Design implications for social-energy applications

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Abstract. Home-energy studies suggest that providing users with real-time and cross-household feedback may nudge users toward sustainable behaviors. Although methods of comparison yield significant savings, only a limited amount of home-energy research has explored social communication with feedback devices. Inspired by our prior energy studies in low-income communities, we present the results of a needs-validation study and provide design implications for real-time, community-based feedback displays.

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INTRODUCTION

Energy use and its environmental implications are topics of global concern. In the U.S., a country with high *per-capita* energy use, households consume 21.7% of the total energy and generate 21.1% of the total carbon emissions [9]. The average annual cost of electricity is $1,000 *per* household yet consumers often lack knowledge about the amount of electricity they consume or the factors that influence their consumption [2]. Researchers, who have spent decades examining home-energy consumption and conservation, have found that providing users with real-time energy use feedback can produce savings of 10–15% [3,7,14]. Research has also shown that public commitment, comparison, and other forms of cross-household feedback may contribute to energy savings [1,3,7]. Although comparison is a feedback method shown to encourage additional savings [1,3,7], home-energy research studies exploring social communication and comparison around feedback devices are limited [8].

We conducted the studies described in [6] and [5] to further explore and identify socioeconomic factors affecting energy usage. In [6] we looked at energy use in low-income households; in [5] we focused on the impact of landlord/tenant relationships on energy use. Our population included a broad range of household types that included one person, a family or extended family, roommates, and long-term visitors and ownership relationships that included landlords/renters, government-run buildings, and homeowners.

Our results demonstrate the importance of socioeconomic context: A closer look at the dynamics of low-income households reveals that beyond the heads of households living in a home, energy use may be affected by neighbors, other members within a community, and landlords. All of these stakeholders affect energy consumption directly and indirectly and communication between these stakeholders could benefit all parties. In addition, an individual's beliefs, cultures, household structure, and the availability of money may all affect energy consumption. Landlords may pay for energy consumption, and low-income individuals may receive stipends from the government. In some cases, a household will be allocated a certain number of kilowatt-hours per month.

The complex effects of these factors require a deeper look at what is going on in low-income and rental household communities. In this article, we describe the results of generating over 25 initial concepts around real-time energy monitoring to address the needs identified in our prior two studies of energy consumption in low-income communities. We clustered our concepts into five dimensions based on potential solutions derived from our prior research: feedback, privacy, sharing, knowledge, and organization in the sense of enabling group action. We were also interested in details related to how to introduce our concept to our target audiences.

APPROACH

Our goal was to validate findings from prior studies of energy-consumption in low-income households [6]. We wanted to understand how others perceived our concepts and to flesh out usability details. To achieve our goal, we conducted a speed-dating

study, a design method for rapidly exploring application concepts and their interactions [4], using needs validation. In this method, we drafted concepts as scenarios of settings similar to those of our audience (see Figure 2 for an example). Each of these scenarios introduced a technological intervention to address a need in each setting, or situation presented. The design concepts presented in each scenario included interventions that could detect real-time energy consumption and that could display information about the data collected, how individuals consume energy, and how they engage around energy consumption, for example. We analyzed our data by writing extensive notes, organizing responses around our five dimensions, and by comparing results between our participants.

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 solutions from our previous studies:

- feedback
- privacy
- sharing
- knowledge
- organization (in the sense of enabling group action).

We were interested in ways to introduce our concept to target audiences. We presented our scenarios to renters, students, homeowners and one landlord. We asked participants to provide feedback on the scenarios including potential benefits to their households. We used probing to understand the responsiveness of participants to the solutions presented. We modified and updated scenarios based on participant feedback and removed unpopular concepts.

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 over half of our participants 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 that made less than $30,000 per year.

RESULTS

Overall, we found that our concept primarily benefits the party responsible for paying electricity bills. As a result, our goal was to reach an agreement between the two parties. In the next section, we describe the conflicts we identified in relationship to various household types, privacy issues, design implications, and possible platforms to host our service.

