they encountered, though they faced more, severe challenges than affluent households of either type.

Technology could address some of those barriers. For example, sensing and feedback technologies used by the Ubicomp community to support energy savings (*e.g.*, Fitzpatrick & Smith, 2009) could allow participants to effectively engage with landlords about inefficiencies. These technologies could also encourage the participation of unsupportive household and community members (Chetty, Tran and Grinter, 2008). Below, we discuss some ways that common Ubicomp approaches to saving energy might need to change to support low-income households.

3.3.1 Feedback

Very few participants, regardless of whether they paid for their own energy, knew the amount of energy consumed each month. Chetty *et al.* found similar results in "typical" households

(2008). Our participants wanted feedback, but those whose energy was subsidized usually did not receive a bill or feedback of any kind. Even simple policy changes like showing residents their bills could have a positive impact. However, feedback represents a particular challenge in communities where *per* unit energy information may not even be available to the utility or landlord. Novel sensors that can extract unit-level information are needed.

To be accessible to a large number of low-income individuals easily, feedback might need to leverage the (relatively) ubiquitous cell phone as a display device (*e.g.,* Froehlich, Dillahunt, Klasnja, Mankoff, Consolvo, Harrison, Landay, 2009), or other mobile devices. Although more than 50% of low-income households use the Internet (Horrigan & Smith, 2007), only 30% have access at home where it would best support frequent feedback. In contrast, about 60% have

Table 3 - A comparison of key findings in our work and studies of more affluent households

Result	More Affluent Households (Green (Woodruff *et al.*, 2008), Typical (Chetty *et al.*, 2008))	Our findings
Reasons for saving energy	**Green:** Future generations; Activism; Religion/ethics, Trendy utopian optimism; Rugged independence; Self-reliance; Habit **Typical:** Money, Comfort, Environment; What can I do?	Future generations; Religion/ethics; Habit; Money; What can I do?
Approaches to saving energy	**Green:** Pairing household members with "green" mentors; Creating mental challenges for household members related to energy consumption; In depth learning exercises **Typical:** Better bulbs; Programmable thermostat; Lights off & unplugging things (Chetty *et al.*, 2008)	Some examples: Repair work/stopgap measures; Efficient & minimal use of appliances/lights; Re-use and Do It Yourself (DIY); Gardening/fishing
Barriers to saving energy	**Green:** Quality of public transportation; Availability of products **Typical:** Money (*e.g.*, for energy audits); Poor technological interfaces (*e.g.*, programmable thermostats); Inferior service of new technologies (quality of CFLs); Limited decision making as a result of sharing infrastructure with others; Household members; Safety (Haines *et al.*, 2007)	*Control:* Living space inefficiencies; Availability of services; Availability of products; Habit; Household members; Limited decision making as a result of sharing infrastructure with others; Community members *Basic Needs*: Safety; Money (*esp.* up-front costs)
Sharing	**Green:** Enjoyed expressing their identities **Typical:** Interested in "benchmarking" energy consumption against others, not necessarily sharing behaviors due to privacy	More common in NC, less so in PA. NC residents shared ways to save energy to help relatives and compared their electricity bills with others.
Monitoring energy use	**Green:** Detailed tracking among "green" participants **Typical:** Would like real-time information to help save money, have comfortable homes, and be environmentally friendly.	Almost no data available to participants; Some monitoring by necessity (*e.g.*, watching thermostat settings, meter dial speed)

access to mobile phones (Sullivan, 2008).

3.3.2 GETTING FROM INCENTIVE TO HABIT

Feedback is valuable, but ultimately, change requires learning new habits. Even when there is no financial incentive to save energy, participants' habits still keep them saving energy. To the extent that habits encode longer-term behavioral changes, Dahlstrand and Biel argue that unfreezing old habits, or creating new habits, is vital for change (1997). Habits form over time through procedural learning (Graybiel, 2000), and may be learned by observing others around us (Bandura, 1997). Although the notion of breaking habits is not called out explicitly by Woodruff et al., the "bright green" individuals they describe are reflective about their choices and continuously evaluate their behaviors (Woodruff, Hasbrouck and Augustin, 2008). Reflection and evaluation can help people break old habits and develop new ones. Technological interventions can have more long lasting effects if they also support this process.

A deep connection to God strongly motivates energy-saving behavior in some participants, while others wish to help their children and their children's children succeed. Both of these motivations are an integral part of participants' lives, and affect many things outside of energy use. Past work shows that in order to express and follow their beliefs, religious households may appropriate technologies creatively (*e.g.*, Woodruff, Augustin & Foucault, 2007). Similarly, green households use technology to support a different set of values (Woodruff, Hasbrouck and Augustin, 2008). By developing technologies that integrate with these values we may be able to support and enhance conservation.

3.3.3 ENGAGING ALL THE STAKEHOLDERS

The prevalence of complaints about the impact of other household members on saving energy demonstrates the importance of involving the entire household in conserving energy. The varied relationships among household members in the population we studied need to be addressed (*e.g.*, boyfriend, roommate, spouse, grandparent(s), kid(s)).

The presence of sharing among our NC participants demonstrates the value of engaging with other households as well. In a study of low-income individuals and healthy eating, Grimes showed that participants enjoyed sharing information, and felt empowered by their success in improving their diets (Grimes, Bednar, Bolter and Grinter 2008). Perhaps this same sense of empowerment can be achieved by technologies promoting energy saving tips to communities open to sharing.

As with affluent households, willingness to share and concern for privacy varied, with PA participants being less open. Although these concerns echo those found among affluent users of other social technologies, any exploration of sharing in the low-income communities we studied must be especially sensitive to concerns like safety.

Many participants were simply unable to save energy due to structural inefficiencies, lack of access (*e.g.*, no energy efficient bulbs available) and lack of support from other stakeholders (*e.g.*, landlords, other residents). On the other hand, some lived in communities that were fairly progressive with regard to saving energy. More exploration of the forces behind these differences is needed, as is policy and advocacy work to increase support for green practices. Technology that could help residents measure and calculate the potential for savings from an investment in more efficient structures or appliances would be of great value.

3.4 SUMMARY

Energy use and energy saving behaviors take place across all sectors of our society. This work focuses on low-income households. Our results demonstrate that existing motivations generalize to low-income communities. We also highlight the need for different emphasis and strategies for saving energy. Through our photo-elicitation study, we were able to explore a range of factors that influence energy use in this group. Many of our participants were environmentally motivated, while others wished to save money or to comply with a moral and spiritual aversion to waste.

We show how real-world constraints such as renting, safety (*e.g.,* leaving lights on at night to feel safe), and unsupportive household or community members affect participants' control over their energy use. A successful intervention may need to overcome these barriers by engaging stakeholders such as the landlord, other household members, or community members. In the next chapter, we extend this work by exploring the landlord/tenant conflict around energy consumption.

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

While Chapter 3 explored issues of income, this chapter explores a different but related topic: the impact of diverse stakeholders on energy use. Issues such as tenancy, class and poverty affect the autonomy of individuals with respect to energy use. Based on our results from Chapter 3, we conducted a second study of the landlord/tenant relationship and it's impact on energy use. In this chapter we explore how the autonomy of tenants and their relationships with other stakeholders affect the use of energy.

In this chapter, we argue that by learning more about the other 30% of residential energy consumers (tenants), we can create technologies that are relevant to a broader audience. This chapter extends the work described in the previous chapter. We added two new qualitative studies (*e.g.*, landlord interviews and role-play scenarios) to the photo-elicitation study described in Chapter 3 to explore how landlord/tenant relationships and conflicts that exist between the two parties impact energy-consumption behaviors.

Our results demonstrate the importance of understanding the ways in which power imbalances influence how energy is used (and wasted). This understanding, in turn, has implications for the technology we will create and how we will design it. We show that sensing and communication technologies can shift three factors that affect power: information, communication, and community actions. In the next section, we review related work and present an analysis of our photo-elicitation interviews, landlord interviews, and role-playing sessions. We provide a set of design recommendations identifying new challenges for sensing and social technologies that may help landlords and tenants discover new resources and improve communication. This work is published in Ubicomp 2010 (Dillahunt, Mankoff, Paulos, 2010).

4.1 BACKGROUND

Much of the research on landlord/tenant relationships emphasizes the power landlords have over their tenants (Keller, 1988; Popplestone, 1972; Vaughan, 1968). Based on a one-year ethnography of a low-income, multi-unit dwelling, Vaughan argues that low-income tenants are "relatively powerless" in the landlord/tenant relationship (Vaughan, 1968 p. 215). Vaughan (1968) observed that tenants showed a lack of trust in landlords and feared exploitation. Despite tenants' fear of exploitation, when Vaughan asked tenants if they would join others in an organized attempt to improve their units and/or lower their rents, tenants consistently responded *yes*. However, local volunteers/organizers within the community reported difficulty in mobilizing the community to take action.

In a legal analysis of the relationship between landlords and tenants, Keller concludes that landlords hold the upper hand in the landlord/tenant relationship (1988). Factors affecting the landlord/tenant relationship include the status of the housing market, socio-economic status of tenants, and existing laws (Keller, 1988). For example, since there is a smaller supply of inexpensive apartments than more expensive apartments, Keller argues that those who are paying less may have difficulty moving if they are unhappy with their current housing. For the same reason, landlords renting in low-income markets do not have too many problems filling vacancies. As a result, they have more power. Furthermore, in some markets, landlords can pick and choose the best, or most suitable tenants from those tenants who are willing to pay, another advantage they have over tenants. A landlord may also be able to affect a tenant's life more than the other way around; a landlord withholding heat, for example, is likely to have a greater impact on the tenant's life than a tenant will have by withholding rent from the landlord.

While a tenant may legally withhold rent or use it to pay for fixing major problems on a property, the landlord may claim the tenant is late with rent and attempt an eviction. Therefore, withholding rent represents a greater risk to tenants than to landlords. While laws may empower both landlords and tenants, the existence of "pro-tenant" laws may not have much impact on the overall balance of power (Keller, 1988).

Collective action such as tenant and rent strikes can help tenants gain power through strength in numbers (Keller, 1988). However, when landlords maintain personal relationships with tenants, it may become more difficult for tenants to take collective action (Popplestone, 1972; Vaughan, 1968). Remarkably, despite conflicts that may exist, tenants usually bear no hostility and often believe that group efforts to bring about change will distress their landlord (Vaughan, 1968).

Though factors such as personal relationships and knowledge can affect the balance of power, landlords appear to have “the upper hand” in most landlord/tenant relationships. Our analysis highlights the ways in which such power (or lack of power in some cases) influences the use of energy.

4.2 TENANT PERSPECTIVES

In this section, we discuss tenant descriptions of their relationships with landlords, based on a new analysis of our work described in Chapter 3. For this Chapter, we re-analyzed the subset of data dealing with such conflicts and extracted common themes related to their sources and resolutions.

4.2.1 TENANT METHOD

The data we analyzed came from photo-elicitation interviews, a qualitative method in which participants take their own photos that are subsequently used to elicit information that may otherwise remain invisible to the interviewer (Clark-IbáÑez, 2004). Craigslist ads, posted flyers, and in-person meetings at community centers were used to recruit participants living in 26 low-income households across two locations: a small town in the Southern U.S. and a metropolitan area in the Northern U.S. As described in Chapter 3, participants were given a week to “take pictures of objects and/or scenarios that make you think about personal energy use or anything that makes you think about energy.” During follow-up interviews, one- to two-hour discussions of the photos were transcribed. Data from one participant, a homeowner, was thrown out, as we were targeting renters. The remaining data was re-analyzed with a focus on the landlord/tenant relationship.

We used a bottom-up approach in our analysis and assigned low-level codes to the data based on significant concepts that included gripes, overcompensation, responsibility, successful actions, and so on. This resulted in 19 codes, which were then grouped into themes such as the value of knowledge and the presence of an imbalance in power. We connected the themes to our problem space by exploring their impact on energy-use conflict in the landlord/tenant relationship. This approach was influenced by the open and axial coding used in *grounded theory* (Glaser & Strauss, 1967). We did not use prior theory to drive the selection of codes or themes. Instead, the themes that we found led us in an iterative fashion to an exploration of power in interpersonal relationships.

4.2.2 TENANT RESULTS

As described above, most of the 25 participants in this study were African American (21), female (20) and earned less than $10,000 (18) *per* year. Because of public subsidies, only four participants paid their entire energy bill. Nine participants only paid when they exceeded a set allocation of kilowatt-hours *per* month, and eight received stipends (for part of the rent and/or utilities). Either independent landlords or publicly run housing authorities paid for the energy bills of five of the tenants. Nine were tenants were Section 8 rental units, a form of subsidized housing available to low-income households at a fixed low rate (based on factors such as unit size); all Section 8 apartments must pass regular inspections.

One of the key goals of our study was to understand the impact that the landlord/tenant relationship has on energy use; we found that conflict between landlords and tenants plays a large role on energy use. Therefore, as a part of our data analysis, we categorized types of conflict that we found into themes. We also identified ways to address some of the conflict. In the next subsection we describe these themes, which we grouped into sources and resolutions of conflict.

4.2.2.1 SOURCES OF CONFLICT

Sources of conflict fell into two broad categories – financial responsibility and overall imbalance of power.

Impact of Financial Responsibilities: As described earlier, some residents paid for their energy bills while others received stipends from the government or were not responsible for paying at all. We saw differences among some of these payment models. For example, landlords were reportedly more proactive when they were responsible for paying energy bills. In one case, a resident was contacted by her landlord for a leak in the bathroom. Her explanation was: *"They pay it. That's why he was concerned"* (Yasmine).

Many residents felt that landlords did not address issues when they were not wholly responsible for paying energy bills or could not afford to fix things. *"I guess they don't have funds or whatever"* (Brian). Here, Brian gives the landlord the benefit of the doubt, justifying the unaddressed issue. Brian felt that landlords need to make ends meet, too. One resident commented that the *"external element controls my bill more than it should"* in reference to the building structure that let outside air in. She comments: *"I'm concerned because that's excess funds out of my budget that I could utilize in another way"* (Catherine). To summarize, residents were concerned about wasted energy and reported that fixes were dependent in part on who was financially responsible for energy bills.

Imbalance of Power: Seven tenants described situations in which they did not express their needs to their landlord. In many cases, residents did not report issues primarily because of their expectations related to income and status. For example, one resident stated, *"I think I have a hole in the wall and that's where air is coming from but they're not going to do anything about it…It's public housing. If it was a house, they sure will find anywhere the air is coming from"* (Claudia). Another resident stated, *"We have some older appliances in the building, but they're owned by the landlady, and she wasn't high up on the idea of buying all new for a Section 8*" (Eve). When residents did advocate for their needs, they did so for several reasons: knowing tenant rights, successful negotiation with their landlords, prior knowledge about energy efficiency, and the results of energy audits.

Resolution of Conflict

Some tenant actions led to successfully conflict resolution and infrastructure improvements to save energy. Conflict resolution, as described by tenants, was driven by two primary factors: increasing knowledge and strengthening communities.

The Value of Knowledge: One participant spoke up regularly because she knew her rights as a tenant. She said, *"I'm perceived as a trouble maker because I'm always questioning…I'm demanding because I know I have the right to have it...It's like they hate to see me coming but I notice with my complaints, they're starting to do things sometime a little different"* (Catherine). In this case, Catherine had previously lived in a better public housing facility; she knew her current conditions were unacceptable and she had success when voicing her concerns. In many cases, residents of low-income communities have no basis for comparison because they have not had the experience of living in any home other than low-income housing. Our results showed that energy audits could increase tenant knowledge and even provide advocacy support. For example, Eve said that as a result of an energy audit, *"they talked the manager into finally cleaning* *out some of the appliances,"* and she estimated that she saves an additional $60 *per* month as a result: *"especially the furnace, because all that dust in there, the heat wasn't getting in. The filters were dirty"*. In this case, the landlord did not have to purchase new appliances and the resident saved money.

Strengthening Communities and Community Action: Our results show that strengthening communities and group action may have been successful for tenants that required new windows for their apartments. One resident stated, *"I know there was one time when it got real cold and everybody's electric bill was over 200 something dollars and everybody was freaking out….'Hold up, that's more than my rent', you know…they did make adjustments because they replaced the windows…"* (Geraldine). It can be inferred that since *everyone's* electric bill was expensive, the landlord took action despite the expense of doing so. It is possible that tenants brought the issue to the landlords because they feared they would not be able to pay their rent. It is also possible that the landlord took action for fear of mass vacancies. Overall, it is unclear why the situation was resolved. Our related work suggests that collective action may not always be so successful (Popplestone, 1972; Vaughan, 1968).

4.2.3 Conclusions from Tenant Perspectives

While conflicts existed in landlord/tenant relationships, especially among tenants who felt that complaints would be unproductive, a few found effective ways to influence landlords. Successful efforts involved knowing tenant rights, seeking new information and advocacy support from organizations that provide energy audits, and applying collective pressure.

4.3 Landlord Perspectives

At this point, our data on landlord/tenant relationships was based entirely on tenants' perspectives. To complement this, we held semi-structured interviews with seven landlords. Our goal was to identify common landlord responsibilities and points of conflict between tenants and landlords.

4.3.1 Landlord Interview Method

We interviewed a total of seven landlords for 30 minutes to two hours each (the more experience and tenants a landlord had, the longer the interview). We recruited five landlords from metropolitan areas in the Northern U.S., *via* a website used by Section 8 landlords and tenants to find housing, one *via* Craigslist and one *via* word of mouth.

Our interview questions centered around landlord responsibilities, *e.g.*, who pays for utilities, yearly cost of updates, and what type of maintenance and/or updates are required each year. We also sought information regarding the cost of monthly rent, how participants determined prices, and what aspects of the job landlords enjoyed most and least. Landlords were not asked directly about conflict with tenants because we wanted data equivalent to that used in the tenant study. Indeed, the issue of conflict emerged on its own.

We took detailed notes during the interviews and wrote a memo shortly after the interviews ended. We then compared and contrasted the landlord and tenant findings.

4.3.2 Landlord Study Results

Five of the seven landlords were male and ranged in age from 30 to over 60. Landlords had one to 25 years of experience and owned one to more than 200 units. Five landlords owned Section 8 housing. Since rent is paid directly by the government, landlords who participate in Section 8 enjoy increased financial security. In return, the housing must pass regular inspections to remain eligible for the Section 8 designation. Though tenants cannot withhold rent from the landlords directly, they can report issues to the Department of Urban Housing (HUD). HUD can withhold rent from landlords and also prevent landlords from further renting to Section 8 households.

With regard to energy use, we found that landlords who paid tenant utilities often felt that tenants were taking advantage of them. This stands in contrast to the tenants who often gave landlords the benefit of the doubt. Landlords we spoke with did not describe themselves as taking advantage of tenants though they were cognizant that tenants might feel disempowered. Several offered a landlord's perspective on how tenants could increase their success in requesting improvements.

