Empowering Users To Become Designers: Using Meta-Design Environments to Enable and Motivate Sustainable Energy Decisions

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ABSTRACT.
Unsustainable energy consumption is a systemic problem facing societies. While technological innovations are necessary to address this problem, they are not sufficient but need to be integrated with social and behavioral changes. Our approach is based on understanding and using participatory design not just as a paradigm to design software, but as the foundation for socio-technical environments that enable and support a cultural shift from passive consumers of energy to active decisions makers.

Our research is grounded in two theoretical frameworks, *meta-design* and *cultures of participation,* which we have explored extensively. We are in the process of developing EMPIRE, a socio-technical environment, supporting rich ecologies of participation enabling people to become active designers of their energy consumption. While EMPIRE engages people to participate in the design of the system itself, it supports individuals and communities more broadly in understanding and making more sustainable choices regarding energy.

Author Keywords:
meta-design, cultures of participation, rich ecologies of participation, design-in-use, decision-making, energy sustainability

ACM Classification Keywords

INTRODUCTION

There is overwhelming evidence that our current lifestyle is not sustainable and human energy consumption causes global warming [Intergovernmental Panel on Climate, 2007]. Governments, industry, and environmental groups are undertaking major efforts to reduce energy consumption, largely resulting in systems that, although technically innovative, are static and closed, viewing the end-user as a passive consumer. To reduce energy consumption to sustainable levels, technological innovations and policy changes are not sufficient—changes in human behavior are necessary [Ehrhardt-Martinez et al., 2010] and systems that involve end-users as active decision makers [Fischer, 2002] are needed.

In this paper we first describe findings and concepts from social psychology and behavioral economics relevant for motivating and enabling people to become decision makers with socio-technical environments. We then illustrate the use of our theoretical frameworks, *meta-design* and *cultures of* participation in the application context of energy sustainability emphasizing the importance of supporting richer ecologies of participation. The central part of the paper describes EMPIRE, a socio-technical environment to motivate and support participants in reflecting on and changing their energy consumption as part of their everyday lives. We conclude *by* describing the implications of this research for broadening the scope of participatory design.

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MOTIVATING AND ENABLING PEOPLE TO BECOME DECISION MAKERS WITH SOCIO-TECHNICAL ENVIRONMENTS

To reach the goal of reducing energy consumption at a societal level, socio-technical interventions [Mumford, 2000] that go beyond simple presentations of facts are necessary. Changes in behavior to reduce energy consumption can be fostered through both social and technological interventions. Feedback, goal setting, and tailored information are useful in motivating people to change their energy behavior [Abrahamse et al., 2007]. Steg and Vlek [Steg & Vlek, 2009] have shown that a meta-design approach [Fischer & Giaccardi, 2006] in which participants are asked to become active in planning their energy environment increases the probability of participants changing their behaviors and saving more energy. Staats, Harland and Wilke [Staats et al., 2004] found in their longitudinal study that one of the most important contributing factors for changing behaviors and energy savings were supportive social environments. In addition, computer-based feedback mechanisms [Froehlich et al., 2010; Holmes, 2007; Kirman et al., 2010] are effective in reducing energy consumption [Abrahamse et al., 2007; Ehrhardt-Martinez et al., 2010; Fischer et al., 2008] and have been implemented taking advantage of smart grids, smart meters, and advanced metering infrastructures *(http://www.oe.energy.gov/smartgrid.htm)* [Reeves et al., 2009].

Beyond these global findings, we have identified two concepts from the social sciences: *psychological ownership* and *motivating social environments* as being critically important for involving consumers yet are being insufficiently taken into account in traditional fields of participatory design and specifically in the energy domain.

Psychological ownership [Pierce et al., 2002] describes a state in which a person feels closely connected to an

