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Smart Energy Systems

EDITOR'S INTRO

We have six Works in Progress this issue that look at various ways to differentiate energy-use patterns and otherwise refine options for managing energy systems intelligently and autonomously. They range from programs focused on collecting use data for analysis and profiling to studies of user behavior and human-computer interface design and, finally, to research challenging the basic assumptions about energy that underlie the way we approach engineering energy systems.

—Anthony D. Joseph

GREENERBUILDINGS: ENERGY AWARENESS USING SENSORS AND ACTIVITY RECOGNITION

Oliver Amft,
Eindhoven Technical University

Buildings account for more than 40 percent of energy consumption worldwide and are the largest carbon dioxide (CO_2) producers in many regions. Making efficient use of energy in buildings is critical both to conservation and to reducing greenhouse effects. To date, automated control and adaptation systems in buildings are often limited to occupant commodity installations that regulate aspects of the indoor climate, such as room temperature and CO_2 levels, or control lights through motion detectors.

GreenerBuildings is a new project funded by the European Commission to investigate how buildings can dynamically adapt their operations according to actual use and context. The project aims at substantial energy savings, especially in public and commercial buildings (offices, shops, hotels, and hospitals) that involve highly dynamic use patterns but whose operational settings are fixed at building design time and rarely changed thereafter. GreenerBuildings develops an integrated framework to realize energy-aware adaptation using energy-harvesting sensors, occupant activity and building-context recognition, and embedded software for coordinating thousands of building-distributed smart objects.

The project's methodological principles include occupant-behavior and thermodynamic building simulations, building-wide dense sensing of activity and state, and living-lab validations. GreenerBuildings specifically focuses on adaptations of heating, ventilation, and air conditioning (HVAC) systems, lighting, and intelligent appliances. An energy-aware framework will be retrofitted to existing buildings, enabling the evaluation of so-far theoretic and experimental findings regarding energy-saving potentials. Furthermore, the evaluations will address user comfort among the overall benefits of activity- and context-aware buildings.

For more information, visit www.greenerbuildings.eu or contact Oliver Amft at amft@ieee.org.

CONNECTING PEOPLE AND RESOURCE CONSUMPTION IN REAL TIME

Richard Medland and Marcus Foth,
Queensland University of Technology
Petromil Petkov,
Technical University Munich

We're currently engaged in two projects to improve human-computer interaction (HCI) designs that can help conserve resources. The projects explore motivation and persuasion strategies relevant to ubiquitous computing systems that bring real-time consumption data into the homes and hands of residents in Brisbane, Australia. More specifically, we're developing a set of interface guidelines that will improve the persuasiveness of design interventions and lead to more sustained behavioral changes.

The first project seeks to increase understanding among university staff of the tangible and negative effects that excessive printing has on the workplace and local environment. This information is conveyed through ambient devices that communicate office printing activity and software that provides regular feedback. The software also delivers motivational techniques focused on personal and team printing in detail.

The second project seeks to shift attitudes toward domestic energy conservation through software and hardware that monitor real-time, in situ electricity consumption in homes across Queensland. Part of this project