Landlord Responsibilities and Goals

An understanding of landlord/tenant conflicts is only possible when overall landlord responsibilities are clear. This may vary a great deal, but ultimately a landlord is running a business with the goal of making money. In contrast, the goals of most tenants are to have a comfortable, safe, and affordable living environment. These goals may not always align.

Landlords we interviewed put a lot of time and money into managing and maintaining their apartments. However, the environment and saving energy were not major factors in decisions about updates, fixes, and purchases. Instead, they were viewed as a responsibility, necessary to maintain the properties and keep tenants. Energy reduction was a secondary benefit. As a result, landlords did not invest in energy efficient appliances such as washers and dryers and they reported cutting corners to save money. For example, landlords discussed purchasing used appliances, or purchasing carpet with no padding. Some justified their actions by referring to damages that had occurred as a result of tenant negligence.

All the landlords we interviewed were responsible for at least some utility bills (*e.g.*, landlord paid for water but not electricity), primarily because some buildings were master-metered (*i.e.*, one common meter for a building with several apartments). Additional landlord responsibilities included repairs, ensuring the plumbing and electrical were operating at all times, keeping the grass cut in the summer and removing snow if needed in the winter.

Sources of conflict

The key source of conflict as seen from the landlord's perspective was tenant neglect or wastefulness, which incurs cost to the landlord. Research suggests that residences deteriorate due to landlord negligence more often than they are destroyed by tenant harm (Keller, 1988), despite the fact that "landlords are convinced that tenants don't take care of property" (Vaughan, p. 216, 1968).

Despite this trend, with regard to energy use, most (5/7) landlords we spoke with reported that tenants at times took advantage of them. Landlords especially felt taken advantage of when they saw resources wasted that tenants did not pay for. For example, James described a situation where 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 James found someone to address the issue). James came across as a fair landlord; he seemed to be concerned about issues such as safety and ensuring his property was well maintained. However, he felt tenants should understand the consequences of not paying their bills on time and that some issues may go unaddressed as it takes money to fix issues. James said, "*I'll keep a pair of socks on or a sweatshirt and since they aren't paying for it, they're in shorts,*" implying that tenants care less about saving energy if landlords are responsible for the bill. Landlords were also sensitive about tenant behavior that affected safety or required extra work. For example, Pedro was upset that residents remove batteries from smoke detectors to put in their children's toys. Removing smoke detector batteries presents a safety hazard and extra work for landlords to ensure smoke detectors are working at all times. Pedro wished the tenants were aware of these safety risks and landlord responsibilities.

Perhaps because of the perceived wastefulness of tenants, most of the landlords we spoke with were fairly critical of tenants and their actions with regard to energy use. However, many of the landlords we interviewed seemed to want a reason why tenants were wasteful. Explanations landlords produced included that *"[residents] don't care because they are not paying utilities…there's no way to force them to be energy efficient when they don't care."* (Gerald), "*people feel uncomfortable [in regards to raising issues], they don't want to be viewed as a complainer*." (James) and "*maybe just because they don't have much and feel like, 'what's the use?' Or maybe it's their upbringing."* (Pedro). These explanations demonstrate a range of assumptions about tenants (lack of caring, fear of retribution, and resignation).

Resolution of conflict

Though landlords felt they were being taken advantage of, those not renting to Section 8 tenants can increase the rent to address this. One landlord mentioned communication oriented strategies for encouraging tenants to conserve energy (such as suggesting that a tenant wear warmer clothing before turning up the thermostat, and sending a letter to his residents encouraging them to help keep costs down in the winter by reporting issues as soon as they arise). It is not clear whether either strategy (raising the rent, or asking tenants to change their behavior) is effective in increasing conservation.

The landlords we spoke with also had suggestions for how *tenants* could work to resolve or avoid conflict. For example, James suggested tenants avoid potential problems by investigating a landlord's maintenance habits before they sign a lease. Cheryl rents part of her home to one tenant, and was open to tenants notifying their landlords if they could fix an issue themselves. She suggested that landlords could reduce tenants' rent payment to cover the cost of fixing unaddressed issues. James also stressed the importance of tenants *"knowing what their rights are."* He felt that landlords and tenants *"need to work together for a win-win."* Each of these strategies involves communication or negotiation. All of the landlords felt that keeping their places occupied was a priority that they (and other landlords) would be willing to negotiate and address landlord/tenant issues to keep tenants from moving out.

4.3.3 Conclusions from Landlord Perspectives

As with tenants, a primary reason for conflict was financial responsibility. From the landlord perspective, tenants seemed wasteful of resources they did not pay for, while from the tenant perspective, landlords avoid repairs when it is tenants' money that is at stake. Landlords seemed to take tenant behavior personally, were aggravated by their wastefulness, were likely to directly ask them to change (or raise the rent), and spent time trying to explain *why* they would waste. In contrast, tenants tended to give landlords the benefit of the doubt, and to avoid confrontation over issues they thought of as impossible to solve.

4.4 Role-Playing Scenarios

To find out more about how tenants might approach conflict resolution with landlords and how they viewed landlords, we conducted a role-playing session with eight participants. We asked participants to explore landlord/tenant issues in concrete scenarios so they could consider both landlord and tenant perspectives and work toward a solution. The use of scenarios is a technique to elicit problems and focus on solutions (Bødker, 1999). Scenarios work well for encouraging reflection and discussion between individuals.

4.4.1 Recruitment and Role-Playing Methods

We sought participants (tenants or home owners who had been tenants in the past) earning less than $30K *per* year hereby, referred to as "residents." We recruited from Craigslist and a community center located in a local public housing community. To include a range of opinions, flyers were not specific to energy consumption, stating, "you will participate in a collaborative exercise to brainstorm ideas on how to improve certain areas in the home with technology." There were a total of eight participants in the role-playing session. Our data included extensive notes taken at each session and demographic information collected *via* surveys.

We started off with two five-minute brainstorming sessions. We first asked tenants to brainstorm about what causes them to take action so we could learn about their values. Since this was a brainstorming activity, we left the question open to interpretation, *i.e.*, participants were not told a specific event to think about. Instead, we prompted them by asking questions such as, what caused you to: "come to today's session" or to "vote or not vote in the most recent election." We then asked tenants to brainstorm about what causes their landlords to take action to understand how residents perceived their landlords' values.

After the brainstorming, residents broke into two groups of four for role-playing. Participants in each group were randomly assigned to one of three roles: landlord (1), tenant association (1) and tenant (1 or 2). The tenant association was included to explore the impact of a community group on conflict resolution. Each role also included a list of priorities based on what we found in our studies (shown in Table 4).

We gave both groups two problems: an uncooperative community member and a randomly drawn structural inefficiency. One group drew inefficient appliances and the other group drew a drafty apartment. Participants were instructed to discuss and negotiate the problems within their group until they reached a solution. The "tenant association" group member was instructed to serve as a mediator. In one group, the landlord was responsible for paying electricity and in the other group, the tenants were responsible for paying electricity.

We took extensive notes during these sessions and documented points of contention, questions, frustrations, and what solutions were successful or unsuccessful during the session. We compiled all notes, pictures taken during the role-playing session and debriefing sessions and searched for commonalities between groups (*e.g.*, questions, frustrations, solutions). We used audio recordings to verify specific quotes.

4.4.2 Recruitment and Role-Playing Results

Six of the eight participants were women. Ages ranged from 18 to over 60 and the majority earned less than $20,000 a year. We found that residents' reasons for taking action: money, safety, health, personal beliefs, family, and likelihood of success. Residents felt that landlords took action because of costs (*e.g.*, insurance, taxes, water, and maintenance), their reputations, the law, safety, and inoperable facilities such as broken heat or electricity. Note that residents' values and the values they perceived their landlords have are relatively similar.

Sources of conflict

We found that the two primary sources of conflict arose from the lack of communication between landlords and tenants and power-imbalances between the two parties. Overall, there was relatively little discussion of how landlords or residents might take advantage of each other. This may be because the exercise was so focused on communication, a key element that may be missing in attempts to solve the landlord/tenant problems brought up in our interviews. However, one resident had a concern about raising issues with the tenant association. She felt that if residents went to the tenant association, or above the landlords' head, the landlord would do his best to mistreat the resident filing the report.

Resolution of conflict

Residents acting out the role of tenants wanted to know *how* to prove to the landlord and tenant association that issues existed. They brainstormed and began to think of different types of information that might help such as comparing their electricity bills with those from past months, and comparing their bills with other residents to show appliances were inefficient. In addition, residents suggested sending letters to the landlord to make the issue known. This caused tenants to realize that they could also ask the landlord for information such as when the last time the county inspected apartments. They wanted to create ways to find out if the appliances were working efficiently when they first moved in. Residents also wanted a way to directly forward their energy bills to landlords and highlight differences. Another idea was to enable everyone in the community to share their bills with others, including landlords if they desired. Those residents responsible for paying energy initiated this idea.

Participants who played the role of landlord would negotiate with the other participants to find a solution. One "landlord" was unwilling to replace the windows in the scenario of the drafty apartment; however, she and the tenants negotiated caulking windows as an effective solution. The "landlord" made her decision based on the costs of replacing windows. The other "landlord" agreed to purchase a camera to monitor his apartments as a result of uncooperative community members. He felt that purchasing the cameras was the best option, as they would pay for themselves in the next 3-5 years. Some tenants disagreed with this solution because of privacy concerns. In fact, this interaction resulted in tenants suggesting the formation of a community "watchdog group" – a solution cheaper for the landlords but potentially beneficial for the community. Perhaps effective communication between landlords and tenants provides opportunities for both parties to negotiate and make compromised decisions.

Table 4 - Roles and Priorities used in Role-Play Activity

Roles	Priorities
Landlord	- Keeping apartment units filled with residents - Not spending any more than what I'm spending already - Willing to invest in something if it pays off in the next 5 years.
Residents	- Safety ("I'm afraid to turn off the lights at night for fear of destructive community members") - Comfort ("I like to feel cold in the summer") - Saving Money - Ethics/Spirituality/Religious reasons
Tenant Association	- Improving tenant-landlord relationships, building conditions, and services for tenants under a "strength in numbers" model. - Encouraging regular communication and community awareness among tenants

4.5 Discussion

We have presented three qualitative studies that explore conflicts between landlords and tenants with respect to energy use. Here, we highlight key sources of conflict, which leads us to explore the impact of power in interpersonal relationships on energy use.

Conflicts in our study arose when one party failed to meet the expectations or needs of the other. In many cases, material issues (*e.g.*, money, dwelling temperature) were at stake. For example, some tenants failed to report issues to landlords when tenants were not paying the bill, leading to extra costs for landlords. Similarly, a common complaint was that landlords did not fix air leaks, which affected the comfort and utility bills of residents.

At the surface, structural problems such as a lack of common interest between stakeholders seem to drive conflict. But our results point to a deeper problem in the landlord/tenant relationship. Although we have been talking about *conflict* throughout this paper, from a theoretical perspective, it is *power* that determines who will "win" when conflict is present.

Many forces affect the power of different parties in a conflict. These include resources (money, information, education, powerful friends, *etc.* (Galbraith, 1983), existing hierarchies and cultural norms such as respect for elders (Ekstrom & Danermark, 1991), and the connections among groups of people (*e.g.,* those engaged in collective action) (Galbraith, 1983; Giddens, 1995; Weber & Matthews, 2008). The material reality in which tenants live, combined with the social structure in which they operate have a concrete impact on the resolution of conflict. In this sense, conflict is not just about a specific tenant and landlord, but also the broader context in which they live. For example, a tenant's relationship with other service providers (such as welfare), a landlord's ability to leverage a utility company's customer support, and the existence of tenant organizations or other mediators may all affect the possibility of conflict and its outcome.

To some theorists, the forces described above can be captured in a structural view of power (*e.g.,* (Galbraith, 1983; Giddens, 1995; Parsons, 1960; Weber, 1978)). In this structural view, power is visible and has the potential to be shifted by changes in resources, connections, and so on. An example is the impact that a landlord's financial responsibility for a utility bill increases the likelihood that a problem will be fixed at a tenant's request.

An alternate view of power focuses more implicit interpersonal relationships without assuming the presence of conflict. For example, conflict may be avoided (as in the case of residents who feared the consequences of reporting issues) (Lukes, 1974). Vaughan's work suggests that tenants may even worry about the burden their requests may have on landlords (1968). Power may also be internalized as with Foucault's "governmentality" (Foucault, 1994), to the point that "perceptions, cognitions and preferences [are shaped] in such a way that they accept their role in the existing order of things…." (Vaughan, p. 24, 1968). For instance, some tenants did not expect issues to be addressed because of their low income and status.

Power is a complex concept, and many theories exist that attempt to explain power from political, economic, and social perspectives. Our discussion has focused two forces that help to describe power in landlord/tenant relationship: Structural forces and implicit forces. Structural context including financial responsibility for energy, income, and the broader market can affect the outcome of conflict between landlords and tenants. When conflict arises, changing the distribution of resources can shift the outcome. With respect to tenants and landlords, this most often means a change in the information asymmetry between landlords and tenants or the additive change in resource strength brought on by collective action. However, power is not always connected to conflict (Lukes, 1974) and can be internalized to the point that it implicitly shapes behavior, as when tenants self-censor, ignore irritations and speak up only in emergency situations (Vaughan, 1968). To the extent that power implicitly shapes behavior, it may do so not only for tenants but also for landlords. For example, the assumption that *"tenants don't care"* reflects a possible misunderstanding of the root causes of behaviors that bypass conflict. In fact, tenants' reported worries demonstrate both caring and awareness of energy wasted even when they do not report it.

Thus, a study of the role that technology may play in this setting must consider two facets of power. First, technology may influence the distribution of resources (such as information) affecting structural power. These resources may in turn influence the outcome of conflict around energy use. Second, technology may interact with implicit forces that shape outcomes even in the absence of conflict. An example is the impact that surveillance technologies may have on behavior. Our next section will explore these ideas in more depth.

4.6 DESIGN RECOMMENDATIONS

Our recommendations will focus on two powerful forms of technology: sensing technology and social technology. While the former technology produces new information and the latter facilitates the sharing of information, both may influence action indirectly. For example, our study showed that information, improved communication, and community action can all help to resolve conflicts and change the balance of power. Other factors (*e.g.*, privacy) affecting the balance of power are not directly amenable to technological intervention, though successful interventions may need to account for them in some way.

4.6.1 SENSING TECHNOLOGIES

Sensing technologies are essential to monitor and provide feedback about energy use. In a review of over twenty studies, it was found that feedback resulted in a 5% to 12% reduction in energy consumption (Fischer, 2008). Clearly, these technologies are powerful and effective. However, eco-feedback studies have primarily focused on individuals or at best multiple individuals within a household. Issues of class, conflict, and power among stakeholders as different as landlords and tenants are rarely surfaced, if at all.

As stated earlier, information represents a resource that structurally impacts the way in which power plays out in conflict situations. In particular, information asymmetry, in which one stakeholder has more information than others, has been shown to affect how conflicts are resolved (Overdest & Mayer, 2008). Indeed, the potential for information to change outcomes surfaced in all three of our studies. This is not surprising considering that information is a resource that is relatively easy to change, with a corresponding shift in power (Foucault, 1980; Giddens, 1995). Feedback technologies can change who has access to information and manufacture new information.

For example, we found that tenants often do not have access to information about their own energy use (or that of other tenants in their unit). Landlords may have access to this information in limited form (such as monthly utility bills). Eco-feedback may bring information about energy use into the home (Froehlich, Findlater, Landay, 2010). New feedback technologies may sense water (Froehlich, Larson, Campbell, Haggerty, Fogerty, Patel, 2009), electricity (Patel, Robertson, Kientz, Reynolds, Abowd, 2007) and gas (Cohen, Gupta, Froehlich, Larson, Patel, 2010), at the level of individual appliances, producing a very detailed record of personal activity. This information could be used by landlords for surveillance and possibly lead to sanctions against problem tenants, vandalism of technology by tenants trying to protect their privacy, and other forms of conflict. On the contrary, the same technology could be used to identify problematic energy use across many units (or supports exploratory visualization) and could alert landlords, tenants and/or future tenants about problems.

Although we have demonstrated concrete ways in which sensed information ties into structural forms of power, even the straightforward applications we have described must also consider the presence of implicit forces. New information will inevitably shape behavior. For example, information ownership, abuse (such as surveillance of tenants by landlords), and security are all factors in who has power over whom due to the presence of new information. For example, an application that identifies problematic energy use could be designed to help tenants see the true costs of inefficiencies and thus engender community action. Similarly, the mere knowledge that information about energy use is shared with others could affect a tenant's behavior or sense of security even in the absence of abuse or direct conflict.

To summarize, our results challenge many of the assumptions underlying existing eco-feedback systems. Any technology that wishes to reduce energy use needs to be cognizant of the fact that a range of structural and interpersonal factors, both explicit and implicit, affects energy use.

4.6.2 SOCIAL TECHNOLOGIES

Landlords we spoke with seemed to feel that improving communication with tenants might help to reduce conflict. For example Pedro felt that tenants might not be aware of the safety risks and landlord responsibilities affected by their decisions to remove smoke detector batteries. James suggested that landlords talk to their tenants more, and discussed the idea of sending a letter to his tenants encouraging them to keep costs down by reporting issues more quickly. The idea of improved communication also came up in role-playing, where participants suggested asking landlords for more information about inspections, or informing them about problems that were common to more than one unit. Strengthening communities (leading to community action) was a final factor that could affect the resolution of conflict.

Technology can support social action by making it easier to communicate, organize, and or discuss common issues (DiSalvo, Nourbakhsh, Akin, Louw, 2008; Overdest & Mayer, 2008; Vieweg, Palen, Liu, Hughes, Sutton, 2008). For example, Vieweg *et al.* show how large-scale distributed problem solving can occur in disaster situations with the aid of social technologies (2008). In another case, DiSalvo *et al*. helped a community to express neighborhood concerns through a participatory design process involving critical engagements with robots, sensors, and other technology (2008). Paulos *et al.*, argue for the role of citizen science in enabling participatory urbanism (2008). This research has shown the potential power of enabling community action. However, little attention has been paid to the role of community action in addressing energy use (Dourish, 2009), or to the role of social technology in shifting structural forces or shaping the implicit role of power in how tenants and landlords use energy.

As with sensing and feedback technologies, social technologies can influence the structural forces affecting conflict resolution. For example one of our tenants described how high building-wide heating bills led a group of tenants to advocate for building improvements. As a group the tenants were successful in achieving their goals, where an individual might have failed. Organized groups can have greater power than individuals (Galbraith, 1983). For example, in a sociological model showing the causal logic of how rental housing markets operate in American cities, tenant movements was the only factor out of several, including home prices, growth, tax policy, interest rates, and the world economy (war, inflation, oil, deindustrialization) to cause rent decrease (Gilerbloom, 1989).

Clearly information plays a role in this example, and social technologies naturally support shifts in information asymmetry. For example, the sort of feedback technology proposed in the previous subsection, if they supported communication across tenants, could have facilitated our example by alerting tenants much sooner to the building-wide problems and potentially helping them to organize.