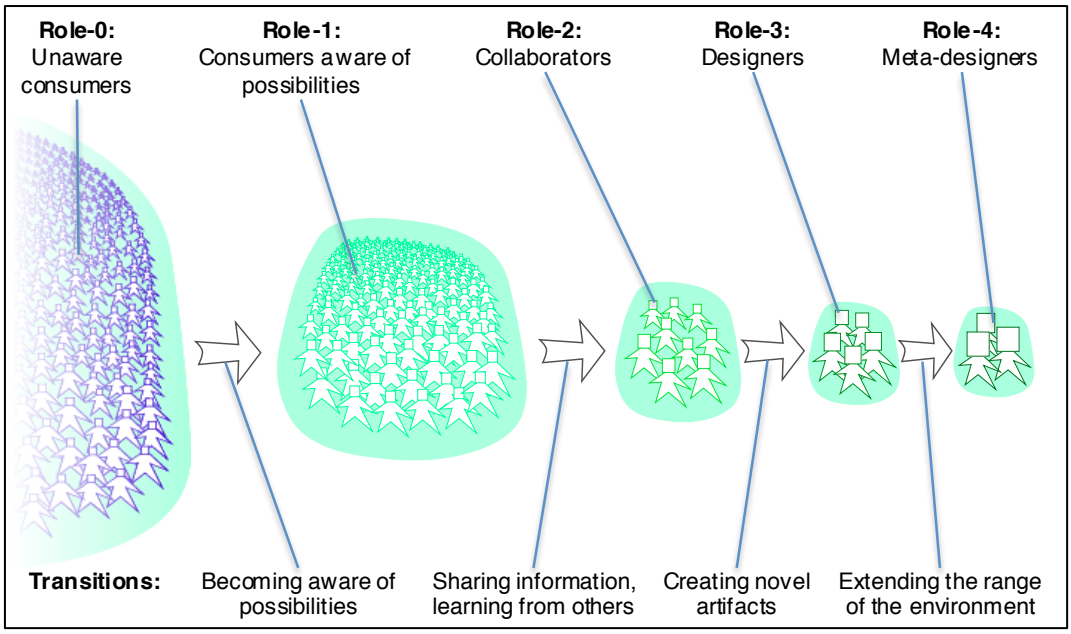

Figure 1: Identification of Different Roles in Rich Ecologies of Participation

object or idea, to the degree that it becomes part of an 'extended self'. When people are involved in solving a problem [Rittel, 1984] or making something themselves (the Ikea Effect [Ariely, 2010]), they place a higher value on that activity and are more likely to continue to invest time and effort in it.

In a meta-review of research on psychological ownership, Pierce and colleagues have found several requirements for psychological ownership: (1) *control*, (2) *investment of self*, (3) *intimate knowing*, and (4) *modifiable targets* [Pierce et al., 2002]. If an object or an idea fulfills all of these requirements, people are more likely to feel ownership for this target [Benkler & Nissenbaum, 2006]

Whereas smart grids and smart meters support the basic technological foundations for these requirements, the software infrastructure available to end-users does not make effective use of the information these systems gather. In almost all developments of smart grids to date, consumers are given very limited *control*. The technical implementation and the utility companies do *not reward investment of self*. The grid is designed as a system for passive consumers who are all given the same monthly bills that list overall consumption in the abstract unit *kWh*, without *supporting intimate knowing* of how energy is being used in the individual setting or how energy could be saved in unique ways. Finally, the only thing that consumers can change in the current smart grid is which electricity-consuming devices they use and how often they use them; the system does *not provide any means of modifiability* to end-users.

Motivating Social Environments. Although changes in the social environment have been shown to cause people to use less energy [Schultz et al., 2007; Schultz et al., 2008], supportive social environments are not commonly used in this fashion. For example, *social proof* [Cialdini, 2009] describes the effect that people act a certain way because they observe others acting this way. In such situations, the fact that others chose something acts as *proof* that this choice is preferable.

However, energy consumption is completely individualistic and invisible to the consumers themselves and to others [Ehrhardt-Martinez et al., 2010]. Aside from choosing to drive a Toyota Prius as a means of being more energy-efficient or installing solar cells to take advantage of renewable energy, people have few ways to share their energy attitudes or behaviors. Thus, for highly energy-relevant behaviors like the temperature of the thermostat, the installation of house insulation, or the choice of appliances, no generally established social norms exist that could motivate and guide consumers to reduce energy consumption. Without awareness of other people's actions, no social proof can be created.

CONCEPTUAL FRAMEWORKS

Over the last several years, we have developed the foundations of two theoretical frameworks: meta-design [Fischer & Giaccardi, 2006; Giaccardi & Fischer, 2008] and cultures of participation [Fischer, 2011] that fundamentally change the way we perceive the end-user in the design process. Meta-design enables people to produce their own applications, and it thereby extends the design process into use. Cultures of participation motivate and support end-users to become designers hereby dissolving the boundaries between use and design [Henderson & Kyng, 1991], and challenging our general understanding of users as participants in the design process. Our ongoing research is demonstrating how these two frameworks can be successfully exploited to motivate more sustainable energy consumption.