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 me 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

Figure 1 - Participant details

Concept viability/Receptiveness to Concepts

In regard to 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. However, some of those not responsible for paying the electricity bills were not as thrilled. In one case, we ran our concepts by a landlord not responsible for paying his tenants' bills, but he had concerns. Specifically, he was concerned about whether or not 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 extra costs. 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, and residents 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 concept. 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. Take 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].

Based on this scenario, participant 8064 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.*" Participant 8118 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, participant 0731 stated that the concept should, "*Speak a language we can all understand and that's money."*
Considering these findings, we must make the benefits to all stakeholders clear in our design. 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).

Privacy
We presented several scenarios to participants to understand the level of privacy they were comfortable with providing. Our results were not too surprising. Overall, we found that there were three categories of individuals. Two of these categories are similar to Westin's categories [17]:

- 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. 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. 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.

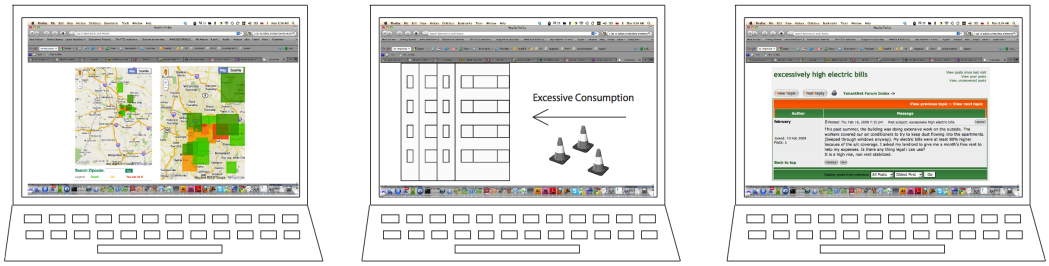
Several participants, P1938, P731, and the landlord strongly suggested adding any information about real-time energy monitoring to the lease if the landlord provided the technology. For example, participant 1938 stated, "*The lease could be used to say what could be done with the information...*" and 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 little to no privacy concerns.

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



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 2 - Sample Scenario: A scenario describing how an individual may use a system designed for sharing energy consumption

feedback as presented in our concepts, they preferred information that would automatically identify and/or point out relevant issues for them.

We also 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.

Though participant 8064 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 [7]. 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?" [10,11].

Another participant, 2320, 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 [12].

In terms of feedback in general, Participant 2011 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.

Sharing Knowledge/Social Engagement

Overall, very few participants wished to engage with their neighbors outside of an electronic forum. In one instance, P731 said that she has definitely spoken to her neighbors about her consumption. She said it was a step in the right direction to try to narrow down issues. However, she only initiated this conversation while one set of neighbors was moving out; she was able to see and speak to some of her other neighbors at this time. She heard one of her neighbors complain about electricity and that, "*they spent $500 for one month even though they weren't even home.*" P731 says that in the future, she will ask questions about electricity costs and the types of appliances her neighbors use before moving into a new place.

Just as residents from PA did not wish to share their consumption data with their neighbors [6], most participants in this study did not want to discuss electricity information with their neighbors. Overall, 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.

Participant 8064 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.*" Participant 1471 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, participant 2320 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.*" Participant 2477 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 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.

Participant 2477 stated, "*Wonderful! I'd use this system…nothing is identified here, the information can be anonymous and still be helpful.*" Another participant, 2011, 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 with this audience (*e.g.,* low-income Pittsburgh communities).

Organization and Group Action
Based on the results from the last section, 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 [16]. One participant, 8064, responded by describing how our concept 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. 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.

DESIGN IMPLICATIONS

We summarize our findings below as design implications. Additional implications from scenarios not discussed above include preferences for interaction, preferred technology platforms, and the need for incentives. We discuss these implications also and support them with prior research.

Design for Multiple Stakeholders
Stakeholders include landlords, tenants, roommates, and other family members. It is important to consider all stakeholders when designing real-time energy displays. For example, one must consider the stakeholder(s) responsible for paying electricity bills. Householders not responsible for paying electricity may perceive a feedback display differently than a household responsible for paying electricity. This supports McMakin's findings that successful intervention efforts should explicitly contain the characteristics of the targeted living situation and its residents [13].