Results from our studies suggest improved communication provides individual community members with access to new information and helps to resolve common problems within a community. Online forums for renters or landlords represent a viable way for social technologies to produce this information (an example is the free legal forum http://thelaw.com). For low-income tenants with limited Internet access (Gerber, Stolley, Thompson, Sharp, Fitzgibbon 2009), it could be valuable to bring information that exists on-line into a more accessible medium: mobile text messaging. It would not be hard to create an SMS gateway that could connect tenants to such a forum, or even to a more general social question answering system such as Aardvark (Horowitz & Kamvar, 2010).

A primary way in which social technologies can structurally affect power and the resolution of conflict is by sharing information among people who can act on it, thus affecting forces such as information asymmetry. Social technology can also structurally affect the relationships among people, as by helping tenants to organize themselves in preparation for a confrontation with their shared landlord.

Yet, tenants may face difficulties in taking collective action against landlords (Popplestone, 1972; Vaughan, 1968). The roles and relationships that already exist among tenants and between tenants and landlords can implicitly affect tenants' willingness to create conflict. As discussed in Chapter 3, for example, in some communities, tenants are less inclined to share details of their energy use with other tenants. Existing assumptions about what actions are worthwhile may also affect the success of social technologies (*e.g.*, tenants may not agree about whether to act in non-emergency situations). A successful social technology must take these aspects of power into consideration in its design.

To summarize, in addition to well-known issues such as retention and recruitment, social technology design must be based on an understanding of the implicit forces affecting energy use in the landlord/tenant setting. If careful design is able to achieve balance between anonymity, access, and interest, there is great potential for social technologies to support the creation and sharing of information and thus influence the outcome of landlord/tenant relations around energy use.

4.7 CONCLUSIONS

As Dourish argues, HCI must consider the political, cultural, social, economic, and historical contexts of the technology it produces to effectively address complex issues such as environmental sustainability (Dourish, 2009). New technologies (sensors, data mining, visualizations, and so on) may be better able to add knowledge, support communication, and enable positive action if designers keep in mind how those contexts affect the use of technology.

We contribute an understanding of the power landlord/tenant relationships in the context of energy consumption. We found that conflicts between landlords and tenants over energy use are driven by the imbalance of power between them. Power is derived from many things, but one of the most fluid is information. In our studies, new information and better communication of information were two of the most salient forces driving conflict resolution. We argue that sensing technology and social computing can play a role in conflict resolution because of their ability to interact with these forces.

We focused our discussion of power on two things: structural issues (including information asymmetry and social hierarchy and other concrete forces affecting the resolution of conflict); and more implicit forms of power such as the internalized forces shaping behavior discussed by Lukes (1974) and Foucault (1980). Technology, then, may influence structural forces affecting conflict resolution. At the same time, we argue that designs that fail to consider more implicit forms of power face the possibility of negative outcomes.

Our work has some limitations — the work presented in Chapter 3 and expanded upon here was not focused on landlord/tenant conflict and might present an incomplete picture of the issues as a result. It is likely that the landlords we interviewed tended to only describe their most positive interactions with tenants. Additionally, the vast majority of our participants were female, perhaps because women lead many low-income households. It is possible that there are gender-related issues that also play into the conflicts with landlords. Despite these limitations, our results as a whole seem to be consistent with existing theory in power relations reviewed in this section, and with past work on landlord/tenant relations (Horowitz and Kamvar, 2010; Vaughan, 1968).

Our work challenges the research communities to tackle a new set of research questions on the connection between technology and power. Power is an omnipresent component of human interaction. Technologies that support communication and provide information affect the balance of power in human relationships. Issues such as privacy are in large part important *because* the information being revealed may give one party harmful power over another. It is time to expand our notion of impact to consider the invisible social forces that may be affected by our technologies.

5 The Design of a Social Eco-Feedback Application for Rental Households

Household types (i.e., rentals, single-family, etc.), socioeconomic context, and stakeholders (i.e., landlords, community members) play a key role in household energy consumption and understanding how technologies can take these factors into account could benefit home-energy conservation. Unfortunately, very little research investigates technologies in this context and there are no design guidelines for implementing energy-feedback technologies to take these factors into consideration. In this chapter, we review existing interventions to reduce home energy consumption; identify gaps in these technologies; and explore opportunities to improve future interventions. We then describe the results of generating more than 25 initial concepts around real-time energy monitoring to address the dynamics of varying household types, socioeconomic contexts, and stakeholders. We presented these concepts to a diverse group of tenants to validate their needs and discuss our findings. We present a set of design guidelines and conclude with the design and implementation details of our own.

5.1 Competitive Analysis of Eco-Feedback Technologies for the Home

As we discussed in 2.3.1.1, direct feedback is perhaps the most effective form of feedback. Several review papers of feedback technologies show that direct feedback can lead to a savings of ~5-15% (Darby 2006; Fischer, 2008), where as indirect feedback typically leads to a 0-20% reduction (Fischer, 2008) depending on the quality of information provided. In this section, we perform a competitive analysis of eco-feedback technologies for the home and explore the techniques these technologies employ. We first show the various types of eco-feedback technologies and describe how we narrowed our focus to review specific devices for this dissertation.

5.1.1 ECO-FEEDBACK TECHNOLOGIES

Several commercial eco-feedback technologies and initiatives to conserve home energy exist. These technologies may be dedicated feedback displays, mobile phones, and/or web-based applications. In an online survey to gauge usability ratings and user preferences of home energy monitoring technologies, the majority of 50 early adopters of eco-feedback preferred dedicated feedback displays to web pages (2011). In a follow-up study, the authors found that users prefer a display medium but expect to be able to access their energy data across additional media such as a web page or smartphone application (LaMarche, 2011). Mobile devices integrating eco-feedback information are still fairly new, and there are very few, if any, comprehensive evaluations and reviews. Therefore, we limit our reviews to those techniques used in dedicated feedback displays. These displays typically show consumption in terms of CO_2, dollars saved, and the amount of kilowatt-hours consumed. We summarize the general strengths and weaknesses of these devices next and discuss new energy-saving techniques to be explored.

5.1.2 METHOD

We collected information for this analysis from online product documentation, existing reviews of commercial energy displays and our own personal installations and demonstrations of these technologies. The first review we analyzed was conducted from the perspective of commercial devices for residential electricity demand response settings (Peffer, 2009). The second review was done to better understand behavior change associated with home-energy use (Carroll, Hatton and Brown, 2009; Fischer, 2008). We first selected a representative sample of commercial devices similar to those used in pilot studies of eco-feedback devices (Table 5). We then provided a short survey of research studies that show significant energy savings *via* energy feedback techniques and eco-feedback devices (Table 6).

Table 5 lists all available features and functions that we could find for each commercial device. We marked the features and functions available in the product with an "X". If the feature or function is not available, the box is left blank. Note that darker shaded areas include the least explored opportunities available, while the lighter shades present the second most least explored opportunities.

Table 5 - Competitive Analysis of Eco-Feedback Technologies

			Information Displayed															
			Feedback										Non-Feedback Techniques					
			Cost							Comparison								
Name	Whole-house	Medium	Current	Daily	Monthly	Projected	kW	CO2	Temp	Load Profiling	Historical	Social	Energy saving tips	Goal-setting	Communication	Integrated Entertainment	Device Information	*Notes
AzTech In-Home Display	yes	isolated display + smart meter with red, yellow, green LEDs to show peak rates	X			X	X				X*			X			www.generalpacific.com/services/metering/aztech-in-home-display	Historical view only available for the last 30 days
AlertMe	yes	display + website	X	X	X	X	X	X	X	X*	X		X	X*			alertme.com	The AlertMe monitor allows users to set alarms in case they reach a certain maximum or minimum point. This could potentially be used as a goal setting feature.
Black and Decker Power Monitor	yes	isolated display	X			X	X		X	X*							http://tinyurl.com/95nsoee	Device can show you how much power certain appliances are consuming using the tare feature (allows one to compare to appliance ratings)
Cent-a-meter	yes	isolated display	X				X	X	X								http://www.centameter.co.nz/	Can be expanded to display gas and water information
Demand Response Electrical Appliance Manager (DREAM)	yes	isolated tablet display	X	X	X	X	X		X	X*	X						NA	Pilot technology, not available (Peffer, 2009); Load profiling pre-set by researchers to include AC, washer/dryer, range/microwave, dishwasher, tv/computers, lights, refrigerator
EcoMeter	yes	isolated display + smart meter with red, yellow, green LEDs to show peak rates	X	X	X	X	X				X						www.ecometer.com.au/overview.html	displays gas and water
Energy Orb	yes	ambient display	X															
EML 2020-H	yes	isolated display	X	X	X	X	X			X	X						www.brultech.com	
EMS-2020	yes	isolated display + smart meter	X	X	X	X	X							X*			www.usclcorp.com	Budget feature allows households to set up budget-related goals
Home Energy Reports (OPower)	NA	paper					X					X					www.positiveenergyusa.com	
Kill-a-watt	no	device specific plugin	X	X	X		X										www.p3international.com/products/special/P4400/P4400-CE.html	
MEA (Mobile Energy Assistant)	yes	isolated display	X	X	X		X	X			X						www.svetinc.com	Not currently available (device is being used for pilot studies) (Carroll, Hatton and Brown, 2009)
PowerPlayer	yes	isolated display + smart meter	X	X	X	X	X		X					X		yes	www.homeautomationeurope.com	Designed to allow for entertainment media such as audio/video file viewing and a digital photo display to increase interaction
The Energy Detective 5000	yes	display + software	X	X	X	X	X	X	X	X*	X			X*	X*		www.theenergydetective.com	The website does provide a blog post for customers to post questions and comments but it is not linked to consumption. Load profiling is limited to 5 devices to be chosen by the customer. The TED allows users to set alarms in case they reach a certain maximum or minimum point. This could potentially be used as a goal setting feature.
The Energy Joule	yes	isolated display + smart meter with red, yellow, green LEDs to show peak rates	X				X		X								www.ambientdevices.com	
Community Monitor + TED5000	yes	isolated display					X		X			X	X	X	X	X	NA	

Table 6 - Recent U.S. summary of in-home display studies and their effect on electricity consumption[1]

Study	Description	Conservation Impact	Methodology Notes
Darby (2006)	"The literature reviewed here mostly consists of primary sources, with a few review papers. Most of it comes form the USA, Canada, Scandinaiva, the Netherlands and the UK." (p.3)	"Savings are typically of the order of 10% for relatively simple displays…"(p.11), similar to The Energy Detective; Pay-as-you-go systems with feedback resulted in savings of 10-20% for Ontario systems	Survey paper of other studies on energy use feedback, Time of Use (TOU) pricing and other behavioral efficiency approaches such as pay-as-you go (used in Ontario).
Fischer (2008) citing Dobson and Griffin (1992)	Report of a field experiment testing 100 US households. The experiment involves continuous feedback on electricity consumption and cost, broken down to various appliances and time intervals.	The treatment group reported 12.9% less consumption than control groups.	The experiment occurred during a 60 day treatment period.
Faruqui *et al.* (2010)	The paper reviews a dozen utility pilot programs in North America and abroad that focus on the energy conservation impact of in-home displays (IHDs)	Finds that consumers who actively use an IHD can reduce their consumption of electricity on average by about 7 percent when prepayment of electricity is not involved. When consumers both use an IHD and are on an electricity prepayment system, they can reduce their electricity consumption by twice that amount (Arizona pilot, 100 participants over ~1 year).	Meta-study (examines studies employing various methodologies) up to 18 months. Ex: San Diego study pilot with 300 enrolled participants (who volunteered for the study) evalauted the effect of conservation phone calls and emails on consumption patterns with in-home displays - PowerCost Monitor. Resulted in a 13% reduction from previous year.
Mountain (2006)	Hydro One's July 2004- September 2005 pilot with 500 constomers have real-time monitor (like The Energy Detective) and 52 do not.	"Overall, the aggregate reduction in electricity consumption (kWh) across the study sample was 6.5%" (p.3)	
Ehrhardt-Martinez (2010) citing Allena nd Janda (2006)	Real-time energy feedback using The Energy Detective (TED) among consumers in Ohio	Not significant	60 (10 meters, 4 low income and 6 upper income)
Parker, et al. (ACEEE 2010)	Two-year pilot evaluation of home energy displays	Annual normalized electricity consumption reduced 7.4%	Used control group of utility customers (~2 million). 17 homes given home energy displays.

[1] Table derived and modified from Table 3 of Amber Malone and Ben Haley's "Overview of Residential Energy Feedback and Behavior-based Energy Efficiency" report. This table excludes all studies done outside of the U.S. and studies conducted before 1990.

Table 6 consists of several U.S. survey studies that suggest high-energy savings. We derived and modified the table from Mahone and Haley's review report of residential energy feedback and behavior-based energy efficiency studies, which consist of past review studies (Darby, 2006; Fischer, 2008; Ehrhardt-Martinez, Donnelly, and Laitner, 2010). We use this review as it is the most comprehensive and consists of the intervention studies with the highest reductions in energy consumption. These interventions serve as a proof of concept though some of these results are based on short-term, small-scale studies conducted on non-representative households. The larger-scale studies were done in collaboration with local utility companies.

5.1.3 RESULTS

In a comparison of 15 different commercial displays, Peffer found that most displays specified the current number of kilowatts per hour consumed, the projected bill, and outdoor temperature (2009). As we show in Table 5 none of these displays directly focused on communication and very few on social comparisons. These two features could both address the presence of multiple household members or multiple stakeholders within a community. In addition, only one device (with the exception of our Community Monitor, which was deployed on an Internet tablet and discussed at the end of this chapter) attempted to integrate entertainment features to keep householders engaged. This device (the PowerPlayer) was allowed for entertainment media such as a digital photo displays and audio/video files viewing to encourage interaction.

In the six review studies shown in Table 6, Mahone and Haley find that the most successful feedback studies consist of programs that integrate several energy feedback and behavior-based intervention strategies. From the table, we see that these include pay-as-you go plans and phone call and emails consisting of consumption patterns. Fischer concluded in her review that successful feedback interventions include direct feedback, which we discussed earlier, provides frequent and long-term feedback, is presented in a clear and appealing way, and provides appliance-specific breakdown (2008). We see reductions of 10-20% with these techniques integrated into real-time feedback, or in-home displays. Unfortunately, certain techniques and strategies are limited to certain locations (*e.g.,* pay-as-you-go plans).

After conducting the analyses, we noted other technological shortcomings and concerns regarding eco-feedback. These include inconsistencies with the device and actual billing data (Kiselewhich, 2008; Parker, 2008) as well as drop-out rates due to issues such as dead batteries. Further, individuals put the devices away once the novelty had worn off (MacLellan, 2008). These are critical issues: if the device is not functioning, or householders ignore the feedback, there is no way to access one of the ways to reduce consumption. Though real-time feedback has been shown to be effective, current home-energy displays do not successfully engage consumers or maintain their long-term interest, each of which compromises their energy savings (LaMarche, Sachs and Roth, 2011).

In this section, we reviewed 15 eco-feedback technologies and found several opportunities to explore comparison, better understand communication, and engage individuals, households and communities within eco-feedback technologies. Though we only presented a subset of in-home display review studies conducted, very few of the total studies reviewed used social engagement techniques and results of social comparison studies were mixed. In the next section, we present the results of a study aimed to validate need to integrate some of these features into an energy monitoring application.

5.2 Concept Validation via Speed Dating

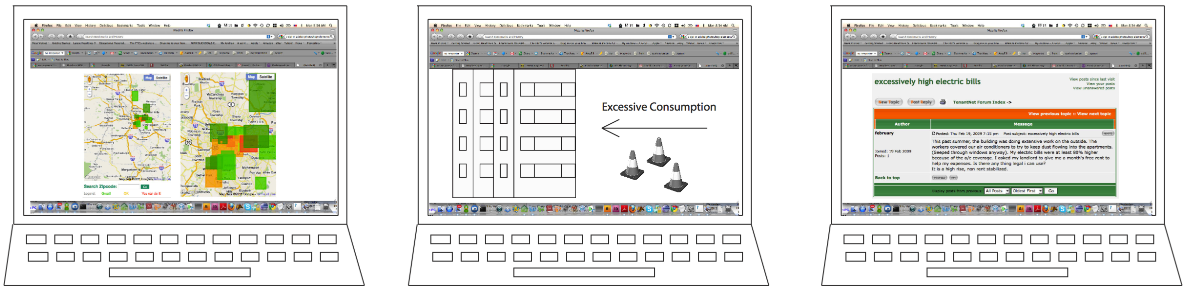
Our past work demonstrates the impact that multiple stakeholders, such as community members, extended family, and landlords have on home-energy consumption. Our competitive analysis and review of past studies show that eco-feedback technologies rarely, if ever integrate social factors as techniques to encourage energy reduction. For example, very few research and technologies explore how multiple stakeholders interact with eco-feedback technologies, or consider ways to bring multiple stakeholders into the conversation. Further, although methods of comparison yield significant savings, only a limited amount of home energy research has explored social comparison with feedback devices. Inspired by Chapters 3 and 4, we present the results of a needs-validation, or concept-validation study in which we explored a range of concepts around energy data that could inform the design of a social-energy application.

5.2.1 Method

Speed Dating is a design method for rapidly exploring application concepts and their interactions (Davidoff, Lee, Dey, and Zimmerman, 2007). We sketched and presented scenarios of new technological interventions all involving real-time energy consumption data. Our goal was to explore multi-stakeholder scenarios and identify potential areas of concern in multi-stakeholder contexts.

Using this method, we drafted concept scenarios of settings based on issues that arose in our prior studies discussed in Chapters 3 and 4 (Figure 10, for example). Each of these scenarios introduced a technological intervention to address a need in each setting, or specific situation.

The design concepts presented included interventions that could detect real-time energy consumption and display information about the data collected, how individuals consume energy, and how they engage around energy consumption. We analyzed our data by writing extensive notes, organizing responses around our five dimensions, and by comparing results among our participants.



Sam views a map showing how his neighborhood compares to the rest of the city in terms of energy consumption.

Sam zooms in more to compare his energy consumption to others in his apartment building.

Sam sees that there's a way for him to post questions to the system. He posts a question about suggestions for excess costs as a result of local construction.

Figure 10 - A scenario describing how an individual may use a system designed for sharing energy consumption

5.2.1.1 Scenarios

To address energy consumption needs as identified in our prior work, we generated more than 25 initial concepts around real-time energy monitoring. We clustered these concepts into five dimensions, based on design issues raised in our previous studies:

- feedback,
- privacy,
- sharing,
- knowledge,
- enabling group action.

We presented our scenarios to seven renters, two students, two homeowners, and one landlord. To help understand how responsive participants were to our proposed solutions, we asked them to provide feedback by imagining themselves as the main character in each scenario (*e.g.*, potential benefits to their households). Their feedback helped us modify scenarios and remove unpopular concepts.