Meta-Design. Meta-design is a design methodology [Ye & Fischer, 2007] for creating socio-technical environments in which users are able to identify, explore, and reassess their needs during use time and act as designers that can change the environment accordingly when needed.

An important element of a meta-design environment is the *"Seed-Evolutionary Growth-Reseeding" (SER)* model [Fischer & Ostwald, 2002]. In this model, designers do not attempt to build a complete system; instead they

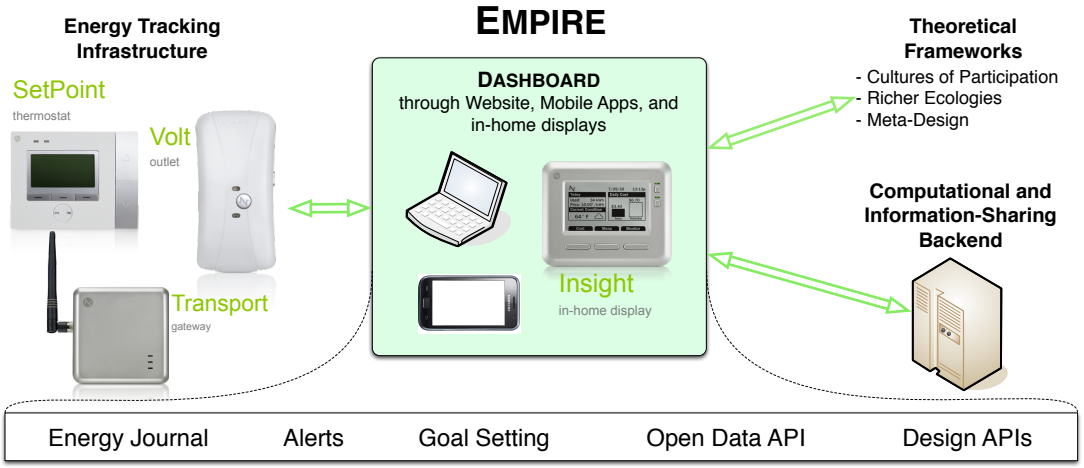

Figure 2: Overview of EMPIRE

create *seeds* for users that provide basic functionality and can be modified by end-users. All users can modify and expand the seed in the *evolutionary growth* phase before the designer *reseed* the system with the contributions made by the community.

Meta-design environments foster psychological ownership by giving users control and openness and rewarding investment of self in the ongoing development of the system. Being an owner of the system makes people more likely to prefer the system to others, invest more time in it, and develop extensions to it. Their own extensions, in return are something for which users are likely to feel responsible for, increasing their feeling of ownership and their motivation to contribute on an ongoing basis.

Cultures of Participation [Fischer & Ostwald, 2002] offer a new platform for human connection, bringing together otherwise unconnected individuals and replacing common background or geographic proximity with a sense of well-defined purpose and the successful common pursuit of this purpose as the condensation point for human connection. Our research contributes to elaborating a *richer ecology of participation* in cultures of participation by differentiating, analyzing, and supporting five distinct roles that can be found in cultures of participation: *unaware consumers, aware consumers, collaborators, designers, and meta-designers* (see Figure 1, which was inspired by work at the University of Maryland [Preece & Shneiderman, 2009] and further extends our own initial analysis [Fischer & Giaccardi, 2006]).

Cultures of participation and meta-design environments are tightly integrated [Fischer, 2010]. To be a successful meta-design system, users have to be able to share their ideas and developments, to get help from other users, and to find extensions and developments that have already been implemented by others; they have to form a culture of participation. Cultures of participation require the underlying software system to be open and modifiable so that users can participate in meaningful problems. The software underlying a culture of participation has to be dynamic and has to allow users to adapt it to their needs, and to reseed their own developments with others in the community; meta-design environments are needed. Cultures of participation are well suited to foster and support motivating social environments in which people can create social proofs and social norms by providing tools for sharing and for creating awareness. Since people are not merely consumers of a system but active participants of a community, they are more likely to be influenced by the actions and opinions of others.

EMPIRE—A SYSTEM TO REDUCE ENERGY CONSUMPTION

The current energy domain requires large efforts from consumers who want to become educated decision makers. We are building EMPIRE (see Figure 2), a meta-design environment supporting a suite of tools that enhances value from, and reduces effort needed for, participation in order to foster and support migration to more active roles as well as to encourage differentiated roles within the energy domain (see Figure 1). By creating more nuanced steps with immediate value requiring less effort, consumers will be able to assume active roles within the energy domain more easily than the current infrastructure affords. The components of EMPIRE allow consumers to understand how they use energy, compare their energy usage to that of others, and make educated decisions based on their new-gained insights. These components are described in detail below.