WORKS IN PROGRESS

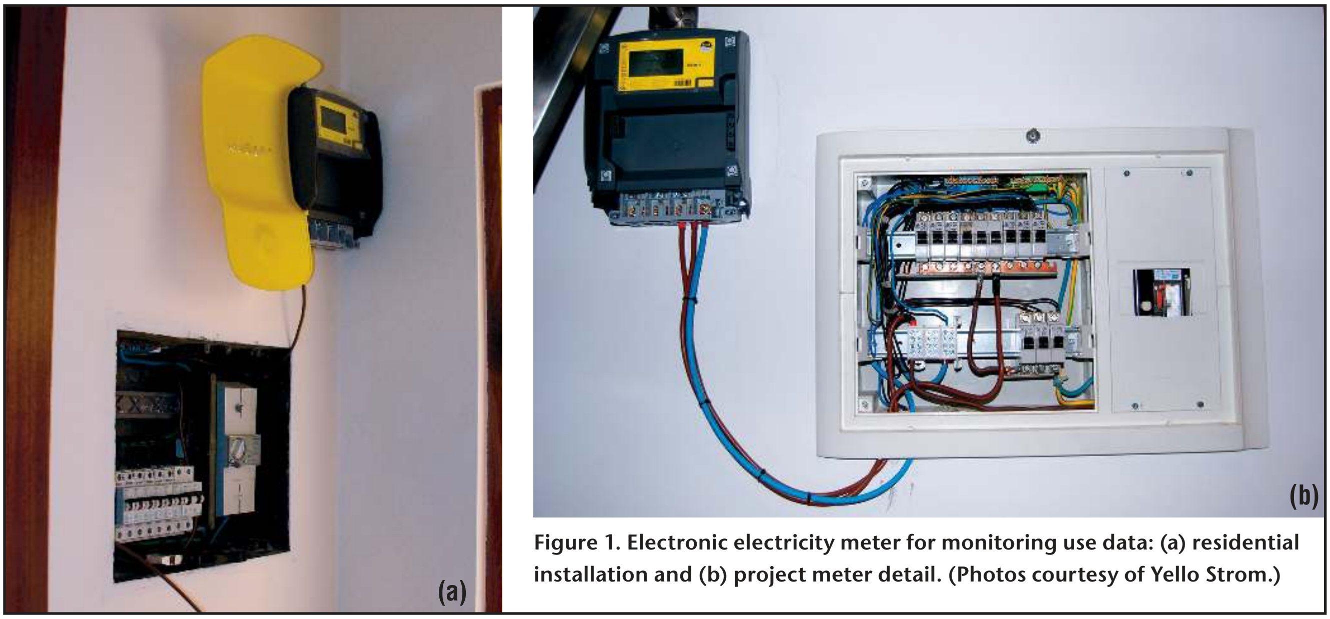

Figure 1. Electronic electricity meter for monitoring use data: (a) residential installation and (b) project meter detail. (Photos courtesy of Yello Strom.)

aims to determine the effectiveness of different types of comparative feedback on domestic energy consumption through a mobile application based on the Android platform. Tailored to user preferences, the application lets users review and compare their energy consumption with Facebook friends, thus looking at ways this social media might motivate behavioral change.

The insights drawn from these projects will help develop resource consumption user archetypes, providing a framework linking people to differing interface design requirements.

This research is funded by a Queensland Government Smart Futures Fellowship and cosponsored by National ICT Australia (NICTA). For more information, visit www.urbaninformatics.net or contact Richard Medland at richard.medland@qut.edu.au.

UNCOVERING DEMAND-RESPONSE POTENTIAL IN RESIDENTIAL ELECTRICITY SERVICES

Joana Abreu, *MIT Portugal, Technical University of Lisbon*
Francisco Câmara Pereira, *Coimbra University*

Many European and North American homes today have electronic electricity meters. Together with home area networks, these devices present the technical basis for a paradigm shift in residential electricity services, enabling individual users to become intelligent agents of the market. As more use data becomes available, researchers can better understand ways to distinguish the potential for a specific consumer segment to respond dynamically to signals from the network (demand response).

We're part of an interdisciplinary study of residential electricity consumption involving 15 electronic meters installed in randomly selected apartments (see Figure 1). The first step of our work is to look at periodicities in the data and identify the eigenvectors for each family that characterize its use of fixed and flexible components—hence, the main activity components. We'll apply this methodology to determine the load-shifting potential in households. Finally, we'll perform a clustering analysis to group families according to their consumption profiles.

Together with demographic data, our methodology will support more informed, dynamic planning from the supply side.

This research receives funding from Portugal's Fundação para a Ciência e Tecnologia. For more information, contact Joana Abreu at joanamabreu@ist.utl.pt.

