The Local Energy Indicator: Designing for Wind and Solar Energy Systems in the Home

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ABSTRACT
This paper proposes and investigates the area of *local energy* for interactive systems design. We characterize local energy in terms of three themes: contextuality, seasonality, and visibility/tangibility. Here we focus on two specific local energy technologies domestic, electrical generation from wind and solar. In order to investigate this area we design, deploy and study a novel local energy device: The Local Energy Indicator. We conclude by outlining directions for future work related to local energy for interactive design.

Author Keywords
Design, local energy, energy, sustainability

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

INTRODUCTION
The design of systems to support and encourage sustainable energy consumption has become an important area of concern for HCI research, most notably with respect to work in the area of home energy-monitoring and eco-feedback technologies [e.g.,2]. However, HCI as a field has apparently been slow to situate such work within the context of recent trends towards new infrastructure, policy and consumer technologies for producing, distributed, and consuming energy, including a range of technologies associated with the "smart grid" and smart metering [9]. In this paper we focus on the design of interactive technologies in the context of two areas of energy technologies that have not been given much attention within HCI: distributed generation and renewable generation. *Renewable generation* refers to electricity generated from naturally replenished energy sources, such as sunlight, wind, geothermal heat, and tides *Distributed generation* typically refers to the means of generating electricity using technologies that have both smaller generation capacities and are located within close proximity to the people and technologies that consume that energy. *Microgeneration* refers to the use of small-scale distributed generation to support one's own needs. Two popular examples of microgeneration are photovoltaic generation ("solar panels") and micro-wind turbines. (See [9] for additional discussion of distributed and renewal generation in the context of interactive systems design.)

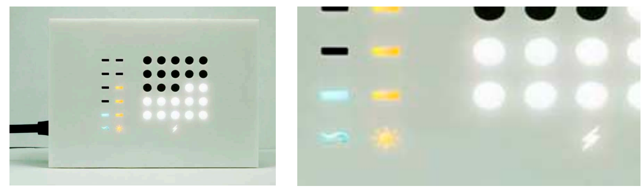

Figure 1. Local Energy Indicator. Current levels of wind and solar power from domestic solar panels and wind turbine are displayed, as well as the total amount of stored energy available.

Based on these trends, our goal in this paper is to delineate and concretely investigate the area of *local energy*. In order to explore this new design space, we designed, built, deployed, and studied The Local Energy Indicator, a novel system that measures and displays local energy information. In what follows we first describe our framing of local energy around three themes, and outline research questions guiding our design and study. Next we describe the design and implementation of the Local Energy Indicator, followed by a discussion of findings from our deployment of this system. We conclude with a discussion based on our work.

LOCAL ENERGY
Our framing of local energy is based on the idea that distributed and renewable generation departs in interesting and important ways from current centralized systems of energy production, such as large coal and nuclear plants. This is most evident in the case of domestic microgeneration, the subarea of distributed and renewable generation that we focus on in this paper. Some empirical work has found that householders with microgeneration systems are more likely to actively manage their resource consumption [see, e.g., 11,13]. Other scholarly writings have discussed how microgeneration can afford new forms of awareness and engagement both in terms of individual consumption as well as more broadly in terms of community and political involvement with energy issues [e.g.,2,12].

Building on these ideas and prior designed-oriented energy research [1,6,7,8], our work characterizes and sets out to investigate local energy in terms of three themes. The first is *contextuality*. In contrast to large, centralized modes of energy production, microgeneration is situated physically close to consumers. Consequently, those that consume microgenerated energy may have direct knowledge of where and how it was generated. Further, different geographic regions have different capacities for microgeneration. For example, some regions have a higher amount of wind and solar potential than others. These characteristics of domestic microgeneration highlight ways that *local energy may be strongly tied to a particular place or context*.

The second theme is *seasonality*. Because microgeneration is highly reliant upon local conditions, it is often characterized by unpredictable and intermittent generation. For example, in the case of wind and solar power, generation is directly related to local weather conditions. These characteristics highlight ways that *local energy may be highly dependant on particular seasons*, where season generally refers to a particular period of time.

The third theme is *visibility and tangibility*. Domestic microgeneration technologies such as solar panels and wind turbines, in contrast to most large centralized generation facilities, can oftentimes literally be seen and even touched by consumers during the course of everyday life. Because microgeneration may also be dependant on factors particular to a certain time and place, it may also be less readily and consistently available. This inconsistent availability of local energy may lead to individuals being more aware of the particular contextuality and seasonality of the energy they use. These characteristics highlight ways that *local energy may be more visible and tangible* as compared to energy that is non-locally produced.

Our work sets out to investigate design research questions related to these themes, such as: Can local energy systems be designed to promote new forms of awareness and engagement with one's local environment, including the household, community, or local weather conditions? In what ways and to what extent can local energy systems amplify the visibility and tangibility of energy? Is the "seasonal" nature of local energy always a problem? Or could seasonal energy be enjoyed and appreciated in ways similar to the ways seasonal foods and drinks are sometimes appreciated?