Design Requirements

Several requirements for a system that fosters and supports cultures of participation can be deduced from these psychological and design theories described above. In brief, the requirements can be divided into three categories:

- **Awareness of Possibilities.** People need to be aware of the existence of the culture of participation as well as its potential and the different roles within that culture. We have been working on approaches that identify and recommend such relevant information for over 20 years, (e.g., critiquing systems [Fischer et al., 1998]), and are using insights from our previous research to make people aware of roles that are relevant to them.
- **Perceived Value and Motivation.** To assume more advanced and more demanding roles, people have to

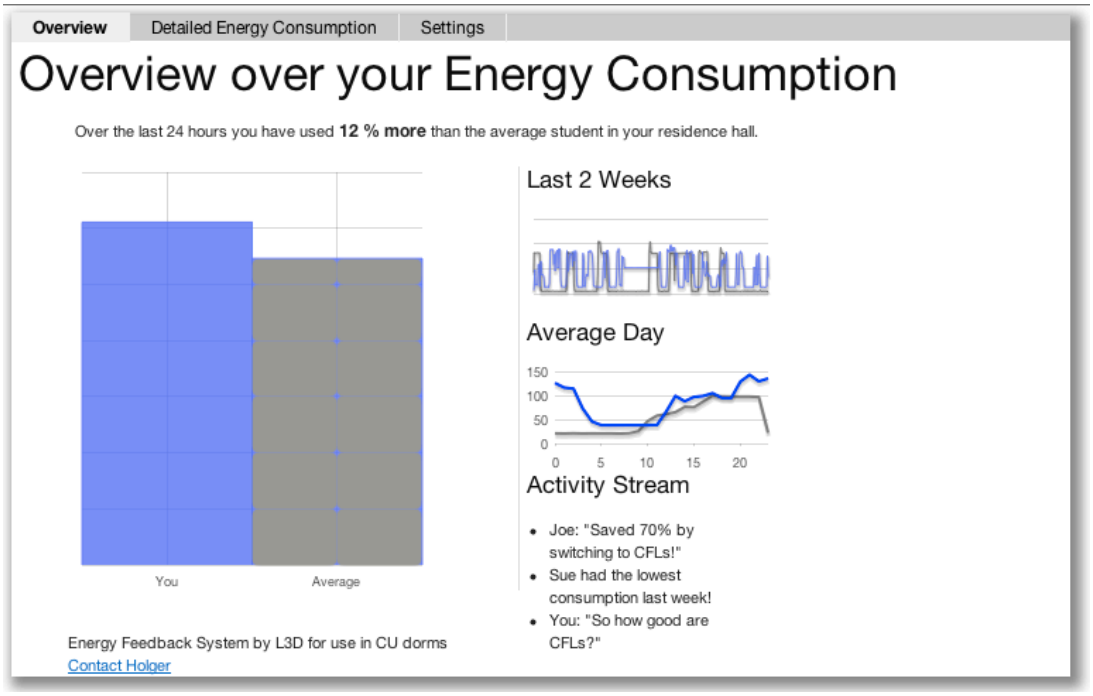

Figure 3:The EMPIRE dashboard

be motivated [Csikszentmihalyi, 1990]—there are no external pressures or rewards that would make users assume these roles otherwise. Users have to see value in the migration to another role. We are in the process of implementing and evaluating different approaches that have proven useful in other domains and contexts in a dashboard, a central place for various sources of information.

- **Role Migration and Sustainable Choices**. Technology alone does not determine social structure; nor does it change human behavior. Technology does, however, create feasibility spaces for new social practices [Benkler, 2006], and it can persuade and motivate changes at the individual, group, and community levels [Locke & Latham, 2002]. Research in *behavioral psychology* [Ariely, 2010] has shown that providing feedback, goal setting, and tailored information is useful in motivating people to make new choices.

Thus, to foster and support a richer ecology of participation, we have identified three necessary user interventions: (1) tools that create awareness, (2) tools that foster interest and motivation to assume different and more active roles, and (3) tools that support users in their migration to these roles. To this end, we propose to use approaches that have been shown to raise and support awareness [Biehl et al., 2007; Naaman et al., 2010] as well as our own insights from our work on critiquing systems [Fischer et al., 1998].