5.2.1.2 Participants

We recruited renters and homeowners from Craigslist in Pittsburgh, PA, and a landlord via word-of-mouth. Renters included students and employed and unemployed individuals. Seven renters lived in low-income households earning less than $30,000 per year, while two individuals lived in households earning more than $70,000 per year. Ages ranged from 19-59 with a median age of 29. Seven individuals were male and more than half of our participants

Table 7 - Participant details (participants are referred to in this section as P+ID, *i.e.*, P0731)

ID	Living Status	Occupation	2010 Income	Gender	Age	Race/ Ethnicity
0731	Renter	Unemployed	50-60k	F	29	African American/ African Descent
1095	Lives with parents who are home owners	Full-time student	70k+	M	19	Asian/Pacific Islander
1471	Renter, public housing	Looking for work	10-19k	M	59	Caucasian/White
1938	Lives with parents and on campus	Full-time student	70k+	M	20	Caucasian/White
2011	Renter	Looking for work	10-19k	M	21	Asian/Pacific Islander
2320	Renter sharing space with partner	Full-time employee (NA)	30-40k	F	29	African American/ African Descent
2477	Home Owner	Unemployed	10-20k	M	29	African American/ African Descent
2771	Renter, public housing	Unemployed	<10k	M	23	Caucasian/White
2848	Owner	Attorney, Landlord	70k+	M	33	Caucasian/White
4211	Renter in a shared space	Part-time employee	<20k	F	22	Caucasian/White
8064	Home Owner	Music teacher	10-19k	F	57	Caucasian/White
8118	Renter	Part-time employee as a hospital staff member (looking for work)	20-30k	M	30	Asian/Pacific Islander

included Americans from African and Asian descent, while the remaining renters were Caucasian American. Most participants we interviewed lived with housemates, family members, and/or partners. We also interviewed one part-time landlord who worked as a full-time attorney. This landlord rented primarily to students with less than $30,000 in annual income.

5.2.2 RESULTS

Based on the overall feedback we received from the majority of our scenarios, we concluded that our concept primarily benefits the party responsible for paying electricity bills. In the next section, we identify and describe some of the conflicts related to various household types, privacy issues, design implications, and possible platforms to host our service.

5.2.2.1 CONCEPT VIABILITY

In terms of concept viability, our results were mixed and varied based on who paid for energy bills. For example, renters responsible for paying their electricity bills were very excited about the idea of using technology and tools that: 1) provided electricity information about their community and community members; 2) provided an opportunity to seek outside resources by leveraging modes of communication such as chats, blogs, and/or bulletin boards; and 3) helped them better manage their consumption. For example, the landlord was concerned about whether the system would identify issues that could result in extra costs for him. If the system identified inefficiencies in his apartments, he would be required to make the updates, and though he claimed to be a reasonable landlord, he was not pleased about having to pay for the improvements. Residents that did not pay for their utilities did not have a definite preference. Overall, they felt that if the landlord paid the bills, then the landlord was entitled to install the devices. Those we interviewed were willing to try our design concept as long as their privacy was not violated.

Another finding in terms of viability related to how individuals identified with the concepts. In some cases, participants assumed that characters in the scenarios were environmentally conscious and felt the technology interventions were designed specifically for those with concerns with the environment. Consider for example, the following scenario:

> Malcolm's landlord tells him about the community website that will allow him to track his energy consumption and to compare his consumption with others. Malcolm goes up to his new apartment and checks out the site. Malcolm decides to create an account on the website and provides [household information below, *i.e.*, apartment name, length of time in household, number of people in household, number of kids in household, number of bedrooms/bathrooms, number of hours at home, number of plug-in devices, types of appliances, and address (never shared)].

Malcolm's landlord tells him about the community website that will allow him to track his energy consumption and to compare his consumption with others.

Malcolm goes up to his new apartment and checks out the site.

Malcolm decides to create an account on the website and provides information about himself:
Apartment name
Length of time in household
people in household
kids in household
bedrooms/bathrooms
of hours home/apartment is occupied
Number of plug-in devices
Types of appliances
Address (never shared)

Figure 11 - Scenario 2: Welcome to your new apartment!

Based on this scenario, P8064 stated, *"If it's a way to help make me more green, I'd respect it. But I'm not a [green] fanatic. I do care though; I take my own bags to the grocery store."* P8118 said, *"It would be great to those that are concerned about energy consumption issues…[but] I'm not concerned about energy issues so it's a maybe for me."* Similarly, P2320 felt as if *"the participant needs to be interested in the environment or finances."* In response to a screen showing the amount of CO_2 and number of kilowatts consumed, P0731 stated that the concept should, *"Speak a language we can all understand and that's money."*

Given these findings, we must take into consideration that stakeholders will benefit, or be affected by the design. We must account for this factor by minimizing the impact on those who may be affected in a negative way or findings ways to share benefits of the design. For example, though this technology may make residents aware of issues that the landlord must address, taking care of these issues could keep tenants happy and decrease vacancies. Therefore, landlords may see the concept as beneficial even if his or her tenants are responsible for their own electricity bills, and the tenants must see the concept as beneficial even if their landlord pays for the electricity bills. Furthermore, the concept design must not come across as though it targets a particular group (*e.g.*, "green," or landlords only, or tenants only).

5.2.2.2 PRIVACY

We presented several scenarios to participants to understand the level of privacy they were comfortable with providing. Overall, we found that there were three categories of individuals. Dr. Alan Westin is a Columbia Law Professor who has conducted significant research in the consumer data privacy and data protection sector. He has conducted more than 30 privacy surveys and summarized his findings in Privacy Indexes. Our participants' views of privacy were very similar to Dr. Alan Westin's privacy index categories below (Westin, 1991):

- individuals who were extremely paranoid with providing personal information to websites and assume their information will be compromised, privacy fundamentalists (4)

- individuals who automatically trust certain sites and assume the sites are safe, and are marginally concerned about safety (3).

- individuals with no concerns about privacy in the context of our tool and did not mind sharing all of their data, including location information and real-time energy consumption with the community (1)

All individuals agreed to provide information regarding the physical description of their households including the number of baths, bedrooms, plug-in devices, and appliances to the site. Participants were okay with this information being shared with others inside or outside of their community. However, most participants opposed providing specific details such as the types of devices and appliances within their homes, or information that could reveal their identities such as the number of hours they spend in the household, their apartment numbers, or the name of their apartment (to those outside of their community). At least one participant stated that she maintains privacy by providing false information.

When probed about providing information as a complete household, or group, most participants felt that providing information about which floor they lived on was too much information. Assuming they were comparing their information with others in their community, many participants were willing to provide the name of their neighborhood or apartment building.

Three participants, P1938, P731, and P2848 (the landlord) strongly suggested adding any information about real-time energy monitoring to the lease if the landlord provided the technology. For example, P1938 stated, "*The lease could be used to say what could be done with the information...*" and the reasons the landlord is monitoring the apartment.

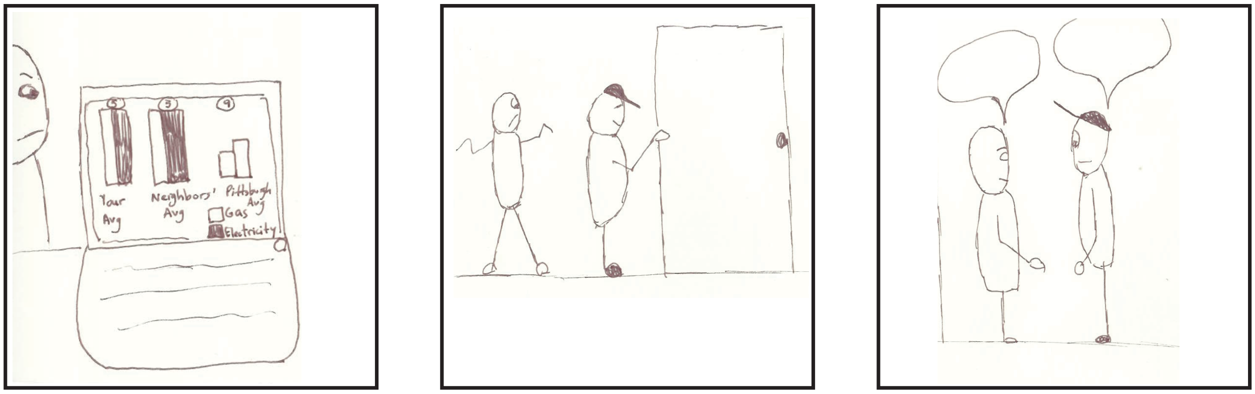
We must take the three types of privacy categories into consideration when presenting information. Requests for sensitive information must be optional to meet the needs of both privacy fundamentalists and those individuals with few or no privacy concerns.

5.2.2.3 FEEDBACK

Our scenario interventions provided feedback about real-time energy consumption, total costs of energy, historical consumption data, and information about CO_2 consumption. There were two major conclusions based on the information provided. First, individuals wanted information to help reduce their consumption and feedback to help them identify energy-related issues. Secondly, some individuals did not expect to have to interact with the data frequently. They preferred to receive timely and informative alerts about excessive consumption and/or weekly alerts about their status (*i.e.*, how they compared with their neighbors).

Though participants stated that they could deductively identify issues using the feedback as presented in our concepts, they preferred information that would automatically identify and/or point out relevant issues for them. We provided participants with this scenario:

> Justin uses a website to compare his consumption with the rest of his neighborhood. Justin sees that he consumes more electricity than anyone else. Justin decides to ask his neighbor about his consumption. Justin discovers that his neighbor's payments are much lower, and he tries to find out why. Once he realizes that more than one neighbor is having this issue, he organizes a tenants' meeting.



Justin uses a website to compare his consumption to the rest of his neighborhood. Justin sees that he consumes more electricity than anyone else.

Justin decides to ask his neighbor about his consumption. Justin discovers that his neighbor's payments are much lower and he tries to find out why.

Once he realizes that more than one neighbor is having this issue he organizes a tenant's meeting.

Figure 12 - Scenario 13: Group Discussion

Though P8064 felt that the ability to compare with others in the neighborhood is a great concept, he specifically wanted to know, "*How do I get my bill to go low? What's going on?*" and what he could do, *e.g.*, "*have someone check the system, unplug devices, seal the room.*" He wanted the system to be able to determine probable causes of the higher consumption on its own. This is consistent with prior research, which says that the more clearly someone can link consumption to specific activities and appliances, the more clearly behavior patterns become pertinent to the size of the energy bill (Fischer, 2008). Additional research shows that individuals like to receive the means to answer questions related to energy consumption such as, "How much money did I save this year?" or "Is my new energy-efficient heater really saving energy?" or "How am I doing compared with people in houses like mine?" (Gardner and Stern, 2002; Kempton, Darley, and Stern, 1992).

P2320 wanted SMS or email alerts of status updates and issues. For example, she explained that she would not actively look at the consumption data, but that she preferred "a weekly report of these things [consumption data] sent to her," and wished to be alerted via SMS or email. This is similar to findings from (Kjeldskov, Skov, and Pathmanathan, 2012) where households using an electricity monitoring application on their iPads thought it advantageous to receive SMS alerts or reminders.

In terms of feedback in general, P2011 expressed that "*landlords have been hesitant in giving me that type of information.*" In other words, landlords have been wary in letting him know the past year's consumption data and/or the past consumption of other households. He found it very beneficial to have access to historical consumption data.

In terms of our participants providing a technological application with additional information, participants did not respond well. For example, participants did not wish to provide information to help identify the cause of spikes and peaks within their real-time energy monitoring graphs (*i.e.*, Figure 13). Some found it acceptable to provide the information every now and then but unacceptable if our concept required frequent interaction as described in this scenario:

> Sam sees from his display that around 11:38 pm there is a drop in his power and that around 11:40 pm there is another peak. He is asked to label these data points from a list of the devices he listed at sign up. Sam remembers hearing the refrigerator compressor turn off and back on. He enters refrigerator for [peaks] A and B.

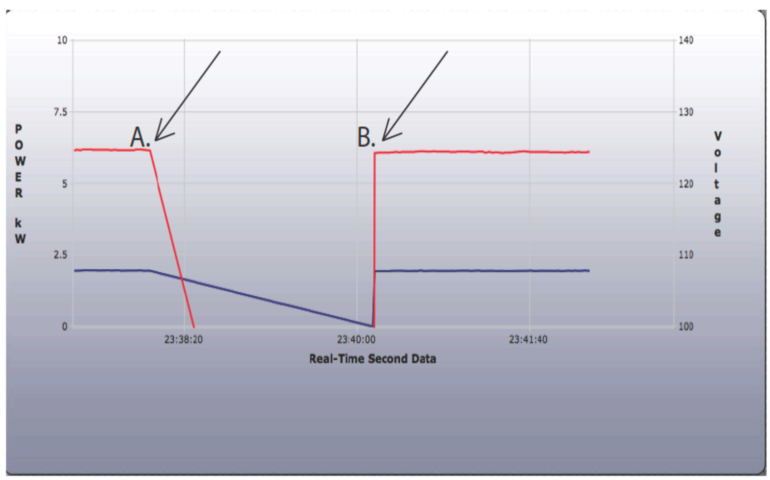


Figure 13 - Scenario 19: Sam labels his data

In response, P2320 stated, *"I don't want to have to check-in or provide [additional] input."* Based on his tenants' remarks, the landlord, P2848, stated that the scenario was *"Unrealistic because no is listening to the refrigerator coming on and off….they are too distracted with Jersey Shore."*

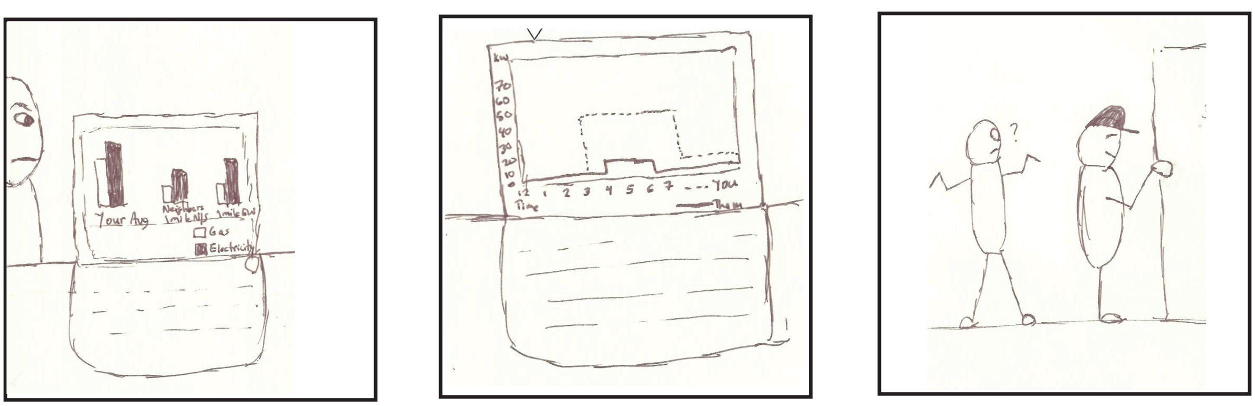
In summary, based on scenario responses, users prefer feedback that identifies, or helps to identify energy-related issues. They also wanted information that could be used to help them reduce their consumption. Though participants wished to receive this type of information and feedback from the system, they did not wish to provide additional data, such as why an event occurred to the system.

5.2.2.4 SHARING KNOWLEDGE/SOCIAL ENGAGEMENT

Overall, very few participants wished to engage with their neighbors outside of an electronic forum. In one instance, P731 did speak to her neighbors about her consumption and viewed it as "a step in the right direction to try to narrow down issues." After hearing one of her neighbors complain about electricity, she explained, "*They spent $500 for one month even though they weren't even home*." As a result of her interactions with neighbors, P731 says she will ask questions about electricity costs and the types of appliances her neighbors use before moving into a new place.

Just as we saw in Chapter 3 that PA residents did not wish to share their consumption data with neighbors, most participants in this study did not want to discuss electricity information with their neighbors. In general, participants were not able to relate with scenarios where individuals sought information or help from his or her neighbor. Presented with the following scenario, for example, many participants would try to identify the issues themselves before seeking help from neighbors:

> Sam, another resident of the community takes a look at this week's comparison chart from his computer. The website shows that he has higher consumption than his neighbor in the early evening on average. He knocks on his neighbor's door. He discovers that his payments are much higher than his neighbors and he tries to find out why.



Sam, another resident of the community takes a look at this week's comparison chart from his computer.

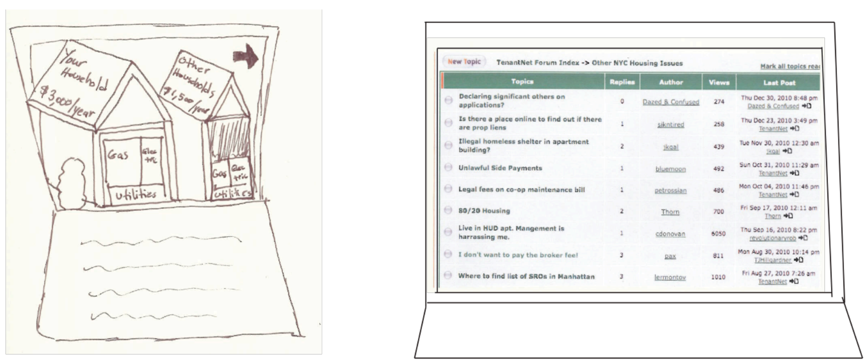
The website shows that he has higher consumption than his neighbor in the early evening on average.

He knocks on his neighbor's door. He discovers that his payments are much higher than his neighbors and he tries to find out why.

Figure 14 - Scenario 3b: Sam's excess consumption

P8064 responded, "*I should be able to deduce exactly what's causing my excess consumption*" from the concept. When referring to the scenario, P8064 stated, "*There should be a way for him to figure it out…the chart is like going to the neighbors.*" "*I wouldn't talk to my neighbors [in this case], it's unnecessary.*" P1471 said, "*I'd never knock on the neighbor's door,*" "*Sam should be able to do it on his own,*" meaning that Sam should be able to identify the issue using the concept. However, P1471 did state that experience matters in this scenario. For example, Sam may have gone to his neighbor's because he was a new resident and did not know the cause of the excess consumption. Similarly, P2320 stated that she would "*start with some testing of my own in my apartment first….maybe doing some experiments like shutting everything off, or only being in one room.*" If there was an issue, she would immediately talk to her landlord, not her neighbor. She added, "*My neighbor can't do anything about it.*" P2477 stated, "*I think its weird if a neighbor comes up to you with information about your energy consumption and tries to compare it with you…It feels like it's crossing boundaries.*"

Participants were more receptive to message boards and forums to communicate with others. When presented with the scenario below,



Jamie sees from the system that nearby households have similar average energy bills . In comparison to the rest of the neighborhood, the nearby households and Jamie have the highest consumption in the neighborhood.

Jamie sees that there's a way for him to post questions to the system. He posts a question about how to manage his consumption.

Figure 15 - Scenario 7: Jamie compares his home with others

> Jamie sees from the system that two nearby households have similar average energy bills. In comparison to the rest of the neighborhood, the two nearby households and Jamie have the highest consumption in the neighborhood. Jamie sees that there's a way for him to post questions to the system. He posts a question about how to manage his consumption.