THE LOCAL ENERGY INDICATOR

Based on these themes and research questions, we set out to investigate local energy through the design and deployment of a working system focused on domestic wind and solar microgeneration: The Local Energy Indicator. Our basic approach is informed by exploratory design work [e.g., 1,4,5,], which contrasts with work that aims to empirically demonstrate behavioral or cognitive effects. This approach is particularly appropriate since local energy is a relatively new space and not a common aspect of daily life for most.

Figure 2. Local Energy Displays and weatherstation deployments.

Because of the challenges with integrating our system with a functional microgeneration system, we chose to "simulate" generation from wind and solar energy using data from a home weather station. This led us to design and implement a system that includes three primary components: (1) a set of local energy in-home display units for communicating local energy data (Figure 1,2), (2) a weather station for measuring the actual real-time potential energy collection (Figure 2), and (3) a computer for logging and relaying data from the weather station to the local energy displays. Despite some clear disadvantages, this approach does have the advantage of allowing this project, and future work, to easily prototype and study local energy systems among groups that have not chosen to adopt such technologies.

Our design utilizes the concept of *energy metadata*, which emphasizes data associated with attributes such as the source and location of energy resources [7]. The display unit consists of three primary informational components: (1) current wind power level, (2) current solar power level, and (2) stored available energy. The wind power level and solar power level indicators display the approximate amount of (potential) wind and solar power generation on a scale from 0 bars (no power) to 5 bars (most power) based on current wind speed and ultraviolet (UV) index as measured by the locally positioned weather station. The stored available energy indicator displays the amount of local energy that is currently stored and available to use. Zero dots indicate that no local stored energy is available for usage while twenty-five dots indicates a full storage of available local energy. The stored available energy was estimated based on the average wind and solar levels and an estimated consumption rate that depended on time of day and average household electricity bills. The stored available energy indicator was also designed to fluctuate over time in order to give participants a sense that their local energy levels were in fact dependent on local weather conditions and their own consumption. Although many microgeneration systems are *grid-tied* rather than relying on on-site battery storage, we chose to focus on the latter scenario because it aligns well with the theme of visibility and tangibility.

The information layout of the display was designed to have a simple look and feel. Further we intentionally avoided assigning specific values to the levels, such as "kilowatt" or "dollars per hour". These design decisions were made in order to encourage open-ended responses from participants about local energy and energy metadata beyond the details of the specific display. Our goal here was to present a digital artifact with a polished enough look for participants to accept it into their homes, yet lacking advanced features so that participants can easily imagine very different versions of this type of energy display.

FIELD STUDY DEPLOYMENT AND METHODS

We deployed our systems in 2 homes for approximately 2 weeks each in March of 2011 in Pittsburgh, PA, USA. Participants were recruited through Craigslist and each was compensated $100 USD. We recruited one household with members that self-identified with environmental issues and another group that did not, with the goal of diversifying to draw out comparisons. We briefly summarize each group. *John and Julia's home.* Both John and Julia are in their 30's and live with 3 young children—two of whom are Julia's, one John's. They own their own 4-bedroom house. Both John and Julia are professional computer programmers. *Tom's home.* Tom is in his late 20's, and is a self-described community organizer and activist concerned with social, political and environmental issues. Tom lives with one roommate in a 2-bedroom apartment that they rent.

The field study method involved an initial setup of the system at participants' homes along with a short informal interview, a brief mid-study check-in interview, and a final extended exit interview. Both deployments were accompanied by some technical problems that required a researcher to visit the homes to correct. These visits ended up providing a useful way of learning about the participants and discussing the system with them.

The basic presentation of the system to participants was as follows. First a researcher briefly described the basic notion of domestic solar and wind generation, and then told the participants that this type of display was one that could be used if they had wind and solar generation along with a battery storage system installed in their home. Each component was then described (similar to the way described above), as well as summarized on a handout. Participants were then asked to consider that such a system had in fact been installed, and asked to go about their daily routines with this idea in mind. Participants were told the study was open-ended in that our goal was to learn their various thoughts and opinions of this type of system, and that there would be an extended discussion of various issues at the conclusion of the study.

FINDINGS

Shifting practices based on local energy

All participants discussed ways that they might shift their practices to different times of day depending on the amount of wind power, solar power or stored energy. For example, when asked if the wind or sun power levels would affect any everyday activities, Julia and John quickly mentioned some activities that they would consider shifting:

> Julia: Yeah, I might think [if I saw a lot of wind power being generated], Now's a great time to do the laundry!
>
> John: … or make a loaf of bread, or run the dishwasher.

These findings are encouraging because they suggest that certain practices such as laundering are highly "shiftable" [5] based on the availability of local energy and information conveyed with energy metadata.