Our studies in meta-design [Fischer & Giaccardi, 2006] have provided evidence that people become engaged when they can make decisions and that they will value what they make [Ariely, 2010].

Description of EMPIRE Components

EMPIRE utilizes electricity consumption data from its individual components as well as from technological devices and displays them in a *dashboard* (see Figure 3), providing users with their most salient energy information in *one* place.

The primary (left) pane of the dashboard contains the information most pertinent to the user, such as current energy usage; highlights of recent usage (e.g., usage spikes in the past hour); and the status of any user-specified alerts. The top-right pane enables them to see how their consumption–and the average consumption in their neighborhood–has changed over the last weeks so that they can see longer-term effects of small changes. The middle-right helps them to understand how and when they use energy by showing them an average day. Finally, the bottom-right pane displays recent activities from friends and neighbors. All components within the

Table 1: Envisioned Roles, Demands, and Activities for a Culture of Participation in the Energy Domain

	The Unaware	Aware Consumers	Collaborators	Designers	Meta-Designers
Specific roles	Unaware consumers	Aware users of energy; active decision makers	Assistants; teachers; learners; observers	End-user developer; visualization designer	Leaders, software architects, social community founders
Demands and activities	Use energy unconsciously as part of daily life	Are aware of energy and energy use; know the space of possibilities; make educated decisions	Share data and knowledge with others; compare with and learn from others	Learn advanced languages and tools; use existing infrastructure to design new artifacts	Define tools and languages; perform seeding; create infrastructure; set policies

dashboard provide access to the full-featured components, which are described in more detail below. The display of components (e.g., number of items shown, component location) can be modified by the consumer.

Supporting Migration between Different Roles in EMPIRE

The migrations between the different roles consist of a variety of actions and steps that people have to take. EMPIRE removes these big steps by breaking them into smaller steps. The following sections describe in detail the migration between the different roles (see Figure 1 and Table 1) and show envisioned human-centered development to support this migration, indicating how EMPIRE will improve the ecology of participation.

Migration from Role 0 to Role 1: *Becoming an Aware Consumer*. Cultures of participation not only require the necessary technological gadgets and systems (e.g., smart meters, advanced infrastructure), they also need socio-technical environments supporting unaware consumers (Role 0) to migrate to active decision makers (Role 1). As illustrated in Figure 4, the current energy domain makes this a demanding task by forcing users to take one big step requiring significant effort. First, they need to realize whether (and where) problems exist with their energy consumption. Then they need to identify sources of reliable and personally relevant information, such as about devices and appliances, about behaviors and activities, about energy-production, and about the local energy provider. This information needs to be understood (a nontrivial task, given the abstract and confusing information currently provided by utility companies [Ehrhardt-Martinez et al., 2010]) and to be analyzed in detail to derive conclusions about the users' energy consumption.

Rather than presenting users with one big step and no support, EMPIRE guides and helps them in their migration by offering a variety of many small steps that require little effort and provide value to the users (see Figure 4). The following sections describe components of EMPIRE that address these requirements and support people in their migration from Role 0 to Role 1.

To make it easier for users to *identify problems* in their energy consumption, we will take advantage of existing developments, create *intuitively understandable representations* [Holmes, 2007], that make energy consumption meaningful by putting it into a social context. As shown in Figure 5, EMPIRE presents the user not just with a graph of energy consumption—as so many systems do and which is meaningless to most people—but uses the potential of visual representations to let people quickly explore and understand where their consumption is unusual or higher than normal. Users can use EMPIRE to see how, where, and when other users are using energy to get a better idea of possibilities and social norms of energy usage. By providing social norms, people can get motivation as well as guidance to reduce their energy consumption [Schultz et al., 2007].

Migration to More Advanced Roles. Figure 4 shows that EMPIRE will enable and support roles that go beyond being an informed consumer (Role 1). Roles 2 through 4 are not widely supported in the energy domain; therefore, a central part of the ongoing research is to analyze the unique requirements and characteristics for supporting these roles for this domain. Our previous work on cultures of participation [Fischer, 2011] (see Figure 3) and related research [Preece & Shneiderman, 2009] have demonstrated that the migration paths for more advanced roles present problems similar to the described transition from Role 0 to Role 1: People with an interest in becoming more involved and active are confronted with big steps that require substantial effort to learn new information and use a completely new set of tools without receiving immediate value in return. The following sections describe briefly the other transitions between roles. In the following we will describe in detail how people further migrate from Role 1 to Role 2 with the support of EMPIRE. The migration to even more involved and active roles should happen accordingly and future versions of EMPIRE will focus on these.