P2477 stated, "*Wonderful! I'd use this system…nothing is identified here, the information can be anonymous and still be helpful.*" P2011 stated that, "*I'd be more inclined to [get] advice this* *way…Seems like a nice place for people to help each other out and give each other advice.*" P8118 felt that this concept would "*trigger other tenants to share their concerns and to give their two cents.*"

In summary, engagement is more likely to happen electronically than face to face among our participants (*e.g.*, low-income Pittsburgh communities).

5.2.2.5 Organization and Group Action

Based on the results from Chapter 4, initiating and organizing group action with this audience is difficult. Similarly, Vaughan found that organizers within a low-income community reported difficulty in mobilizing the community to take action (1968). One participant, P8064, responded by describing how the concept presented in Figure 12 could lead to group discussion and that she would possibly be the one to initiate the tenants' meeting. In fact, she said she has organized tenants before though not for this reason (she organized a celebration). None of the other participants who reviewed this scenario had organized group or community meetings in the past. One participant talked about the difficulties (*i.e.*, people work different shifts, people may have other responsibilities such as taking care of kids and that people may attend other meetings). This participant did believe, however, that the concept could make organizing easier.

5.2.3 Summary

In this section, we showed the results of a competitive analysis of existing interventions used to reduce home energy consumption. Gaps in these technologies include the lack of comparison features, specifically social comparisons and the lack of support for social engagement. In this section we also described the results of a concept-validation study of 25 concepts around real-time energy feedback to address the dynamics of varying household types, socioeconomic context, and stakeholders. Our results showed the need to support multiple stakeholders, to provide information that helps stakeholders identify energy-related issues, the benefits of electronic feedback when sharing knowledge or socially engaging with others, and the importance of collective action. In the next section we summarize our findings from related work, prior studies and competitive analysis to identify design guidelines.

5.3 Design Guidelines

Design guidelines convey a set of implementation principles based on prior implementation, research, and/or experiences. They aid designers and developers by providing a starting point for application design and development. We extract guidelines based on our related work, which we discussed in Chapter 2; our prior studies, which we discuss in Chapters 3 and 4; our competitive analysis; and our concept-validation study, which we discussed in 5.2 and 5.3. We categorize these guidelines into three essential areas: making energy visible, bringing in the collective, supporting better communication and addressing habits and routines. We conclude the section with a list of constraints that future designers and eco-feedback technologies should consider when following these guidelines.

5.3.1 MAKING ENERGY VISIBLE

One of the challenges highlighted in the related work, our study of energy-consumption in low-income communities, and from our concept validation work was the lack of energy visibility. Eco-feedback technology research shows that real-time feedback devices have been successful because they make energy visible. However, based on our concept validation results in section 5.2.2.3, individuals want feedback to help them identify energy-related issues. This is somewhat consistent with prior research, which says that linking consumption to specific activities and appliances makes it easier for individuals to associate behavior patterns to the size of the energy bill (Fischer, 2008). Therefore, in addition to making energy visible, it is also important to provide support for individuals to identify energy-related issues. One option is to provide social comparisons to other community members, though as discussed in Chapter 4.6, tenants often lack information about the energy use of other tenants in their units.

5.3.2 BRINGING IN THE COLLECTIVE

Bringing in the collective means accounting for multiple stakeholders in eco-feedback technologies, having an inclusive design that targets more than “green” households and individuals and supports group organization and environmental awareness.

We saw in our related work that Woodruff *et al.* concluded that technologies must provide support for individuals *and* the collective in behavior change (2007). As we discussed in Chapters 3 and 4, stakeholders such as family members, other community members, roommates and landlords may all play a role in energy consumption and we should consider additional stakeholders when designing real-time energy displays. Our competitive analysis also demonstrated that very few research technologies explore how multiple stakeholders interact with eco-feedback technologies, or ways to bring multiple stakeholders into the conversation.

Findings from our related work and concept-validation study imply that eco-feedback technologies should be inclusive in terms of their target audience. For example, Woodruff, Augustin and Foucault argue that designers must prevent the potential of creating a “green” divide by making these technologies accessible to all groups (not just groups that can afford to buy these technologies). Similarly, we saw from our concept-validation study that participants did not particularly relate to "green" lifestyles, CO_2 levels, or the number of kilowatts consumed. Our related work, prior studies and concept validation among households identified several other motivations underlying increased concern for the environment or greater interest in consumption management.

Chapter 4 discusses the importance of gaining strength in numbers through collective action. However, we saw from the results of our concept-validation study that organizing group action can be difficult due to work schedules and other responsibilities. Eco-feedback technologies could add features to support organizing groups, or consolidate group issues that could be used to encourage collective action.

5.3.3 COMMUNICATION AND FEEDBACK

Communication and feedback provides individual community members with access to new information and help to identify and resolve common problems within a community. Our related work and prior studies showed the need for improved communication among stakeholders around energy-related issues. Despite this need, none of the eco-feedback technologies from our competitive analysis supported social engagement or communication within the application. The Energy Detective's main site included a link to a general message board for TED owners, but provided no support for individuals or households that wished to communicate with others in their community.

We saw in our related work that many "green" households wanted to share their success with others and often served as mentors to other community members by answering sustainability-related questions. Leveraging this type of behavior could allow households within communities to share information, strengthen social networks, build social capital, and provide support for other household members. We also saw in our study of landlords and tenants in Chapter 4, that landlords believed that improved communication with tenants might help to reduce conflict. Therefore, supporting communication within neighborhoods and among stakeholders could offer several benefits to residential communities. However, results from our concept-validation study show that electronic forums may be the preferred medium for social engagement; few participants in this study stated that they would initiate conversations with their neighbors.

In terms of static information and feedback, participants from our concept-validation study felt that interventions must have lists of prioritized tips for saving energy. Many participants stated that real-time consumption information and feedback would not be beneficial without practical, energy-saving suggestions. Some participants wanted to receive alerts that would allow them to take immediate action related to consumption peaks or lower-than-expected savings.

5.3.4 HABITS AND COMFORT

All studies we reviewed in our past work as well as our study of energy consumption in low-income communities discussed habits and comfort as a challenge to address when aiming to reduce energy consumption. Addressing these challenges requires an understanding of how to change habits. Based on past research, habits form over time through procedural learning (Graybiel, 2000), and may be learned by observing others around us (Bandura, 1997). Therefore, encouraging frequent behavior and creating new social norms could serve as guidelines to follow to break habits. Another possible solution, discussed in Chapter 3 is to support reflection and evaluation of behaviors as both can help people break old habits. Social sharing and social engagement not only support reflection, they have the potential to change social norms.

5.3.5 PRIVACY

We concluded in Chapter 4 that privacy issues could lead to power imbalances. In other words, information revealed to one party could lead to harmful power over another. We saw from our concept-validation study that requests for sensitive information must be optional; this meets the needs of both privacy fundamentalists and those with no privacy concerns. Our concept-validation study allowed us to identify some of the specific information that participants felt could lead to this imbalance. For example, the results of this study revealed that participants are willing to provide certain information for the benefit of the rest of the community. Many participants found it acceptable to provide information about the makeup of their households such as the number of bedrooms, bathrooms and appliances. At the same time, most participants were unwilling to provide information that could reveal their identities. Willingness to share information largely depended on the consumer of the information. For example, participants did not mind revealing the name of their apartment complex if this information was only going to be shared with others in their apartment building. However, many participants would not reveal information such as their floor number if this information was to be shared with others in their apartment building.

5.3.6 SUMMARY

We provided a list of design guidelines to follow when creating social energy applications based on findings from our related work, past studies, and competitive analysis. We summarize these findings in Table 8 below and explain in the next section, which guidelines we followed to design and implement our own social energy application.

Table 8 - Summary of Design Guidelines

(Source: Related Work – RW, Chapter 3 – Energy Consumption In Low-Income Communities – LI, Chapter 4 – Understanding of Landlord/Tenant Conflict – LT, Concept Validation – NV, Supported as need from Competitive Analysis - CA)

Section	Guideline	Source
5.3.1: Making Energy Visible	Make energy visible and provide support for individuals to identify energy-related issues. Linking consumption to specific activities and appliances makes it easier for individuals to associate behavior patterns to the size of the energy bill (Fischer, 2008).	All
5.3.2: Bringing in the Collective	Provide support for multiple stakeholders, or the collective (*i.e.*, roommates, family members, other community members, landlords, *etc.*); these stakeholders play a role in energy consumption and should be considered in the design of real-time energy displays.	All
	Designs should be inclusive (*i.e.*, unless intentional, design for use for households or individuals with varying motivations, socio-economic status, household types, *etc.*). Designs should include a broad audience as possible to have the greatest effect on energy consumption.	RW, LI, CV
	Provide support for features to support group organization and/or group issues to promote collective action and gain strengths in numbers.	LI, LT, CV
5.3.3: Communication and Feedback	Provide support for communication between and among stakeholders (preferably electronic) to help identify and resolve common community problems.	All
	Provide support for households that wish to share tips with other household members, and/or for household members seeking tips from others (preferably electronic). This supports information sharing, stronger social networks and increased social capital.	CV

	Provide support for static and/or dynamic information (such as prioritized tips for saving energy, or dynamic alerts) to provide practical energy-saving suggestions.	CV
5.3.4: Habits and Comfort	Provide features to modify social norms as a method to help break bad habits and encourage new ones.	RW, CV
	Provide support for reflection and evaluation of behaviors (*i.e.*, social engagement and social sharing features). Reflection and evaluation is also a technique that can be used to break habits.	RW
5.3.5: Privacy	Privacy: Allow responses to requests for sensitive, or identifiable information to be optional (*e.g.*, household details). The point of this guideline is to reveal invisible forces or factors that may be affected by our technologies (*i.e.*, a landlord decides to evict a tenant due to excess electricity consumption).	LT, CV

5.4 Community Monitor Application

We provided design guidelines in the previous sections for future social energy applications. Then, based on some of those guidelines, we designed and built one application, which we discuss next. As described in Chapter 6, we deployed and evaluated it across two rental populations.

We designed the Community Monitor application to support communication, sharing, and social comparison, to engage with both participant intent (through feedback and social engagement, *i.e.*, Figure 2.2.1) and participant habits (through regular presence in their lives). Our goal was to allow households to see what is good or bad in terms of consumption, to whittle down issues, and to be able to have informed discussions with landlords or each other. To accomplish this goal, we primarily focused on five guidelines: 1) make energy visible and provide support for individuals to energy-related issues; 2) provide support for multiple stakeholders, or the collective[2]; 3) provide support for households that wish to share tips with

[2] We targeted roommates, family members and other community members. We did not target landlords because we chose to start by focusing on stakeholders with similar goals. Further, our deployment sites consisted of households in which the landlord paid for electricity and the overall effect of electricity reduction matched landlord goals.

other household members; and/or for household members seeking tips from others; 4) make designs inclusive; and 5) allow responses to requests for sensitive, or identifiable information to be optional. In addition, we provided support in three areas: 1) communication between and among stakeholders (though we do not support communication between households and landlords), 2) static and/or dynamic information (we only provided static information), and 3) reflection and evaluation of behaviors (we do not initiate this reflection). We explain how we follow the five guidelines we fully support in the next section.

Our implementation was designed and piloted simultaneously. Instead of discussing our design iterations and ideas in detail, we present the *final* version of our application, which has been in use since its release on January 5, 2012.

5.4.1 MAKE ENERGY VISIBLE AND PROVIDE SUPPORT TO IDENTIFY ENERGY-RELATED ISSUES

We used the Android™ platform to develop the tablet application and The Energy Detective (TED®, http://www.theenergydetective.com/) to collect home energy use data. We used the StepGreen API to manage data (Mankoff, Fussell, Dillahunt, Graves, *et al.*, 2010). The application could be accessed *via* an Android widget.

Recent studies indicate that people understand the relationship between their actions and the environment better with the use of iconic images (Kim, Honog, and Magerko, 2010). The studies also suggest connecting individual actions to their consequences (Pierce, Odom, and Blevis, 2008). We displayed a single polar bear on a block of ice to indicate high consumption (bad) and are noticeable from a distance and could be seen before household members interacted with a

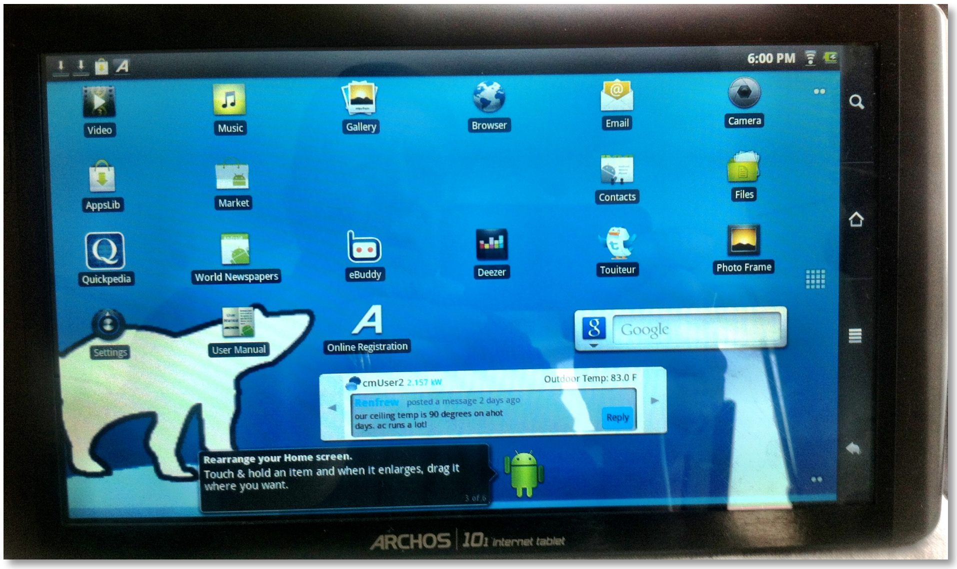


Figure 16- Community Monitor Tablet Application

family of polar bears to indicate low consumption (good). As shown in Figure 16, the images other applications (*i.e.*, games, email, *etc.).*

Android Widget: We used an Android application widget (a small application view that can be embedded on the device home screen and can receive recurring updates) to provide additional information. The widget provides participants at-a-glance feedback about their current electricity usage, the outside temperature, and the latest posting to the community message board (Figure 17).

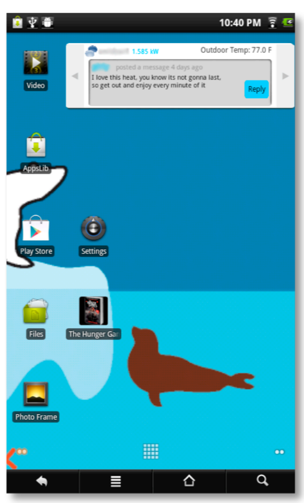


Figure 17 - Application Widget

5.4.2 PROVIDE SUPPORT FOR MULTIPLE STAKEHOLDERS OR THE COLLECTIVE

We supported communication between and among stakeholders by integrating a community message board into the application. The Community Message Board allows participants to communicate with the rest of their community (*e.g.*, information sharing, event planning, and questions). The social aspect of the application also provides an opportunity for knowledge transfer between individuals, which includes sharing tips and seeking information.

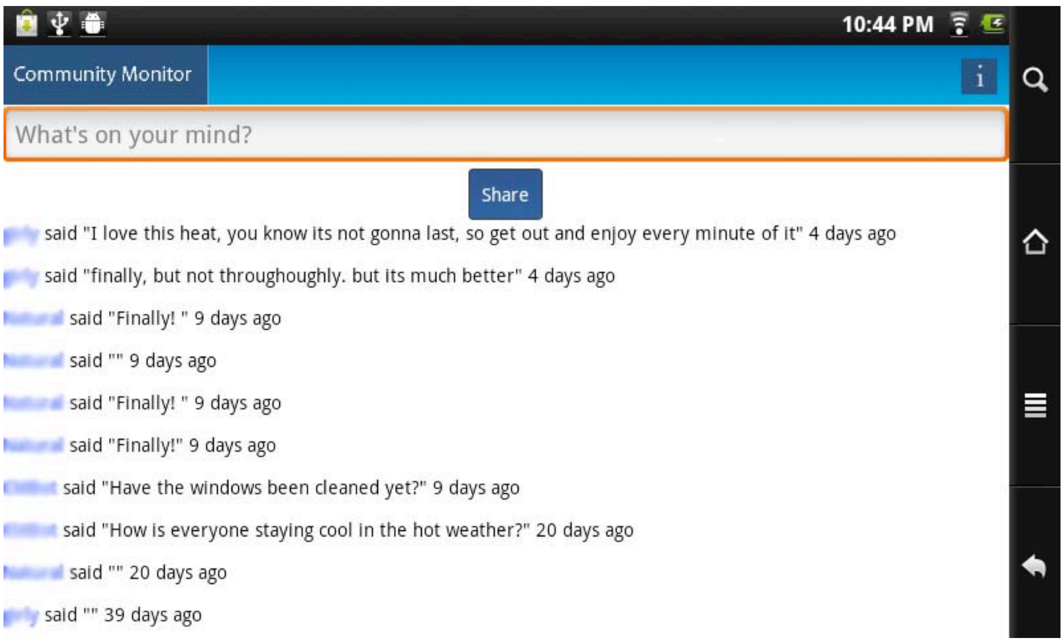
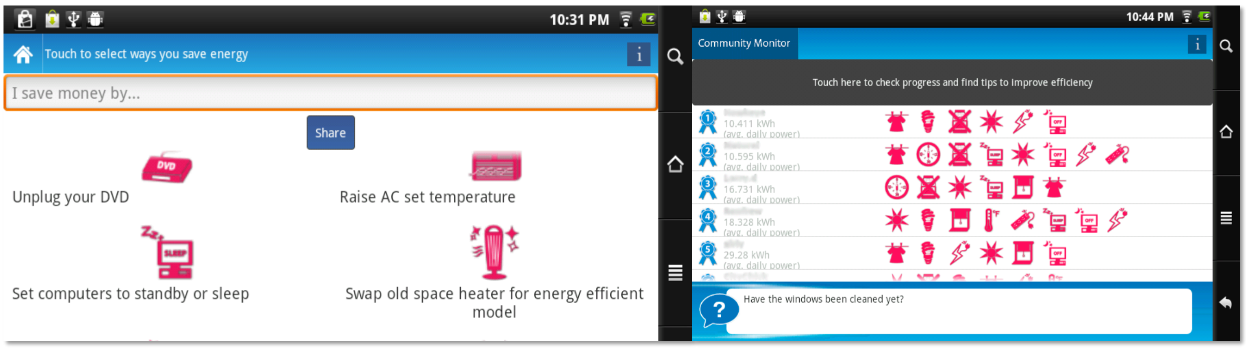


Figure 18 - Community Monitor Message Board

We also provided an opportunity for households to see how they rank among other community households. The Leaderboard, which provides a ranking of household members based on their average daily consumption (see **Error! Reference source not found.**), provides some support for reflection and evaluation of behaviors, though the application does not initiate this response. However, the Leaderboard does serve as a way for households to evaluate their behaviors and how they are doing in comparison to others.