Non-negotiable practices

However we also uncovered practices that were apparently highly resistant to change. Such practices have been characterized in prior works as non-negotiable practices [11]. For example, when asked if they would alter other practices such as cooking John and Julia were much more resistant, stating "But we're not gonna change when we eat our meals. … unless I was feeling playful (John)." Previously we saw that Julia and John find laundering to be a practice that can likely be altered, suggesting a new wind-day laundry routine. On the other hand, Julia and John seem to agree that cooking dinner is not a practice that is likely to be affected by the introduction of local energy or energy metadata. The one notable exception discussed was if John was "feeling playful", where John indicated he might try to create a "no-cook" meal if it was an overcast and calm day.

New local energy practices

In some instances participants suggested changes to existing practices that may be better characterized as new practices altogether. The most salient example is the routine of monitoring local energy levels. Participants also indicated that this might extend beyond the displays. Julia suggested a new practice of checking the weather to gauge energy generation levels and plan ahead accordingly, similar to how she currently checks the weather "obsessively" in order to help plan her day. John and Julia also discussed concerns with maintenance and upkeep of solar panels, wind turbines and batteries, which highlights a completely new area of home maintenance practices.

Conserving local energy

Both groups of participants suggested increasing some conservation measures. In the case of Tom, he suggested a new routine of double-checking to make sure everything in his home was turned off before leaving, especially if his stored energy level was low. Tom's reasoning was that he'd want to "look forward to coming home to a full load of energy." Both groups indicated that they became more conscious of energy and thought the system would help them become "more mindful" of their energy use. Tom's concern also highlights how the Local Energy Indicator draws attention to the total available energy for his home.

Celebrating and wasting local energy

Participants also indicated ways they might increase their consumption. For example, Tom discussed how he considered pre-heating and pre-cooling, as well as turning lights on more frequently when there was available wind or solar power, or during periods when energy storage levels were plentiful. This is interesting because Tom was extremely environmentally conscious and habitually left lights off and used heating and cooling sparingly in order to conserve energy. Yet Tom's remarks suggest that the introduction of microgeneration may actually lead to an increase in his overall consumption. The wind-day laundering and sunny-day bread making suggested by Julia and John may also lead to a form of increased consumption of energy. However, we may also view such practices as a form of celebrating the production and use of personally generated local energy. These findings suggest ways the microgeneration systems can be designed to encourage a new type of relationship to and ownership of energy that one produces and stores at home.

Monetary and "feel good" incentives

Participants mentioned two major types of incentives. The first is the monetary incentive of saving money by using locally generated energy. A second important incentive as described by John as a "feel good" incentive, based on his knowledge that he generated energy "independently" and "efficiently". This "feel good" incentive may be more strongly associated with local or renewable energy than with centrally produced and non-renewable energy.

DISCUSSION AND IMPLICATIONS

Altering everyday practices. A major question guiding our work is concerned with understanding how local energy systems may (or may not) alter everyday practices. Here we highlight three categories of practice to consider. *(1) Shiftable energy practices.* Our study suggests that laundering is one practice that many individuals may be willing to shift depending on the availability of local energy. While demand-response programs typically aim to motivate people to shift their consumption to off-peak hours based on cost, our study suggests a non-financial motivation that is based more on engaging with the local environment and local energy sources. *(2) Non-negotiable energy practices*. Our study also points to areas of everyday practice that are highly resistant to change. Taking these into consideration is equally important in the design of any local energy system, which may involve eco-feedback displays. *(3) New local energy practices.* Finally, our work suggests some interesting opportunities for the emergence of new social practices, such as celebratory meals prepared with local energy. Such practices can serve to inspire new design concepts. For example, Julia's suggestion of checking the weather as a way to measure the energy suggests the design concept of a local *energy forecast*.

Slow energy systems. Related to the idea of designing new social practices in the context of local energy, we highlight *slow energy* as one concept worth pursuing. Paralleling trends such as the slow food movement, and research in slow and reflective technology [4,10], our work suggests ways of amplifying the contextuality and seasonality of energy to encourage slower, more engaged or more thoughtful consumption, such as the windy day laundering and sunny-day bread making practices suggested.

Designing desirable microgeneration systems. Building on the ideas of "feel good" incentive and celebration of local energy, we highlight another design challenge: designing microgeneration that people want to purchase, acquire and use. While the lack of economic incentive is often suggested to be the primary factor inhibiting adoption of microgeneration, our work suggests that these systems could be designed as desirable acquisitions in terms of non-financial value, such as symbolic status, user satisfaction, or experiential engagement.

CONCLUSIONS AND FUTURE WORK

We have investigated the area of *local energy* through the design and deployment of the Local Energy Indicator. Our work has suggested areas for future exploration. In particular, future work is needed to further investigate and generalize findings from this initial study. Nonetheless our hope is that this work can inspire future interactive systems design as well as empirical studies of both novel and existing local energy systems and related technologies.

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