WATTDEPOT: FOR ALL YOUR DATA PLUMBING NEEDS

Philip Johnson and Robert Brewer, *University of Hawaii*

Research on smart energy systems requires a certain amount of plumbing—a way to easily collect, store, analyze, and present energy data. Current approaches are expensive, utility-scale, or tied to specific devices. To facilitate our own research (such as the Kukui Cup described next), we developed WattDepot, an open source software system for collecting institutional-scale energy data.

WattDepot consists of a series of small software services. It supports extensible sensors that poll commercial energy meters, using protocols like ModBus/TCP, and send data such as instantaneous power and cumulative energy to a WattDepot repository. The repository stores the data from individual meters and allows researchers to organize it hierarchically. For example, they can aggregate several meters from one floor of a building as a single source.

To make these aggregate source representations useful, WattDepot supports data interpolation. This allows researchers to estimate a building's power consumption at any given time, even though it's unlikely that all (or any) of the meters will have provided data at that particular time.

WattDepot implements a REST (Representational State Transfer) API, which makes it easy for other researchers to extend and adapt to new contexts. We've written command-line clients, Web applications, and Google gadget visualizations for data presentation.

For more information, visit http://wattdepot.googlecode.com or contact Philip Johnson at johnson@hawaii.edu.

THE KUKUI CUP: OILING CAMPUS ENERGY COMPETITIONS

Philip Johnson and Robert Brewer,
University of Hawaii

Dorm energy competitions are increasingly popular in higher education as a way to engage students in conservation and reduce campus energy costs. These competitions normally last a month or less and award prizes to residents who reduce their use the most or achieve significant reductions of 10 percent or more. A fundamental question with such competitions, and with energy conservation in general, is how to get people to sustain behavioral changes over time.

To investigate this issue, we're designing a next-generation dorm energy competition at the University of Hawaii called the Kukui Cup. Ancient Hawaiians used kukui nut oil for light, so it represents a seminal form of energy in the islands. We're developing custom software to collect near-real-time, floor-level energy data and conducting two parallel competitions: one based on energy reductions, like other competitions, and another based on resident engagement in well-known behavioral change tools, such as making commitments, carrying out educational activities, and setting goals. A point system tracks the individual or floor-level actions, and both competitions will have winners.

In addition, unlike prior competitions, we will continue to track energy use after the competition ends, performing follow-up interviews to determine which floors did and did not sustain their changes. We'll document the impact of the behavioral change tools (if any) on these outcomes.

For more information, contact Philip Johnson at johnson@hawaii.edu.

MATERIALIZING ENERGY AND SMART ENERGY SYSTEMS

James Pierce and Eric Paulos,
Carnegie Mellon University

Many notions of smart energy systems rest on assumptions concerning the source of electricity (assumed to be irrelevant), the amount of available electricity (assumed to be infinite), and the type of energy (assumed to be electrical and centrally generated).

We're conducting research that challenges such assumptions through an approach to design that "materializes" energy. This approach proceeds from a view of energy as a "thing" that individuals in everyday contexts can collect (generate), keep (store), share (distribute), and activate (consume).

Figure 2. Shake-light bottle. Shaking the bottle collects energy, which is activated as light energy by removing the cap.

We explore several interrelated conceptual shifts in energy system design by combining critical design inquiry and exploratory prototyping. First is a shift away from viewing energy as a single undifferentiated phenomenon. For example, we explore applications for energy metadata that can inform dwellers of not only the amount of energy used but also the source of its generation (such as solar, wind, or geothermal), and other properties, such as age and distance traveled.

The second shift is from demand response to demand reduction. We explore methods for communicating the availability of solar, wind, and other energy sources, such as forecasts that promote altering consumption patterns to align more with energy availability.

Third is a shift from alternative energy to energy alternatives. For example, we explore the use of human-powered electrical devices (see Figure 2) as well as systems that encourage the displacement of electricity-consuming products for technologies less directly reliant on commodified energy sources.

For more information, visit www.living-environments.net or contact James Pierce at jjpierce@cs.cmu.edu.