5.4.3 PROVIDE SUPPORT FOR HOUSEHOLDS THAT WISH TO SHARE TIPS WITH OTHER HOUSEHOLD MEMBERS

We developed a "Ways to Save" feature that allows participants to learn about possible actions and share energy-conservation information with one another (see **Error! Reference source not found.**, right). In keeping with our guidelines, such information helps support static and/or



dynamic information

Figure 19 - Application Ways to Save (left), Leaderboard and Shared Actions (right)

(though we only provide static information here). The key purpose for this feature was to allow household members to see and post what others did to reduce their consumption, and subsequently save money.

5.4.4 Designs Should Be Inclusive

To be more inclusive, and to avoid the appearance of targeting a "green" audience, we were very careful not to include the word – or even the color green in our designs. From our concept-validation study results, we saw that some people explicitly separated themselves from this group. At the same time, we did not wish to exclude those that may have identified themselves as "green"; instead, we emphasized the social nature of our application by employing designs and colors that closely resembled social sites like Facebook and Flickr.

Many of our participants had never had Internet access before and we selected a platform that was relatively inexpensive as well as useful for a new Internet user. Because we wanted individuals within a household to share the device, and because tablets are low cost in comparison to laptops, we chose them as the most appropriate technology medium for our demographic. Tablets also provide individuals with Internet access, games, email, and other appealing applications. Additionally, because tablet devices are portable, they can be placed in common areas. The versatility of tablets also encouraged frequent use, and toward that end, we modified the tablet's wallpaper background to represent the household's real-time consumption. Indeed, this strategy has been successful in the past on mobile phones (Froehlich, Dillahunt, Klansa, Mankoff, *et al.*, 2009).

5.4.5 Privacy: All responses to requests for sensitive, or identifiable information to be optional

To adhere to our privacy guideline, we did not request detailed information from our participant households. The only information that we shared directly was daily average consumption (kWh). Each individual household had access to its real-time consumption data. Since there was a message board, any information a participant posted to the message board would be made public to the other participants. In addition, any actions that participants selected from the Ways to Save option was made available. We did ask participants to provide an alias. The default alias was their user id (*i.e.,* user1, user2); however, during setup and installation, we asked for pen names that allowed household participants to use identifiable information, real names, or pseudonyms.

5.4.6 Summary

We described the design of our Community Monitor application and explained how we used four of our proposed design guidelines in section 5.3.5. We designed the Community Monitor application as a social application to help tenants identify electricity related issues by providing comparison information, to engage with other community members, and support household sharing of tips and other information. In the next chapter, we discuss the deployment results of our Community Monitor application.

6 Understanding the Impact of Household Electricity Comparison and Engagement in Residential Communities

As discussed in the previous Chapter, factors such as household types, socioeconomic context, and stakeholders such as community members, play a key role in household energy consumption. However, few eco-feedback technologies directly address the presence of multiple household members or stakeholders within a community or use social factors as features in their products. To explore the effectiveness of household comparisons and community engagement, we deployed the community-focused energy feedback application described in 5.4. We deployed the application to 15 households across two rental communities (one low-income and one mixed-income). Households in the same community could monitor each other's average daily consumption and share knowledge and information. Households could also view detailed information about their energy use and see information about strategies to reduce home energy use. We staggered our recruitment and deployment over a period of 4-10 months.

The study results we discuss next demonstrate: 1) how participants integrated our application into their existing routines and habits and how this led to a positive impact on sustainable behavior; 2) how households from one community identified and addressed energy-related issues discovered as a result of using the technology; and 3) how trust plays a key role in stakeholder communication and environmental behavior. We conclude with design implications for future social energy-related applications and show the importance of encouraging sustainable behaviors at a social, or collective level.

6.1 METHOD

The goal of our study was to study the use of an application that aimed to affect participants' intent and habits around energy use through feedback, social interaction, and frequent engagement in a longitudinal, real world deployment. We deployed our application across 15 households within two communities for 4-10 months. Prior to that, we had piloted the first two versions of our application for one to four months across five participant households to get design feedback and to work out kinks in the study design and technology. Our pilot deployment lasted from August until December 2011 and our official deployment began January 5, 2012. We continued recruiting participants during our pilot and main study.

Since our application relied on TED data and Internet access, we provided participants with installed TEDs, and free Internet and Wi-Fi access. We also provided households with Android tablets. We initially deployed 10" tablets to those households with no technology access and 7" tablets to those who had at least one home computer, and WiFi. Due to complaints regarding the small tablet size, we upgraded all households to 10" tablets and offered 7" tablets to multi-person households by the end of the study. We provided technical support for the system by phone and in person on an as-needed basis.

To recruit participants, we posted flyers around the building and asked management to email flyers (if applicable) or to slide them under each resident's door. We also used snowball sampling to allow participants to recruit among their friends. We offered referral payments as incentives.

6.1.1 DEPLOYMENT LOCATIONS

We deployed to two locations, both maintained and managed by the same company.

Location 1-Hamlet: Hamlet is a 60-tenant, mixed-income, 12-story renovated building. Some residents paid market value rent plus electricity bills, while others paid a reduced rate for their rent that included electricity. Except for gas-heated hot water, paid for by the building, this was an all-electric, individually metered building. It is a Leadership in Energy and Environmental Design (LEED) Green Building. We recruited six households from Hamlet. Two of these households paid for their own electricity.

Location 2-Main Street: Main Street has 23 all-electric, metered townhouse and apartment units on a neighborhood street. Most of these were newly constructed at the time of deployment, and all are rented to low-income households. We recruited nine households from Main Street.

Both sites shared the same type and brand of appliances (*e.g.*, refrigerator, dishwasher, and washer/dryer in most households). Key variations affecting energy consumption between households in the first location included which floors individuals lived on (*i.e.*, higher floors tend to be warmer) and, in the second location, whether or not the household was a 3-bedroom, three-story townhome or two-bedroom apartment. Participants' annual income ranged from less than $10k to over $70k with higher-income households residing in Hamlet.

6.1.1.1 Data Collection

We used collected multiple types of data measures -- application logs, monthly electricity bills, surveys, and interviews.

Environmental Concern. Each participant completed an initial and final survey providing measurements of environmental concern based on the New Environmental Paradigm (NEP). We analyzed these differences to measure changes in household levels of environmental concern.

Application and tablet usage. Logs, in addition to interviews, helped us to determine how often participant used various features of our application and what other applications participants used and installed.

Benefits of social engagement and comparison. We used surveys to gather initial data about their social ties with other community members. There were no significant differences between the two study communities with regard to the percentage of households known within the study (Hamlet, M=73.89, Main Street, M=73.21). However, the Main Street homes were less than a year old, and ties between households may not have been as strong as those in Hamlet. We asked participants in our interviews questions such as: How did households engage with and share the application and tablet; did households discuss any information with others in their household and/or neighbors.

Consumption Impact. We gathered monthly electric bills for participants. Due to the variability across sites and households, relatively small number of households involved in the study, temperature fluctuation and short study length, consumption data did not show any significant change. As shown in Figure 21, Main Street consumed significantly more than Hamlet because of occupancy and size differences (3-bedroom three-story homes and two-bedroom apartments). Main Street (M=1.8, SD=1.3) households also had statistically significantly higher number of "children and other temporary visitors" that stayed at their home ("in the past week") than Hamlet (M=0, SD=0)($F[1,11]=9.3$, $p=.01$). Main Street also had more adults living in the household but the results were not statistically significant. Overall, consumption varies with temperature with higher consumption corresponding to colder temperatures. Average monthly temperature during this time was 48.95°F. We provide a further analysis regarding consumption impact in the results section.

6.1.1.2 APPLICATION AND TABLET USAGE

We conducted bi-monthly interviews to understand how participants and their families and/or guests used the application, how households modified their consumption behaviors, and how they shared the tablets. We used saturateapp (http://www.saturateapp.com) to analyze our interview data. We coded and categorized each household's data and grouped the data into similar themes. We had a total of 90 codes and categorized all codes into 15 themes, or categories. Unfortunately, due to some participants' privacy concerns, we were not able to record and transcribe their interview data; however, the primary author captured detailed notes for each discussion, interaction, and notes about household dynamics during each interview.

6.1.2 PARTICIPANTS

We had a total of six households from Hamlet and 10 from Main Street; however, we removed one from the Main Street location due to problems with the TED and WiFi setups and our inability to meet with the participant to resolve the issues. As a result, we do not include his results in our analysis. We refer to participants by anonymous IDs and location (*e.g. H1* is *household 1* from *Hamlet*, and *M2 is household* 2 from *Main Street).*

A primary participant, or simply *participant*, represented each household. We will also present data about *households* as a whole and *other household members*. Where possible, we will provide IDs for participant quotes. However, because some comments deal with activities or opinions that might be frowned upon by landlords or other community members, we sometimes attribute a quote only to a "participant."

To encourage community building, household engagement, and increase knowledge, researchers posted messages to the message board an average of two times each week part-way through the main study (*e.g.,* tip of the week, questions about how residents save energy).

Researchers used the alias *CMBot* when posting to the message board. The first author also organized a casual pizza party event for both communities.

Table 9 – Household Profiles

Aliases are used for all household IDs. We denote our pilot participants with an (*). Top 3 indicates households with the least energy use for that site.

	ID	Working? (Y=yes, N=no)	Prior home Internet access?	Top 3?	Gender	Num. Ties in Study	Approx. Length in Study
1: Hamlet	**H1***	Yes	Yes	Yes	M	5	10 months
	H2*	No	Yes	Yes	M	3	8 months
	H3	No	No	Yes	M	4	6 months
	H4	Yes	Yes		F	3	4 months
	H5	Yes	No		F	3	6 months
	H6	No	Yes		F	5	6 months
2: Main Street	**M1**	Yes	Yes		F	7	9 months
	M2	No	No	Yes	F	4	6 months
	M3	No	No		F	5	7 months
	M4	No	No	Yes	F	4	6 months
	M5	Yes	No	Yes	F	3	5 months
	M6	No	No		F	6	6 months
	M7	No	No		F	6	6 months
	M8	No	No		F	6	5 months
	M9	Yes	Yes		F	NA	4 months

6.2 Field Study Results

We start our results section with participant demographics and an overview of tablet and application use. We then provide more details regarding consumption impact. We then discuss results on what happened with and around the tablet application and how it affected household *intentions* to change behaviors, *habits*, and finally, how it aided in or potentially prevented households from dealing with *external factors* affecting energy consumption.

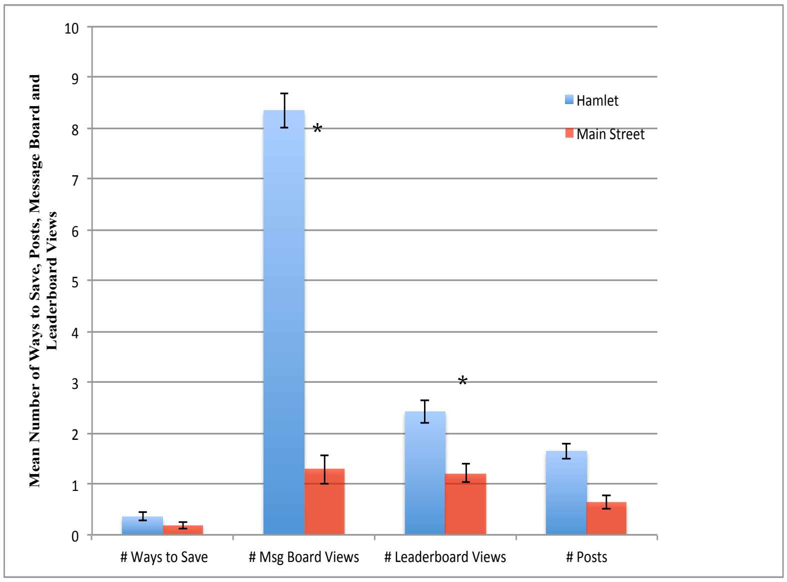


Figure 20 – Application feature interaction between Hamlet and Main

The participant mean age was 52 (SD=13.56). Almost half of the participants (7) were either retired or unable to work; 40 percent (6) worked full-time or part-time; and 13 percent (2) were looking for work. Those who were employed worked in a variety of fields including administration, human resources, environmental services, and property management. Main Street (M=3, SD=.87) households had significantly more members than Hamlet (M=1.3, SD=.52) (F[1,15]=17.73, p=.001).

All participants interacted with the tablet in some way. Hamlet participants used the application more than our Main Street participants and Main Street participants used the Internet tablets more. Hamlet participants were higher users of all Community Monitor application features. The number of community message and leaderboard views were significantly higher than Main Street's on an ANOVA (F[1,15]=7.59, p=.02 and F[1,15]=5.14, p=.04 respectively).

Households from both locations frequently viewed the leaderboard and message board but posted very few messages, and made infrequent use of the "Ways to Save" feature (see Figure 20). Though Main Street households did not use the application as much as Hamlet households, several Main Street participants and some Hamlet participants used the polar-bear display to track their consumption. In interviews, some participants empathized with the bears. For example, M6 said, "*It's been tough on the polar bears since I got the heater…but I got to, it's cold.*"

More than half (8/15) of the households kept the tablet in a common area (*i.e.,* the kitchen, the "main room" or the living area, and dining room), in part, so others could share. The single person households (4) kept their tablets in their bedrooms, on the kitchen table, or near the television in the main room. Households also used their tablets to surf the Internet (15/15), to play games (14/15), to check email (8/15), to search for jobs (3/15), and to read the Bible (4/15). With the exception of three Hamlet households that had access to devices such as iPads, smartphones, and home laptops, all participants used their tablets on a daily basis.

In the next section, we provide further details about consumption and later provide results on how household interaction with our application affected household *intentions* to change behaviors, which we discuss next, *habits*, and finally, how external factors affected household behavior and the level of application interaction.

6.2.1 CONSUMPTION IMPACT

We sought statistical expertise from the CMU department of statistics. We hired Zach Kurtz, a CMU Ph.D. student in the statistics department, to assist us with our time series analyses, which we summarize in this section.

Though our focus was not behavior change, we did evaluate the change in participant consumption over time. We deployed the following energy-consuming devices as a part of our study: the Energy Detective, an Archos Internet tablet, and a Netgear Router. As a result, we estimated the total consumption of these devices over the course of our study (~1.56kWh per month see Table 10) to confirm that the use of these devices was insignificant to total household consumption. Given that the mean monthly consumption of Hamlet was 454 kWh (.003%) and Main Street 1206 kWh (.001%), these effects were insignificant. We do not account for the servers used to host this study or provide Internet as these servers were not dedicated specifically to our participants.

As we mentioned earlier, due to site and household variability, the small number of households, and the short study length, there was no significant change in our consumption data. Because we saw an increase in consumption at our Main Street site, we analyzed the data further for possible explanations as to why this site was higher. Since we did not follow a randomized assignment of our intervention, we could not establish causal effects and therefore looked for association. We conducted a time series analysis to explore this result in more depth.

We conducted a time series analysis of monthly consumption (based on participant utility bills) because it was the best approach for evaluating the effect of our intervention over time. Since

Table 10 - Deployment impact on consumption

Device	Calculation	Consumption (kWh per month)
The Energy Detective (TED)	1 watt x 24 hours = 24 watt-hours per day * 30 = 720 watt-hours per month	.72
Netgear G54 Wireless Router (does not include some of the Main Street participants that needed modems from Internet providers)	1 watt x 24 = 24 watt-hours per day * 30 = 720 watt-hours per month	.72
Archos 10" Tablets	8 watts x 1 hour (charge time) = 8 watt hours X 15 days (assumes 1 charge every other day for 1 month) = 120 watt-hours per half-year	.12 k
Total	.720 + .720 + .12	**1.56**

the length of our study was fairly short in terms of analyzing for consumption, a traditional parametric time series approach was not the most appropriate. We instead chose the Generalized Additive Model (GAM) that includes a smoothing spline for time (*i.e.,* this removed the effect of time everywhere). It does this by locally shifting the monthly average kWh towards zero. The advantage of the GAM approach is that it removes the effect of time and looks at how variables are associated with kWh after assuming that time is no longer a factor. The GAM approach is particularly important in a short study, as it does not require a full period of data (*i.e.,* one year assuming weather is not a factor). A parametric time series approach would have been suitable for longer historical records of real-world data.

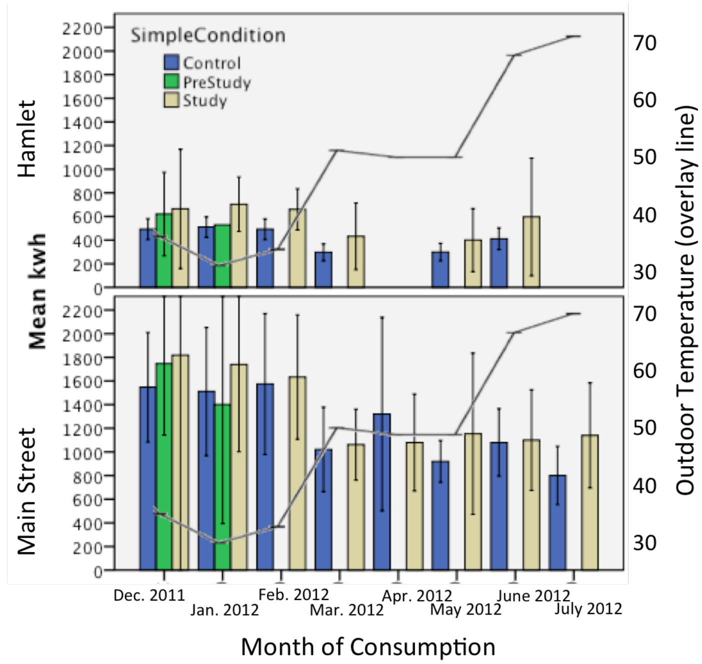


Figure 21 - Comparison of kWh consumed at Hamlet and Main Street.

Leftmost (blue) lines are control households; middle (green) lines represent households in the study without a display deployed, rightmost (light tan) lines represent households in the study with the display. Because of the pilot and staggered deployment there is some overlap between "PreStudy" households and "Study" households. Starting in February 2012, all households were either in the Control or Study condition. Black overlay shows the outdoor temperature, which also affected consumption.

Our final analysis consisted of three additive models: the impact of our intervention, the impact of location and payment type, and the impact of our intervention features and time spent at home on consumption (as measured by kWhs). Each of these models included a smooth term for time (*i.e.*, "seasonal effects", or effects related to time, such as weather were removed). Before narrowing down to three models, we started out with a larger model with many variables and gradually removed statistically insignificant variables until we were left with significant variables. Models were checked for heteroskedasticity to ensure a constant variance in the variance, normality and independence of residuals. We controlled for variables likely to affect energy consumption based on prior research and our prior work (*i.e.*, household size, number of household members, length of time at home, working status, whether or not they pay for electricity). We selected predictor variables based on the use of our application features (*i.e.,* number of ways to save items, number of message board posts and views, and the number of leaderboard views).