Migration from Role 1 to Role 2: *Becoming a Collaborator*. Figure 5 shows the detailed energy consumption visualization of EMPIRE that allows participants to understand their own energy consumption and to become aware consumers by supporting them in comparing their behavior to that of others. To enable users to become collaborators who are actively sharing and interacting, EMPIRE supports them by using the following developments:

- *Look at Others*: Users can use EMPIRE to see how, where, and when other users are using energy to get a better idea of possibilities and social norms of energy usage [Schultz et al., 2007].
- *Automatic Sharing*: EMPIRE lets users choose what data should be shared automatically with other users without having to spend time and effort on manually contributing data.
- *Compare with Others*: EMPIRE allows users to learn from other users by comparing energy consumption and pointing out significant differences between a user's energy profile and that of others, and by showing where and how energy can be saved.

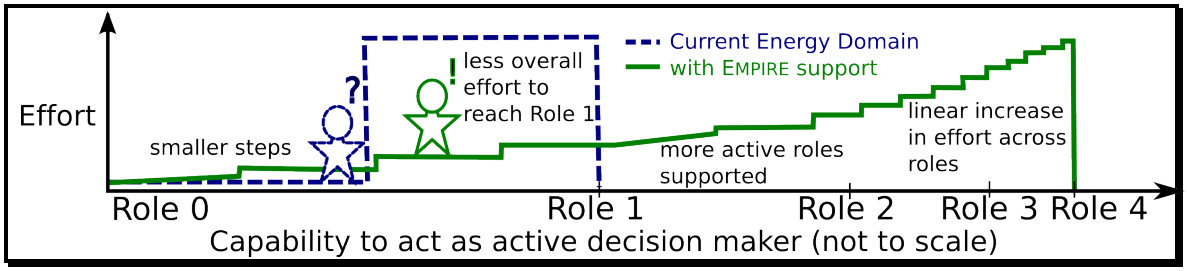

Figure 4: Role Migration from Role 0 to Role 1 with and without EMPIRE

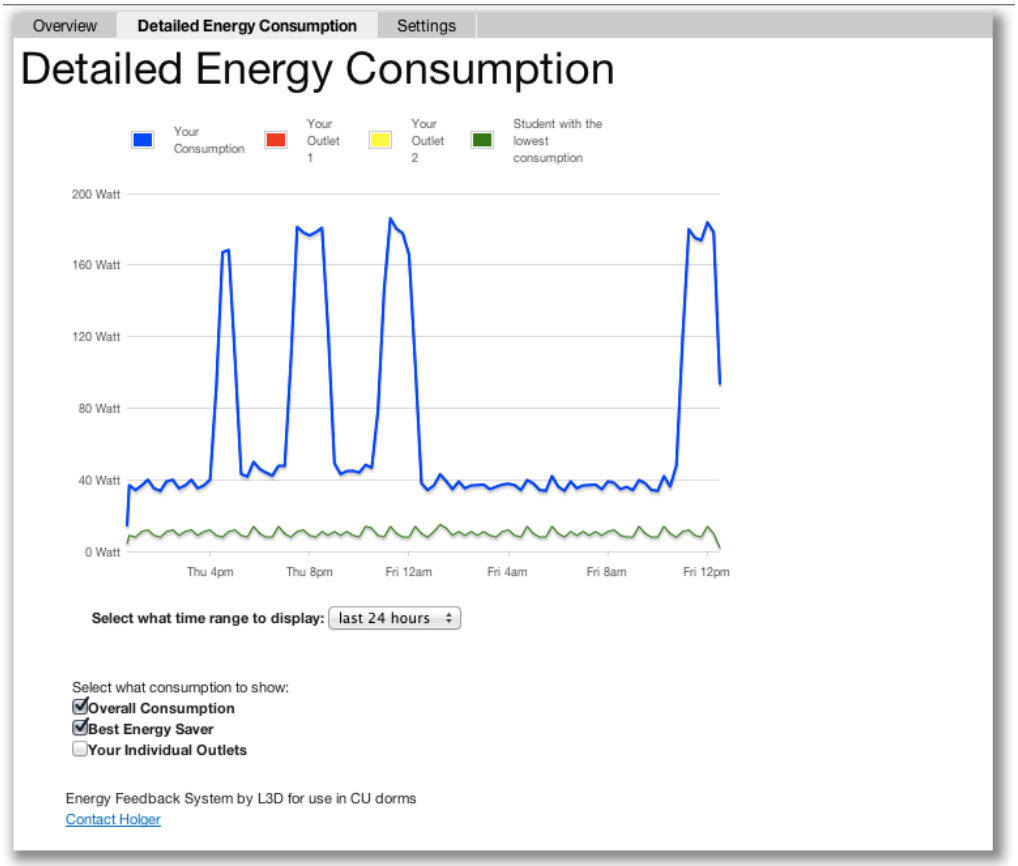

Figure 5: Detailed Energy Visualization in EMPIRE

- *Communicate with Others*: Future versions of EMPIRE will offer an integrated communication platform in which users can discuss, explain, and annotate their energy consumption, contact other users, and share tips about how to use energy more efficiently.

Design Process

In the design and evaluation of our early prototypes we use crowd-sourced user studies within Amazon Mechanical Turk [Kittur et al., 2008]. First, we create personas that are based on a crowd-sourced survey. This approach allows us to cover a wide variety of potential users, interest, and preferences; for the final versions, the personas will be based on the actual users of the system to more accurately fit their specific needs.

