

NCER Assistance Agreement Final Report Executive Summary

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Project Title:

AWARE@home:

A Means to Profitably Integrate Environmental Conservation into the American Home

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Project Description and Objectives

The United States represents less than 5% of the world's population and consumes approximately 25% of its energy. Of the total energy consumption, residential and commercial consumers account for over a third of the total and per capita the U.S. consumes more energy than all but a few industrialized nations. Individual choices regarding utility consumption in the home are a major contributor to this excess consumption. In fact, reducing energy consumption of all US refrigerators by just 1% would save approximately \$140 million dollars in energy costs and 1.5 million tons of carbon released to the atmosphere each year. According to the US DOE Energy Information Administration, this amount is on the same order as the total energy-related carbon emissions of East Africa. This project, called **AWARE@home**, intends to achieve even greater environmental and cost savings.

The goal of this project is to reduce energy and water consumption in the U.S. residential and commercial sectors by creating real-time consumption awareness that can lead to tangible efforts by consumer to save money and protect the environment at the same time. While related technologies exist for industrial use, little has been done to bring energy and utility (e.g., electricity, gas, water) management to individual American homes. Our long-term goal in this project is to develop a system that could help millions of households reduce their expenditures on utility consumption by 10%. While modest and realistic sounding, such an accomplishment would represent a massive reduction in resource utilization and pollution that would begin to put the United States on a more environmentally sustainable path. The personalization of the sustainability issue through such education and *positive* feedback (cost savings) would likely have multiplying effects throughout the lives of citizens across the country.

AWARE@home is a simple-to-use and inexpensive tool for Americans to monitor their own utility consumption patterns. It empowers consumers to save money, conserve resources, and get more in-touch with their "environmental footprint" in both the short-term and the long-term. In the long term, the tool stands to serve the Nation well as a catalyst for positive change in infrastructure, markets, and government-citizen interaction. By reducing U.S. household consumption of natural gas, water, electricity, and gasoline, AWARE@home will help to shift the environmental focus and discussion from developing new infrastructure (putting solutions well off into the future) to much more inexpensively improving the existing infrastructure and consumption patterns today. It will also serve to relieve some of the pressure being placed on water scarce regions, as well as help to reduce dependence on foreign oil.

The AWARE@home prototype system, developed through EPA P³ funding, provides computer users the ability to view their own utility usage (natural gas, electricity, and oil) and expenditures with the click of a button. Since we believe that consumers are generally too busy to actively keep track of usage, we have created a simple interface that only asks the user to input the rates he or she pays for utilities and how much he or she is willing to spend on utilities each month. When this amount is to be exceeded in a given month (say, two weeks into the billing cycle) the system either sends an email or triggers a pop-up window (Figure 1).



Figure 1. Pop-up Alert from AWARE@home System.



Figure 2. Conceptual illustration of the AWARE@home system. Electronic accumulators and wireless transmitters connect to existing metering technologies (gas, electric, water). A USB-compatible receiver is utilized, along with a device to monitor & transmit electricity consumption of single appliances “plugged in to the wall”.

With no effort at all, except for a simple 5 minute up-front installation, the user is given information regarding excess consumption on which he or she can choose to act. As we have proven in this project, the AWARE@home concept is compatible with today’s metering technology, and existing meter designs can be modified with minimal overhead to be compatible with in-home networks (e.g., wireless 802.11b standard). This serves as a natural compliment to already on-going efforts by utility providers to retrofit utility meters with the capability to contact the service provider with consumption information (e.g., using cell phone and modem technology distinct from that utilized in the AWARE@home system). The full AWARE@home system is conceptualized in Figure 2.

The goal of Phase I of the EPA P³ project was to develop a prototype AWARE@home system with the ability to monitor natural gas, water, and electricity consumption on a household level and present it to the user through a clean, simple, and familiar interface. During Phase I, we successfully developed AWARE@home prototypes to monitor natural gas, water, and electricity consumption by retrofitting existing household metering devices. We also developed an AWARE@home “wireless electricity monitor” that can provide users information regarding the electricity consumption of individual appliances on the same network. The user simply plugs the appliance into the device, and can view its electricity consumption over the wireless network. The technological systems that were developed are shown collectively in Figure 3.

In addition to the technological developments in Phase I, we also investigated the potential market for the AWARE@home system via a project conducted by students in the Steven M.