6.2.1.1 Model 1: Impact of Intervention

Our first goal was to evaluate the impact of our intervention on our study participants. The results of our first model show these results. We considered two levels in our first model: our study participants (studyStatus1) and those participants with our intervention (studyStatus2). Our results suggest that our participants were higher-energy consumers than non-participants overall. Though not significant, the coefficient of studyStatus2 suggests that our intervention was associated with a very small increase in electricity consumption.

To find out if our intervention was effective, we selected consumption (kWh) as our predictor variable and controlled for those in our treatment group (studyStatus1) and whether they have our intervention (studyStatus2). Further, our model includes a unique id. This id automatically accounts for information such as participant payment model (pay for electricity or not) and their location and is therefore very accurate. The model explains nearly 80% of the variation in kilowatt-hours according to the R-squared value (p<.001).

These results offer baseline information about participants who chose to join our study and suggest that our intervention was not associated with a significant reduction in energy. To understand the association between specific variables not accounted for in this model, we chose to analyze our data with two additional models, which we discuss next.

Parametric coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.130657	0.012454	492.249	<2e-16***
studyStatus1	0.793172	0.091245	8.693	<2e-16***
studyStatus2	0.033071	0.049863	0.663	0.507393

R-sq.(adj) = 0.798

6.2.1.2 Model 2: Impact of Location and Payment Type (pay vs. not)

Our next goal was to identify the association between specific variables (*i.e.,* location and payment type) and energy consumption; our second model sheds insight on this information. We considered three levels in our first model: a control group of non-participants, a pre-study group that included our study participants before receiving our intervention, and the final study group. Our main finding was that households that pay for energy (N=2, Hamlet) use more energy.

We controlled for household location and whether a household paid for electricity. The model also accounted for whether a household was in the pre-study or study group, and currently using the tablet and application (*i.e.*, had the intervention). According to the R-squared value, this model explains about 55% of the variation in kilowatt-hours ($p<.001$).

This result is surprising, however, paying for electricity may be connected to variables we did not track: Households that paid for their electricity and paid market rent rates, lived on the top three floors of the building. These apartments were slightly larger than the other apartments. Income and apartment size were not included in our model.

Parametric coefficients:

	Estimate	Std. Error	t - value	Pr(>|t|)	
(Intercept)	5.93207	0.02166	273.904	< 2e-16	***
locMain Street	0.98660	0.04049	24.369	< 2e-16	***
payyes	0.42044	0.10160	4.138	3.9e-05	***
studyStatus1	0.10255	0.05297	1.936	0.0533	.
studyStatus2	0.09138	0.07508	1.217	0.2239	
payyes:studyStatus2	0.09473	0.17935	0.528	0.5975	

R-sq.(adj) = 0.547

6.2.1.3 Model 3: Impact of Intervention Features and time Spent at Home

Our final goal was to explore the affect of variables *within* our intervention group such as specific application features and household variables (*i.e.,* posts to the message board, leaderboard views, household population, time spent at home, *etc.*) on energy consumption. The results of this analysis provided us with an understanding of how household variables and specific application features associated with overall consumption. These results suggest which application features worked as expected and should be used in future technologies, or deserve further investigation. The leaderboard feature shows positive results and the model suggests how time spent at home affected consumption; not surprisingly, our results confirm prior research that shows the number of household members has a statistically significant positive effect on energy consumption. Our results also suggest that retirees have a statistically significant positive effect on consumption.

Within our intervention group, our control variables included the number of household members (popHousehold), whether participants worked (workingYes), if participants were retired (retiredYes) and how much time they spent at home on average (hometimeSome, hometimeVery little). Our initial model explained about 80% of the variance in kilowatt-hours ($p<.001$). After fitting the model separately for both locations, the model for Hamlet explained about 56% of the variance in kWhs and for Main Street about 82% (both $p<.001$). The statistical significance of the results from this model may be overstated and the p-values small as residuals may be auto-correlated for each household; however, we use these results to provide direction on the potential effectiveness of our application feature.

Results showed an association between the number of leaderboard views and decreased consumption for both locations. In other words, a decrease in consumption was associated with the number of times households looked at the leaderboard. This was statistically significant for both locations. For Hamlet, a consumption decrease was statistically significantly associated with whether or not household members were home very little, and home some of the time. For Main Street, being home some of the time had a statistically significant effect on consumption increase. This could be attributed to poor behaviors such as leaving electronics on, or having guests stay over while being away.

Finally, for both locations, one of the greatest factors associated with consumption increase was if the household was a retired household. We speculate that Main Street retirees kept their grandkids throughout the day, which may have increased consumption given the introduction of new resources, such as a tablet and Internet access. Observations made during our interviews support our speculation. Having access to the tablet and Internet may have also affected retirees directly – perhaps they stayed home more to use their tablets (*i.e.,* games, email, *etc.)*. Our results showed that the number of household members had a highly statistically significant positive effect on consumption for both locations, which makes sense.

Parametric coefficients:

	Estimate	Std.Error	tvalue	Pr(>|t|)
(Intercept)	5.6753012	0.1915985	29.621	<2e-16***
treat.time	0.0027627	0.0008573	3.223	0.001930**
Leaderboard.Views	-0.0054869	0.0014441	-3.800	0.000306***
popHousehold	0.3769113	0.0475482	7.927	2.5e-11***
workingYes	-0.1115182	0.1266888	-0.880	0.381736
retiredOther	0.3075119	0.1191693	2.580	0.011968*
retiredYes	0.2272590	0.1102959	2.060	0.043077*

hometimeSome	-0.2451109	0.0910456	-2.692	0.008876**
hometimeVerylittle	-0.3758712	0.1753326	-2.144	0.035531*

R-sq.(adj) = 0.778

We fit the model separately for the two locations. For Hamlet we get

Parametric coefficients:

	Estimate	Std.Error	tvalue	Pr(>|t|))	
(Intercept)	3.527728	0.151178	23.335	<2e-16	***
treat.time	0.002990	0.001410	2.120	0.0449	*
Leaderboard.Views	-0.004786	0.002177	-2.199	0.0381	*
popHousehold	1.146105	0.074661	15.351	1.27e-13	***
workingYes	0.451397	0.082197	5.492	1.36e-05	***
retiredOther	1.416091	0.110707	12.791	5.61e-12	***
retiredYes	1.660240	0.162272	10.231	4.65e-10	***
hometimeSome	-1.587749	0.137018	-11.588	4.10e-11	***
hometimeVerylittle	0.451397	0.082197	5.492	1.36e-05	***

R-sq.(adj) = 0.588

For Main Street we get

Parametric coefficients:

	Estimate	Std.Error	tvalue	Pr(>|t|)	
(Intercept)	-6.821728	2.864427	-2.382	0.022135	*
treat.time	-0.019390	0.005256	-3.689	0.000676	***
Leaderboard.Views	-0.005891	0.003158	-1.865	0.069576	.
popHousehold	3.894605	0.812682	4.792	2.33e-05	***
workingYes	2.621475	0.628814	4.169	0.000161	***
retiredOther	-0.544533	0.253276	-2.150	0.037717	*
retiredYes	7.339327	1.603191	4.578	4.57e-05	***
hometimeSome	7.352098	1.730542	4.248	0.000127	***

R-sq.(adj) = 0.817

6.2.1.4 SUMMARY

To summarize our findings, at a high level, our results were not positive. Our models suggested that electricity-paying participants consumed more energy, that the number of leaderboard views were associated with decreased consumption, and factors such as household population, time spent at home, and retiree status are all associated with a statistically significant increase in consumption. We face several complexities in our analysis (*i.e.*, short length of our study, limited control variables); however, we want to conclude with suggestions for future research. Based on our results, we suggest that future studies conduct a randomized sample to help to control for certain variables (*i.e.*, population household, working, pay/no pay) and conduct a longer time period (at least two years).

6.2.2 Intentions to Change Behavior

As mentioned in Chapter 2.2.1, regarding behavioral intentions behavior change, the important factors that drive intentions include *attitudes*, *perceived behavioral control*, and *social factors*. This section describes how our participants' interaction with the application led to intentions to modify behavior *via* these three factors.

6.2.2.1 Examples of reported behavior change

Ten participants responded in a very direct way to suggestions in the Ways to Save list; they reported actions such as avoiding oven use (to heat the home); turning off unused appliances; and using power strips as turn off points. Participants from both locations viewed real time energy use information as a source of ideas for behavior change. When they saw a low number of polar bears (high energy use) during activities such as cooking, washing or drying clothes, they reported reacting with changes. For example, *H4* posted the following message to the message board: *"So I put some clothes in the dryer then checked the real-time usage on the dashboard. The increase made me immediately pull them out and hang them up!" M4* reported that her son knows about the Community Monitor. She said that, *"it helps remind him of being wasteful in terms of electricity; he'd turn my TV off if I fell asleep with the TV on…he'd literally go around the house with the tablet to turn things off."* The immediacy of real-time feedback, combined with the portability of our system (which supports exploration), makes this possible.

6.2.2.2 Examples of attitudes and behaviors that did not shift

Participants viewed some changes as a sacrifice and did not shift their behaviors. For example, some Main Street participants had no choice but to consume energy with the winter cold and thermostat restrictions (which we discuss later).

For some of these participants, comfort came before sustainable behavior; like findings reported in (Pierce, Schiano, and Paulos, 2010) participants' attitudes regarding comfort were "inflexible," and they were unwilling to change their behaviors. According to one Main Street participant, *"I'm not going to wear a coat in my own home to stay warm."* A Hamlet resident stated, *"I'm not going to turn it [thermostat] up to save a couple pennies not to be comfortable. I want to be comfortable. If I'm hungry for steak, I'm not going to buy a hamburger (just because it's cheaper).* This was not an energy-paying participant, but money was still a prominent part of the discussion. Others found it too difficult to change their behavior but presented a more concerned, less defensive view of their actions. In the words of a Main Street participant, *It's been [tough] on the polar bears since I got the heater....but I got to, it's cold.* The participant's perceived control over her behavior influences her actions. She doubts her ability to change due to external factors; however, other options, such as grabbing extra blankets, moving upstairs to stay warm, and/or raising the issue to the landlord were available.

As mentioned earlier, we used the NEP scale (Dunlap and Van Liere, 1978) to measure environmental concern. Overall, all scales had a reliability of .75 or higher measured using Cronbach's α (values were α=.75 for limits to growth, α=.83 for balance of nature, and α=.92 for people over nature). The survey initial survey showed balance between locations and no statistical significant differences (Hamlet, M=3.68, SD=.67 and Main Street, M=3.20, SD=.63), though Hamlet showed a higher level of environmental concern. At the end of the study, all scales had a reliability of .90 or higher measured using Cronbach's α (values were α=.91 for limits to growth, α=.93 for balance of nature, and α=.90 for people over nature). Though there were no statistical significant differences between locations or between the initial and final measures of each location, there was a slight increase in the level of environmental concern at Hamlet (M=3.82, SD=.87) and a slight decrease in the level of environmental concern at Main Street (M=3.12, SD=.64).

6.2.2.3 Social Comparison

Households living in close proximity (*i.e.*, households sharing the same apartment floor and adjacent neighbors) often reported comparing their consumption, ranking, and sustainable behaviors. After a Hamlet participant, for example, noticed that she was ranked much lower than her neighbor, she reportedly *"talked to [neighbor's name] a lot and they gave me an idea of running the fan more instead of running the air more so I tried that."* These social comparisons often led to knowledge transfer and may have helped to establish new norms.

Participants in our study also began to hold other households accountable to certain behaviors, and this influenced their attitudes about performing certain behaviors. We can characterize these activities in terms of social roles. Two that were prominent in our data were the *investigator* and *neighborhood watch* roles.

The Investigator: Several participants knew information about their neighbors such as when they were home and the set temperatures of their thermostats. Households took on an investigative role to understand household rankings, and this often led to concern for others.

Knowing information about others in the study allowed participants to evaluate what they needed to do to "keep up" with their neighbors. In some cases, households deduced detailed information about other participants. For example, one Hamlet participant determined that neighbors consuming less energy had to have set their thermostat to a lower temperature [in the winter] than she did: "*I know that [my neighbor] keeps his [thermostat] around 71 and [another neighbor] is below him [on the leaderboard] so I know the people who sit around in 68 degrees or lower!*" She was not willing to turn her thermostat below 68, but she understood what needed to be done to maintain the place she felt she belonged on the leaderboard.

Neighborhood Watch: Households not only reasoned about what other households were doing, they actively tried to help other households catch problems as they arose. There was at least one example from each location where households looked after one another, showed concern for their neighbors, and held each other accountable for excess consumption.

For example, *H6* noticed that the data about another household in her community was anomalous due to a hardware issue. During an interview, she asked what was going on with the household – she felt the daily average to be impossible for the building. Verifying the system also forced participants to "critically reflect" about household energy consumption, a strategy suggested in (Pierce, Odom, and Blevis, 2008). This type of understanding and concern created a sort of neighborhood watch.

At a researcher-sponsored community event, two households mentioned that *H2* was ranked much lower than normal. In a discussion about community averages, the two households (*H3* and *H6*) brought this to *H2's* attention. The *H2* household was somewhat surprised and explained that they had already put in a work order for a broken AC unit. The *H2* household asked the first author to speak to the landlord because the issue was *"messing up [their] stats"*.

One Main Street participant mentioned that, though home much more, she was ranked higher than a neighbor who had been away all summer: *"If she has air on when she's not home, I'm going to kick her [expletive] – she should be number one. How am I before her and she's never there?"* These two residents had shared information after receiving the application, and this participant said that she planned to speak to her neighbor about the issue.

These participants were behaving in a manner similar to individuals in a community watch program. Neighborhood watch programs consist of citizens that work as a unit, or group to prevent crime. This example shows households working as a unit to discuss potential inefficiencies, and as a result, saving energy.

6.2.2.4 Social Engagement

The previous section discussed how participants engaged in social comparisons. Our qualitative survey results also support an increased amount of social engagement at both locations and a statistically significant increase in social engagement at the end of the study for Main Street. We created our own measure of social engagement based on three factors: 1) how much our participants *discussed* monthly bills, 2) how much participants *shared* methods of saving electricity, and 3) how much participants *know* about the amount their friends, family and neighbors pay for their electricity bills. Overall, our initial scales had a reliability of .86 or higher measured using Cronbach's α (values were α=.97 for discuss bills, α=.95 for share methods of saving electricity, and α=.86 for knowing how much others pay for electricity). The initial survey showed balance between locations and no statistical significant differences (Hamlet, M=2.17, SD=.72 and Main Street, M=2.54, SD=1.06), though Hamlet showed a higher level for engaging with friends, family and neighbors. At the end of the study, all scales had a reliability of .90. Though there were no statistical significant differences between locations at the beginning or end of the study, there was a statistically significant increase at Main Street (M=3.80, SD=1.05) from the beginning to the end of the study ($F[1,14]$=, $p<.05$).

6.2.2.5 Routines and Habits

Breaking habits is not an easy task; however, households did report doing so. Participants also integrated the use of the tablet into their daily routines, which served as a constant reminder of their consumption.

According to *M8*, *"I used to fall asleep with my light on but now I turn my light off when I go to bed,"* and another participant stated, *"I stopped using the oven to heat."* Three households reported checking the Community Monitor's leaderboard as a part of their daily routine. For example, *H3* says he checks his tablet every morning to see *"who's in first place."* He does this along with his morning devotional period, *"I [eat] my daily bread, and then I pray, and then I read the Bible…It* *takes about 45 minutes."* Similarly, *H6* says, *"I wake up and grab the tablet, I check the Community Monitor first to see if anyone responds [to prior posts] and then I read the Bible."* She sees where people are in terms of their energy consumption. *M8* stated that she uses the application every time she uses the tablet to compare herself with her neighbor and ensures that she is not over consuming. As a result of viewing this information daily, participants could better manage their consumption. Instead of creating a new routine, or habit for a specific sustainable action, integrating the application into participants' daily routines gave participants opportunities to identify high level issues, better manage their electricity, and proactively watch their neighbors' consumption.

6.2.3 External Factors

Part of the goal of our application was to provide a deeper understanding of complex energy-related issues. These complex issues often appear as external factors, such as institutional constraints. As expected, external factors affected household behavior and also the level of interaction with our application. We have already mentioned the impact of the relative coolness at Main Street (due to infrastructural issues) on various decisions that participants made. Below we provide more details on this issue and how distrust among and between residents and other stakeholders, and community displacement affected engagement with our application.

6.2.3.1 Physical Constraints

Due to building restrictions related to overconsumption, Main Street participants were unable to raise their thermostats above 71 degrees Fahrenheit. At least three residents stated that even when their apartment reached the maximum temperature, they could still feel cool air coming from the system. Participants blamed the geothermal heating system and some of those reporting discomfort in the winter admitted using the oven to heat households. Tenants who wanted a temperature increase from 71 to 74 had to sign a lease addendum and agree to not use electric heaters. After signing the agreement, some residents continued to use their oven for additional warmth.

When researchers posted the question on the message board, *"How do you stay warm in the winter,"* a Main Street participant responded, *"I have to dress in layers like a bag woman in order to keep warm in a brand new house my heat doesn't go over 71."* None of the other households from Main Street responded to the message board, but at least two participants stated in an interview that they had moved upstairs to avoid the cold. One of these households had placed clothes around the bottom of the door to prevent cool air from coming in; the other stated that her small rug helped to reduce the cool air.

6.2.3.2 DISTRUST OF LANDLORDS

Our results show limited participation with the community message board. In both locations, participants saw what was being posted but chose not to respond because of issues of privacy and trust. One participant said, *"[A participant] could take this…and show him [building owner]."* In another case, *w*e suspect that one participant was troubled about a message posted about him because of underlying implications that he was consuming energy late at night. Because the system was not designed to provide households with real-time consumption data about other households, the participant was upset and felt his privacy had been violated. Though the two households resolved the issue, this ultimately led to limited use of the message board by at least one of our participants.

Not only did concerns of privacy and distrust prevent participants from engaging with each other online, but it also prevented Main Street participants from online discussions about thermostat constraints. Eight of the nine participants were upset about not having full control of their thermostats. Since participants did not know all participating households, many chose not to discuss certain issues using the application. Overall, half of our Hamlet participants discussed building-related energy issues in interviews, but not online. However, one household had negotiated an energy-related solution with the landlord prior to our study.

6.2.3.3 COMMUNITY DISPLACEMENT

The Main Street community was a fairly new community. Five of the nine Main Street households were from a nearby-displaced neighborhood, which may explain a lack of community cohesion. For example, many households from Main Street referred to each other as *"us"* and *"them"* and to an extent, held themselves to different standards. Because households did not know all Community Monitor participants, we believe that the internal separation may have affected the use of the application social features.

In a sense, these real-world, external factors represent the real world in all its disarray. Because of the variety of external factors that can arise, an open question is how best to deal with them in application design.