Then, we measure how the different systems and different representations influence the users' decision-making processes and opinions about their energy consumption.

The first iteration of EMPIRE aimed to address the problem of a missing psychological ownership. Using a meta-design approach, we created several prototypes that let users explore and visualize their own energy consumption by answering questions about their energy profile and integrating a simple energy simulator. The goal of this approach was to foster *intimate knowing* by

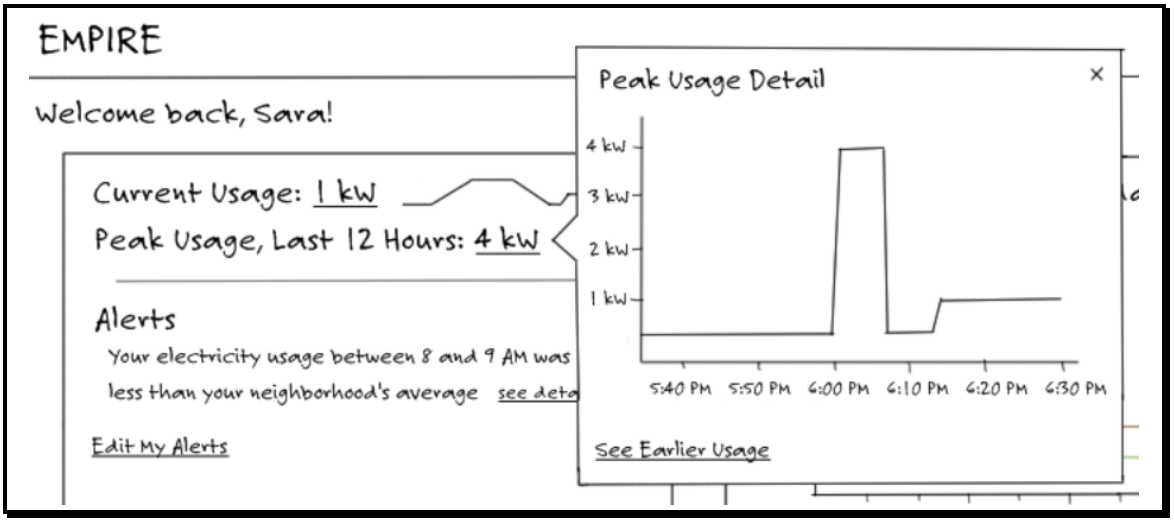

Figure 6: A Peak Usage Tooltip Chart Designed by a Participant

providing the ability to explore the causes and effects of consumption in detail. Initial informal tests with users showed that people were surprised by the results and expressed the opinion that prototypes gave them insights that had not occurred to them before. One participant found, to his surprise, that using a power-strip to turn off his cable box and DVD player at night would save him more energy than getting a new Energy Star certified TV–saving the money he would have spent on a new TV.

As described above, the current version of EMPIRE lets people explore and understand their energy consumption by facilitating a culture of participation that's providing support and motivation. We are evaluating the system in a long-term study with 40 participants that is currently underway. In this study, we analyze how EMPIRE helps people to understand their energy consumption, how it motivates them to reduce their consumption, and how it compares to simple direct feedback mechanisms that provide uncontextualized energy data in real time [Ehrhardt-Martinez et al., 2010].