Feedback should be smart
Another design implication is for energy feedback to be smart. For example, though participants stated that they could identify issues using the feedback as presented in our concepts, they wanted information that would automatically identify and/or suggest potential issues for them. This is consistent with Kempton's work showing that individuals like to be able 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?" [10, 11].

Limit Required Interaction
Overall, individuals were comfortable providing information required for our concept to work, *e.g.*, household characteristics; however, individuals did not respond well when first asked to provide additional information using our concept. 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. 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 Labels his Data: 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.

In response, P2320 stated, "*I don't want to have to check-in or provide [additional] input."* Based on his tenants' remarks, the landlord, 2848, 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, our concept should not require much more user information from participant than what is needed in the initial setup/registration.

Limited Access to Technology

To understand which technology platform elicited the greatest response from our participants, we presented our concept on a mobile device, a laptop device, and on a physical bulletin board located in a common area. We noted that two participants showed a very strong preference for the mobile device, and one other participant preferred to use a mobile device only if it allowed remote control of her devices (*i.e.*, turn devices on or off).

Other participants did not use their mobile phones frequently and/or they did not use their phones as represented in our scenarios. Though some scenarios used the mobile device to display alerts only, one participant believed that he needed to have a smart phone to use our concept. P1471 stated, *"Not everyone's computer literate and sometimes we forget that. The phone is great but you may miss a group of people (unless you can educate everyone to use cell phones). [It's] better to contribute to the website itself*."

Participants also thought that the intervention must have a list of prioritized tips for saving energy. More than half of our participants, for instance, stated that real-time consumption information would not be beneficial without practical, energy-saving suggestions. In addition, individuals wanted to receive alerts that would allow them to take immediate action related to consumption peaks or lower-than-expected savings.

Incentives

The landlord was able to see the system benefits for other landlords responsible for paying tenants' utilities. In fact, he stated, *"I'd tax tenants that were using too much,"* assuming there was a way to trace them. He also explained that he could modify his lease to increase the overall costs if energy was wasted. Prior research shows that financial incentives to reduce demand are only effective as long as the incentive lasts [1]. In this case, the landlord's imposes a fee, similar to a tax, which is one way to bring long-term incentives to keep consumption below certain levels [3].

However, in this particular situation, the landlord's primary question was a valid one, *"What is the incentive to have landlords allow their tenants to install the devices?"*

Perhaps the landlord was only considering short-term payoffs and not long-term gains. Conceivably, the landlord could modify rent based on overall savings made from energy-efficient investments. Or, perhaps the landlord could provide community amenities such as free Wi-Fi with the savings.

DISCUSSION AND CONCLUSION

Socioeconomic factors play an important but largely hidden role in home-energy consumption. Most studies have targeted single-family, affluent households – so the resulting energy-monitoring systems do not address the needs of renters and lower-income individuals. For technology designers and information architects', failure to address the disparity in the use of home-energy devices can no longer be set aside. Lack of access to energy information leaves three out of ten American households without the power to make changes in consumption [15]. In addition, others have concluded that we need further exploration of communities and their roles in energy consumption [12].

Our goal in conducting this study was to validate findings from prior studies of energy-consumption, which highlighted how socioeconomic factors play a role in home-energy consumption [6]. To validate these findings, we conducted a needs validation study across 25 scenarios to understand how others perceived our concepts and to flesh out usability details. We concluded from our study that concept design should not target a particular group identity, (i.e. green) and the design should "*speak in a language that everyone can understand*". We learned that in terms of interaction, individuals do not wish to actively interact with the data but to receive timely alerts about their consumption. Residents essentially want an application that can identify and point out issues that are relevant to them.

As next steps, we are currently developing and deploying an application based on our design implications to 1) further explore how socio-economic factors play a role in energy consumption, 2) to understand how real-time electricity monitoring data enable household sharing and community sharing, and 3) to understand how this data affects conflict among stakeholders in a given location.

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