6.3 DISCUSSION

We explained the results of a 4-10 month field deployment with our Community Monitor application across 15 households across two rental communities. We showed how interaction with our application influenced household intentions to change behaviors, habits, and how external factors affected how households interaction with our application. We showed how the application social factors such as social comparison led to households taking on certain social roles, which affected norms within the community. We also showed how householders modified certain habits and began to use the tablet and application on a routine basis. We discussed the impact our application had on how participants' dealt with *external factors*, such as thermostat restrictions, landlord distrust, and community displacement. Individual factors such as perceived behavioral control and social factors such as subjective norms and external factors played a key role in whether or not households and communities acted on certain sustainable behavior. Though there were mixed results in terms of the impact to energy consumption, we were able to contribute results, evaluate our design guidelines and provide additional design implications for those wishing to develop future social energy applications and those seeking to understand how these types of applications may function in real-world settings. Next, we discuss our findings, some limitations of these findings, design evaluation and implications.

Our findings were consistent with past work (*e.g.,* (Fischer, 2008)) in that real-time feedback and information influence attitudes to perform energy conservative behaviors. Social factors, such as comparison, affected attitudes. Comparison in our study did not encourage competition, as it did in prior studies (Vande Moere, Tomitsch, Hoinskis, *et al.*, 2011). Instead, social comparisons conveyed new norms and knowledge transfer, and as a result, influenced attitudes. We found benefits in our mobile tablet deployment as householders shared the device with each other, and some participants used the tablet on a routine basis. This routine use allowed participants to indirectly monitor their consumption due to the presence of the polar bear display.

Though our deployment was limited to renters, many in low-income environments, we expect most of our findings to generalize to renters and homeowners across socio-economic statuses. However, based on our results, factors such as trust, community cohesion, presence of landlords, access to technology, and community cohesion vary based on specific community characteristics.

For example, Hamlet residents interacted significantly more with the message and leaderboard. As we mentioned earlier, the participants at this site may have had tighter social bonds in comparison to Main Street. Hamlet participants had a significantly lower number of household members; without opportunities for community members to get acquainted, it becomes less likely for them to build trusting relationships (Berger and Calabrese, 1975). The precise reasons for increased interaction are unclear, but it would be reasonable to speculate that loneliness, or even boredom could contribute to increased interaction with Hamlet participants.

Thus, very trusting communities, home owners, and internet users may not have reacted in the same way to our intervention. Income is also likely to indirectly affect generalization for example because of its impact on technology access. In the rest of this section, we provide design implications for future community-focused home energy technologies. Specifically, we discuss how applications should leverage social factors to encourage householder engagement and community trust, and the need to support privacy, social roles, and effective comparisons.

6.4 Evaluation of Design Guidelines

Overall, our design guidelines proved to be beneficial. As we discussed above knowing more information about the types of communities being targeted (*i.e.,* are they tightly knit, supportive, *etc.*), is important if this information is available. In the next section, we review each of the five guidelines that we followed and evaluate the effectiveness of each guideline based on our application results. We provide new design implications in section 6.5.

6.4.1 Make Energy Visible and provide support to identify energy-related issues

The use of the polar bear display and the leaderboard feature both made energy visible to households. Our results showed that the Main Street participants used the polar bear display more than the Hamlet participants but this could have been as a result of Main Street participants using the tablet applications more and the Community Monitor application less than Hamlet participants. Participants did notice the polar bears and some participants showed empathy with the polar bears. This visualization showed positive results; however, other visualizations such as those used in ambient displays may also be beneficial. We chose polar bears because we felt this would allow households to better understanding the relationship between their actions and the environment (Kim, Honog and Magerko, 2010). Perhaps other visual displays could convey this information better. Our results also showed an association with the use of our leaderboard feature and a slight decrease (though not significant) in consumption at both locations. Though we did not notice a 5-15% decrease in consumption as reported in prior studies of real-time feedback, our results show benefits of having this information available. The leaderboard feature did provide support for participants to identify energy-related issues. As we discussed, some of our Hamlet participants identified problems with the AC because they had this information available. We found the leaderboard feature to be a successful way to adhere to this guideline. Other techniques, such as SMS alerts, or showing comparisons against historical data may also be beneficial.

6.4.2 Provide Support for Multiple Stakeholders or The Collective

The message board feature was designed to provide support for multiple stakeholders. We did not have much success in supporting this guideline because participants did not report key energy-related issues they encountered using the tool. This was primarily due to issues of privacy and trust. Further, since our application was not designed as a landlord tool, any issues identified would have needed to be been taken up with the landlord directly. Though the message board served as a means to support multiple stakeholders, perhaps other techniques could be used to be more effective. We provide design implications in section 6.5 to address ways to avoid this shortcoming in future applications.

6.4.3 Provide support for households that wish to share tips with other household members

Our design allowed participants to share tips with others *via* the Ways to Save page and also *via* the message board. Participants shared which actions they currently take to save electricity; however, very few provided this information to the message board. Our results show that participants did share information with other households outside of the application. So, in a way, our application supported this guideline. Our application supported the guideline primarily as a result of the application leaderboard feature. Additional techniques that we could have used to adhere to this guideline include encouraging households to share tips with other household members even if outside of the household. Our application could also acknowledge, or support households that seek information from others and also provide information to others within the application. This could be done with a simple “Thanks for the tip” badge that one household could give to another.

6.4.4 Designs should be Inclusive

Our goal was to design an application that was inclusive to all. For example, we did not want participants to refer to our application as a "green" application as we saw in our concept validation results. Participants did not mention this as a concern in interviews or open-ended surveys. In fact, no one referred to the application as a "green" application, or to himself or herself as "green" for participating in the study. Several of our participants had not used the Internet before; however, all participants knew what the Internet was and viewed it as a useful resource. Many participants knew about computers and viewed the tablets as small computers. Selecting the tablet as a platform for our application was beneficial as it was not unfamiliar to participants and it allowed householders, both internal and external, to show each other how to access certain information and resources. Overall, our tablet application was effective in achieving inclusivity.

6.4.5 Privacy: All responses to requests for sensitive, or identifiable information to be optional

Designing for privacy is a very complex task. Though we asked households for aliases, we did not require any identifiable information from participants. Some participants chose non-identifiable aliases, while others chose their real names. One participant even selected her apartment number as her alias. As we saw in the results, participants posted very few messages on the message board. We see factors such as distrust of landlords and other community members as one reason for the limited usage. We also saw how one participant misunderstood another participant's post to the message board as being a potential violation of privacy. Our suggestion to allow participations to optionally provide identifiable information holds true, however, we present an additional design implication for privacy in section 6.5.

6.4.6 Summary

In summary, we had some success in following our original guidelines. Specifically, our polar bear display and leaderboard feature helped to make energy visible and provided a way to identify energy-related issues. We also supported households in sharing tips with other household members though we need should actively acknowledge those sharing tips outside of the application. We also had an inclusive design. Our shortcoming in providing support for multiple stakeholders was related to privacy and also as a result of not extending the application to landlords. We expand upon our privacy guidelines and on conditions for supporting multiple stakeholders by providing design implications in the next section.

6.5 DESIGN IMPLICATIONS

The previous section discussed the details and results of the Community Monitor deployment across 15 households within two communities for 4-10 months. We explained how interacting with the application influenced participants' intentions to change behaviors and routines. We also discussed how external factors prevented participants from interacting with certain Community Monitor features. In this section, we highlight the strengths and shortcomings of our Community Monitor deployment to provide design implications for future social energy applications. We discuss these implications next.

Social applications should encourage community building in and outside of the application to build community trust. Our pizza event allowed households to share energy-related questions as they socialized with one another. When community members know more about each other, they can reduce the uncertainty about members' behaviors and intentions, which is necessary for developing norms of reciprocity and trust (Berger and Calabrese, 1975). Community building techniques and design ideas include hosting family-oriented activities to strengthen social ties and to bridge social capital across households; a simple system reminder could nudge households to hold regular events.

Social applications should support a framework for the discussion of building-wide issues safely and privately. Though we encouraged participants to use pseudonyms for the application, distrust of landlords and community members persisted. This affected what participants would talk about and limited social interactions with our message board. We designed and posted messages to the message board to support knowledge transfer, community related discussions, and community gatherings. Our goal was to make coordination and communication easier between community members and increase support for energy or non-energy related issues. Design ideas to support safe and private discussions include 1) creating a private space for anonymous issues to be discussed and shared with landlords at an agreed upon frequency (*e.g.,* monthly); 2) incorporating a method to build networks between like households (i.e., similar structure, proximity, *etc.*); and 3) making households aware of other ways to address their issues such as discussing with other community members, or sending their issues to an anonymous space.

Social applications with access to real-time data must protect household privacy. One participant took offense to a message posted about him because of underlying implications that he was consuming energy late at night, and felt his privacy had been violated. Though community members were only able to see each other's daily average consumption, they were able to guess which households were away at work, or home all day. Our goal was to provide enough information to identify issues but not enough information to violate privacy. Though individual rankings supported other goals such as community building and investigation, they were problematic from a privacy perspective. Future applications should consider abstracting individual household data to a community energy score, or abstract representation (*i.e.*, ambient display, use of polar bear theme, *etc.*) of the overall health of the community.

Future applications should support the social roles that households take on. Participants at both locations took on investigative and community watch roles, which may have influenced other households to change. Roles portray how people in certain positions are expected to behave (Forsyth, 2010), and these roles come with normative beliefs (perceived social pressures to engage or not to engage in a behavior). In a way, this holds participants accountable to certain behaviors and can strongly influence attitudes. In one example, taking on the role of community watch may have influenced how our participants dealt with external factors, such as broken ACs. Applications can infer and report potential issues to the community to enable members to take on roles (e.g., detective, investigative) to identify problems. To encourage and support these social roles, applications could acknowledge households that do so with badges, or community posts as incentives.

7 Conclusions & Future Work

This thesis shows that factors such as socioeconomic issues, household types, and stakeholder interactions, play an important but largely hidden role in home-energy consumption. Most studies have targeted single-family, affluent households, and as a result, energy-monitoring systems do not address the needs of renters and low-income individuals. Thirty percent of the U.S. population rent their homes (Current Housing Reports, 2009), and 30% of households earn less than $30k per year (U.S. Census, 2009). Though median-energy use for home heating and cooling is the same as that in more affluent households, low-income households must spend a greater percentage of their income on energy (Shui, 2002).

Despite the common belief that low-income households are not motivated to conserve electricity because economic hardships may force these households to make tradeoffs between necessities such as heat and electricity (Williams *et al.*, 2008), we hypothesized in section 1.1.1 that lower-income households do not have dissimilar motivations for energy conservation than higher-income individuals and households. The results of our first study supported our hypothesis that lower-income households do not have dissimilar motivations for energy conservation than higher-income households, including those identified as "green." In fact, low-income households from our study were, indeed, also concerned about future generations, interested in saving energy as a result of energy-saving habits and motivated to conserve as a result of their religious or spiritual beliefs.

In examining our hypothesis, we contributed an exploratory/qualitative study of low-income households that:

- extended prior research in predominately middle-class and affluent households;

- showed constraints that exist around energy consumption in low-income households;
- revealed and broadened the scope of behavior theories relevant to energy consumption in low-income households;
- provided design implications around basic assumptions: responsibility for bills, home ownership, and reconsideration of the relationships between household members when designing energy-saving technologies.

A large majority of participants from our first study were renters who lack full autonomy over energy use in their homes due to tenancy, class, and poverty issues. Lack of autonomy likely adds to the burdens renters often face, especially when structural issues that may impact energy arise. In these cases, renters must negotiate with landlords. While payment responsibility may be one contributor to failed negotiations, we hypothesized that it was not the sole reason for energy-related conflicts. For example, some renters who did not have to pay for their electricity were nonetheless conscious of energy-saving behavior. We also found that a key contributor to conflicts between renters and landlords is distrust and a lack of communication. Some renters, for example, were reluctant to communicate energy-related issues to landlords for fear they would be seen as troublemakers.

We found from these studies that real-world, disparate constraints such as rental contracts, safety concerns, and unsupportive household or community members also affect participants' control over their energy use. In addition, conflicts between landlords and tenants over energy use are driven by the imbalance of power between them. Power is derived from information, and we showed how new information and better communication of that information were two of the most salient forces driving conflict resolution. In examining our hypothesis, we also contributed an exploratory/qualitative study of landlords and tenants that:

- explores *how* landlord/tenant relationships impact energy consumption behaviors;
- provides an analysis that demonstrates the importance of understanding the ways in which power differences influence how energy is used (and wasted) in renter households;
- presents a set of design recommendations that identify new challenges for sensing

Finally, as a component of this dissertation work, we argued that sensing technology and social computing could play a role in conflict resolution because of their potential for collecting and providing information. Due to a lack of communication between stakeholders such as landlords and tenants, energy-related issues may go unresolved. We hypothesized that a social application that allows individuals to compare their consumption with others and to actively engage around actions that affect energy consumption can encourage social interaction, raise awareness of energy conservation behaviors, help residents to identify and address energy-related issues, and reduce energy consumption. To examine our hypothesis, we explored the effectiveness of household comparisons and community engagement in a concept-validation study that used speed dating and identified a set of guidelines for social applications based on our related work, prior studies, and our concept validation results. Our findings were supported by a competitive analysis of home energy technologies that we conducted. Based on our guidelines, we also designed the Community Monitor social energy application and conducted a longitudinal deployment.

We deployed our application to 15 households across two rental communities (one low-income and one mixed-income) over a period of 4-10 months. Our application allowed households in the same community to monitor each other's average daily consumption and share knowledge and information. Households could also view detailed information about their energy use and see information about strategies to reduce home energy use**.** Our deployment results show that:

- participants integrated our application into their existing routines and habits, which led to a positive impact on sustainable behavior
- households from one community were able to identify and address energy-related issues discovered as a result of using the technology
- trust plays a key role in stakeholder communication and environmental behavior.

Our final contributions also included additional design heuristics for future social energy-related applications. We also emphasized the importance of encouraging sustainable behaviors at a social, or collective level. Future social applications should help convey new norms and support knowledge transfer between stakeholders; they should also encourage community building inside and outside of the application to build trust within communities and protect household privacy.

7.1 FUTURE RESEARCH

Some view sustainability as a political, or economic issue, or one in which requires a significant cultural shift in populations. Some also suggest that it's an issue that cannot be addressed by technology alone. However, information technology has been described as a *"natural bridge between technical and social solutions because it can offer improved communication and transparency for fostering the necessary economic, political, and cultural adjustments"* (National Research Council, 2012). In the next section, we discuss our goals for continuing our work over the next two to three years.

In the near future, we plan to investigate how technology can help us to explore the following three questions:

1) What is the social impact of sharing electricity information among households, and how can we manage issues that may arise as a result of sharing this information?

2) Can socially interactive energy-systems be used to influence positive habit-forming behaviors such as becoming accustomed to lower indoor temperature in the winter?

3) Might crowdsourcing and/or gaming strategies help with the data labeling process and/or accurately predict energy inefficiencies?

7.1.1 SOCIAL IMPACT OF SHARING

What new social issues arise from sharing and comparing energy data among low-income communities and community stakeholders (i.e., tenants, landlords, utility companies)?

As a part of this thesis, we argued that sensing technology and social computing could play a role in conflict resolution because of their potential for collecting and providing information. Similar to the National Research Council's Computing Research for Sustainability agenda, we see the two as a "natural" bridge in changing how stakeholders communicate among and between each other in the home energy domain (2012). However, providing consumption information may have consequences such as exposing energy-related issues and incurring new costs.

In Chapter 3, we found that when tenants shared energy costs with each other, they realized that their energy bills were excessive. When they presented the landlord with this information, they were able to identify and address apartment-wide inefficiencies that helped reduce costs.

Integrating the Community Monitor into low and mixed-income communities could have similar effects; however, it may also expose community-wide stakeholder issues such as poor wiring by contractors and/or billing issues with utility companies. Understanding the social impact and implications for integrating new information and technologies into different real-world contexts is pivotal. Future technologies may allow stakeholders to provide feedback, such as a rating, about the impact of a new technology. This could provide an outlet for stakeholders to communicate and address issues that may arise unexpectedly.

7.1.2 CREATING HABIT-FORMING BEHAVIORS

As we saw in Chapter 3, tenants were motivated to save energy even when they did not pay for it. Individuals who were raised in energy-saving households, for example, often performed habitual energy-saving behaviors such as turning off lights in unoccupied spaces. We also saw in Chapter 6, how householders integrated the use of the application tablet into their daily routines. Understanding how these habits are formed and created could be vital in influencing positive, habit-forming behaviors.

Therefore, we ask: *Can socially interactive energy-systems be used to influence positive habit-forming behaviors?* Such knowledge can lead to further research and the creation of a practical framework; such a framework that could be used to build applications that promote and support energy-saving habits. As a next step, we see an opportunity in investigating how socially interactive systems can be used to influence positive habit-forming behaviors and applied to domains such as education and health.

7.1.3 CROWDSOURCING INEFFICIENCIES

Some of our final-study participants asked for more information about individual appliance usage and how their behaviors affected it. Since average daily consumption was a data point shared among all participating households, one question is whether households may have related individual behaviors to consumption patterns. Various models identify individual appliance usage and behaviors from whole-house energy monitoring data; improving the effectiveness of such models however, requires data labeling. We saw from our concept validation that participants did not wish to provide our application with additional data. Another question for future investigation is this: *Might crowdsourcing and/or gaming strategies (von Ahn & Dabbish, 2004) help with the data labeling process and/or accurately predict energy inefficiencies?* Past research suggests that home-energy displays do not successfully engage consumers or maintain their long-term interest (LaMarche, Sachs and Roth, 2011), and our competitive analysis shows that forms of integrated entertainment into these technologies present an open and unexplored opportunity for new and efficient home-energy technologies.

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A It's Not all About Green

TODO: Appendix

7.3.3.1 – Add codes and themes from saturate app

Appendix (chapter 3 and 4)- (maybe the three required photos for each participant, the list of codes; and the interview guide if you had one). In that case you should state that more details are in the appendix here.

4.3.1 – Landlord Interview method – questions, method, advertisement (recruitment flyers)

TODO:

Add polar bear images used…

B Understanding Conflict Between Landlords and Tenants

B.1 Instructions

C Community Monitor Study Deployment

Surveys/Questions
Advertisement/Flyers
Codes
Pictures…

C.1 Energy Consumption in Low-Income Communities

Flyer

We used the flyer shown in for our study to understand energy use in low-income communities.

Residents Needed for Public Housing Research

**Earn $10 per hour.
No experience needed,
Interview today!**

You will be asked to participate in an interview lasting 1 – 1.5 hours and complete a brief survey ($5 for the survey and $10/hour for the interview).

Must be age 18 and over!

Figure 22 - Flyer used in low-income study

C.2 Community Monitor Deployment Flyers

Two sample flyers (see **Figure 23**) used for the final deployment are included here. Over time, these flyers became less "technical" (sample flyer 1) based on gauged participant interest and feedback from the management company.

Figure 23 - Sample Recruitment Flyers used in the final deployment