This system is a first step to enable people to become participatory designers of their energy consumption. The next steps will be to further improve the meta-design aspects of the system itself and let all users *modify* and expand the system to their needs by creating simulations and visualizations that are meaningful to them. Figure 6 shows an envisioned extension that could be made by an experienced user using the meta-design capabilities of EMPIRE. Currently, they can combine and select elements but not edit or create new ones. These steps should offer further reward for the *investment of self* and offer more *control*.

Finally, the individual's actions are being integrated with a culture of participation, so that users can share their creations and insights, help others, gain social recognition, and take on leadership roles within the community, thereby fostering and *rewarding the investment of self*. We will use our experiences and insights from our former work on supporting Cultures of Participation [Dick et al., 2009] and implement awareness tools [Cress & Kimmerle, 2007], that will allow the community of EMPIRE participants to share and become aware of people's energy improvements, their insights, their behaviors, and their consumption. These tools build the foundation for a *supportive social environment* in which energy usage becomes social.

IMPLICATIONS FOR BROADENING THE SCOPE OF PARTICIPATORY DESIGN

Our theoretically grounded design of the socio-technical environment EMPIRE represents a development for *"Embracing New Territories of Participation"* (the conference theme for PDC 2012). It supports and enables people to participate as active decision makers in everyday life. While EMPIRE explores new possibilities for participation in the specific design context of motivating and supporting changes in energy consumption behavior, the frameworks, architectures, principles and concepts developed in this specific domain are applicable to a wide variety of domains. The following *design guidelines for extending the design process into use* [Henderson & Kyng, 1991] represent an important result from these research activities (and are closely related to the principles derived from our work in open source environments [Fischer et al., 2004]:

- *Support Human-Problem Interaction:* all people should be interested in sustainable energy behavior. Citizens, as they are supported by computational artifacts in their engagement, are not inclined to make large efforts to learn general software skills or complicated energy concepts.
- *Underdesign for Emergent Behavior:* Meta-design focuses not on creating final solutions, but on creating solution spaces in which users can create their own solutions to fit their needs. Systems need to be *underdesigned* [Brand, 1995] so that they are not treated as a finished product, but viewed as *continuous beta* that are open to facilitate and incorporate emergent design behaviors during use. Underdesign does not mean that the creator of the seed transfers their design responsibilities to the users and force users into a "Do-It-Yourself" situation. Instead, it requires: (1) creating tools that users can use to solve those well-defined problems, and (2) supporting "remixability" through the provision of meta-tools that can be utilized by users for occasions not envisioned at the design time.
- *Enable Migration towards more Demanding Roles*: To attract more users to become developers, systems must support richer ecologies of participation (see Figure 1) and role migration (see Figure 4) so that newcomers can start to participate peripherally and move on gradually to take charge of more difficult tasks [Lave & Wenger, 1991; Porter, 2008].
- *Share Control:* Control needs to be shared between the original meta-designers of a socio-technical environment and the participating users. The roles that users can play are different, depending on their levels of involvement. Each level has its own responsibility and authority. Responsibility without authority cannot sustain users' interest in further involvement. When users change their roles in the community by making substantial contributions, they should be granted the matching authority in the decision-making process that shapes the system. Meta-designers need to find a strategic way to transfer some of the control to users. Granting users controlling authority has two positive impacts on sustaining user participation and system evolution: (1) users who gain controlling authority become stakeholders, acquire ownership in the system, and are likely to make further contributions; and (2) having some authority will attract and encourage new users who want to influence the system development to make contributions.
- *Reward and Recognize Contributions:* Motivation [Csikszentmihalyi, 1996] is essential for the success of user participation in the evolution of meta-designed systems. Human beings are diversely motivated beings. We act not only for material gain, but for psychological well-being, for social integration and connectedness, for social capital, for recognition, and for improving

our standing in a reputation economy [Fischer et al., 2004].

CONCLUSIONS

Meta-design and cultures of participation are promising frameworks for designing engaging experiences not only *through participation* at design time but also *for different levels of active participation* at use time. Grounded and influenced by a variety of different views from the literature about rethinking participatory design and based on our own research over the last decade, we are developing EMPIRE as an initial prototype of a socio-technical environment and an initial set of *guidelines* to provide a foundation for empowering citizen to act as active decision makers in the domain of energy sustainability.

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