## A Framework for Enabling Energy-Aware Smart Facilities

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Virtually all homeowners and facility managers rely on aggregate monthly data (utility bills) to understand and manage their spending on electricity. Given that buildings (commercial and residential) account for approximately 70% of the electricity consumed in the United States, reducing this number by creating inexpensive ways to better support these actors during their energy-related decision making, could result in large savings for the country.

The goal of this research is to identify ways to inexpensively provide detailed information about energy consumption in buildings and facilitate conservation. By relying on aggregate data, homeowners and facility managers are blind to the contribution of individual appliances and activities to the overall numbers. And while there is adequate evidence that providing real-time, appliance-specific data allows users to achieve significant energy savings, the available solutions in the market are either inadequately granular or prohibitively expensive.

We are developing signal processing, machine learning, and data fusion techniques to extract actionable information from whole-building power meters and other available sensors. The main objectives of this are: (a) to create a framework for obtaining disaggregated, appliance-specific feedback about electricity consumption in a building by extracting high-value information from low-cost data sources; and (b) to investigate and develop data mining and machine learning algorithms for making use of appliance-specific electricity data, in order to provide users with recommendations on how to optimize their energy consumption and understand the effects of their energy-related decisions.

A series of residential buildings in Pittsburgh, PA are serving as a test-bed for evaluating and validating our approach. We have partnered with Blueroof Technologies, a non-profit corporation located in McKeesport, PA that researches, develops and provides affordable senior-citizen housing with integrated sensor networks and building automation systems. Blueroof provides access to their Research Cottages for this research project. Similarly, we have been working with Robert Bosch LLC, a leading global provider of consumer goods and building technology, who provides additional technical research assistance and expertise, while ensuring that the results of this project can have a strong potential for broad impact and success in the market.

Although we were awarded this grant late in 2009, already the first generation of our prototype system is able to correctly identify most of the appliances in the apartment building where it is installed, and can give energy consumption estimates for some appliances that are accurate to within 0 to 15% difference.

The main intellectual merit of the project is the development of a framework for evaluating energy-use-disaggregation methods according to their value for promoting energy conservation. The resulting data sets will be large enough to produce significant conclusions about the feasibility and effectiveness of the technology, and allow for the development of new models about the trends and patterns of appliance usage in buildings.

The behavioral impacts of providing users with real-time energy use feedback, even at the aggregate level, can produce savings of up to 10-15%. Larger savings are potentially achievable if more detailed data were available not only to the user but also to automated building control systems or to electricity suppliers. This last approach is the end-goal of the present project.