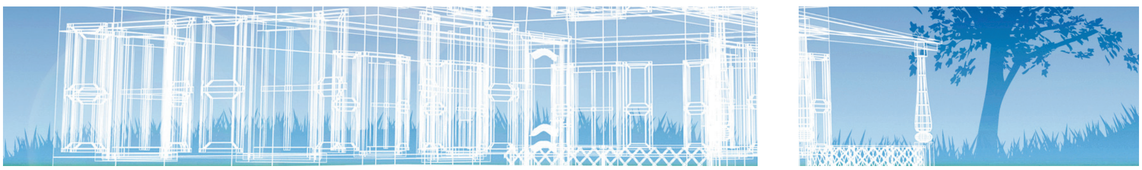
Smart Energy Systems



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The future has crept into our dwellings, and it's looking highly instrumented. In this multi-actuator world that we're forging, building occupants won't be able to flip a light switch or spin a thermostat to control building utilities—such quaint incarnations are living on borrowed time now, as there will be too many devices to control easily with such direct manipulation. Instead, these devices will need to be driven by inferred intention or simple, intuitive, collective control.

More crucially, energy conservation concerns will pull our hands off the dial as environments regulate themselves to balance occupant comfort against energy use. Networks of smart loads will vary their consumption to match fluctuations in wind and solar power and other renewable sources (at least until we safely scale up nuclear fission plants and eventually learn how to harness nuclear fusion practically). Smart energy systems will be a prime pervasive computing application area, dynamically mitigating energy use by measuring, inferring, manipulating, and leveraging human behavior and context across various domains and environments.

Over the past decade, healthcare became a lightning-rod application for pervasive computing researchers. These applications were driven by the clear needs of an expanding aging population, a predicted shortage in elder-care workers, and the maturing of appropriate technologies that fit in the pervasive rubric. Looking forward, smart energy management might well be the next siren that draws many of us to its challenging shores, as the pressing societal need for a solution is clear and there is a close fit with technologies in the scope of pervasive computing.

In This Issue

Research on energy regulation in smart homes and buildings is decades old, and many lessons have been learned in communities tangential to our own. With this in mind, we begin with "Look Back before Leaping Forward: Four Decades of Domestic Energy Inquiry," by Mike Hazas and his colleagues, which presents a broad survey of relevant research, much of which is well outside the standard pervasive computing community. "Domesticating Energy-Monitoring Systems: Challenges and Design Concerns," by Vasughi Sundramoorthy and her collaborators, takes such ideas into the field, summarizing findings from a UK study of home-deployed smart energy systems that involved both persuasive media and diverse energy-consumption sensing.

The next three articles explore aspects of and extensions to *nonintrusive load monitoring* (NILM). In this technique, machine-learning algorithms process measurements taken at a single point on a power line, identify devices loading the line at a given point in time, and isolate their power draws. In "Disaggregated End-Use Energy Sensing for the Smart Grid," Jon Froehlich and his colleagues present a history of these techniques. They also outline new approaches to identify load contributions on the basis of each device's unique transient and dynamic background voltage signatures. In addition, they describe extensions to their electrical approaches adapted to nonintrusively monitor the activities of other home utilities, such as water and gas. In "Circuit-Level Load Monitoring for Household Energy Management," Alan Marchiori and his colleagues tell how they use heuristic and Bayesian disaggregation techniques to separate and estimate different steady-state load contributions on the same electrical circuit. This approach allows dynamic tracking and comparison of different devices' loads. In "Nonintrusive Load-Shed Verification," David C. Bergman and his colleagues report on using NILM to verify that devices scheduled to be automatically deactivated under a load-shed program are indeed shut down. Such automated load shedding and deep demand-and-response are critical to realizing a stable, scalable smart grid.

Finally, in this issue's Spotlight department article, "Paying Attention to the Man behind the Curtain," Mary (Missy) L. Cummings and Kristopher M. Thornburg take a higher-level view. They explore how human managers will integrate with the complex control schemes that smart energy systems will enable. As information flows into the grid with very fine granularity, issues arise at several levels where human and machine supervision intersect. Cummings and Thornburg remind us that the Three Mile Island accident was due primarily to operator misunderstanding of sensor data from an overly complex control panel. They then discuss frameworks relevant to smart-grid management for allocating roles between humans and computers.

As the sensor and interaction systems we develop broadly diffuse into our environments, they'll produce information for many applications. Regulating energy consumption is an increasingly important application, so we're confident that pervasive computing research will have broad synergy with smart energy systems. The articles in this special issue afford us but a glimpse of the rich harvest to come.

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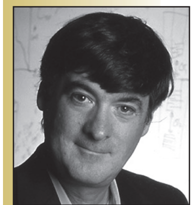

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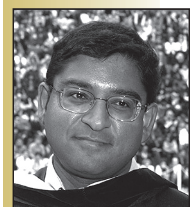

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