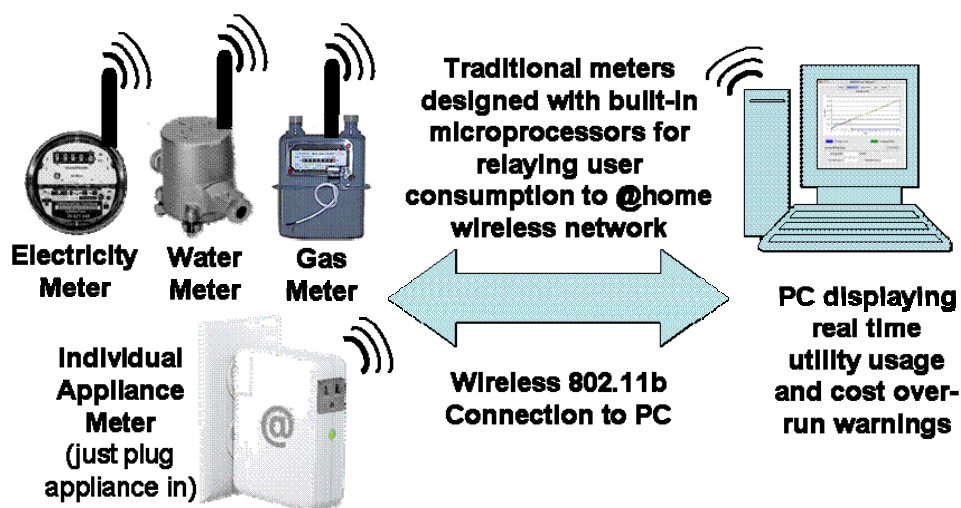


Figure 3. Summary of technology accomplishments during Phase I of EPA P³ program. Analog-to-digital transducers and wireless micro-processors have been integrated to existing meter designs and programmed to communicate on a wireless system. These figures are conceptual, as they would likely be developed in Phase II of the EPA P³ program. At the final competition, working versions of each of these meters will be shown in their existing prototype form. Note: the representation of the appliance meter is an edited graphic from AirPort Express (Apple Corporation, www.apple.com) and is used here for illustration purposes only.

Ross School of Business. In an eventual Phase II follow-up to this project, the capability of the existing prototype system will be extended so that it can monitor gasoline consumption in household cars. In future work, we would also test the AWARE@home system in numerous households so that we could better understand how users would interact with the technology. This knowledge would then be utilized to find the best strategies to turn AWARE@home monitoring data into conservation action.

Summary of Findings

We are pleased to report that 20 students from 4 University of Michigan (UM) classes took full responsibility for the AWARE@home project and led it to a successful Phase I outcome. Three classes were in the College of Engineering (ME 589: Eco-Design and Manufacturing, ENG 490: Engineering for Community, ME 450: Capstone Senior Design and Manufacturing), and one was in the Steven M. Ross School of Business (MKT 618: Marketing Research).

A prototype AWARE@home system was produced that includes both hardware and software components. On the hardware side AWARE@home compatible utility meters were designed and prototyped for in-home electricity, natural gas, and water consumption. A prototype AWARE@home meter for individual appliances was also prototyped. All the meters show up on a wireless network, and can interact with AWARE@home software designed by ENG 490 students during this project. For details on the technological approach, it is recommended to visit the following website: <http://www.engin.umich.edu/labs/EAST/@home/home.htm>

A number of high-level engineering design requirements were used as a guide during the development of the AWARE@home system. These requirements, which are listed below, describe the characteristics of the system:

- **Simple to use.** The computer interface has both basic and advanced functions. The installation process is simple and quick. A homeowner can install the software in under 5 minutes. Monthly monitoring can be conducted in a few minutes.
- **Robust, durable design that can fit inside existing meter packages.**
- **Wireless and FCC compliant.** Meter installation requires no wires to the host computer. The wireless module complies entirely with FCC Part 15 Class B. Wireless system is operational even in the presence of electromagnetic interference present in the home.
- **Stores Data without Computer.** Microprocessor must not only process and relay information by also store it in case computer is turned off or a power outage has occurred.
- **Inexpensive.** Expected manufacturing costs less than 50 dollars in production.
- **Uses less Energy than it Saves.** The microprocessor and sensors should consume a negligible amount of electricity.

Conclusions

A functioning prototype of the AWARE@home concept was developed that meets these specifications. For natural gas, electricity, and water meters, existing designs were re-designed to include AWARE@home compatible technology. We proved that this could be done with minimal impact on existing designs. In all cases, hall-effect sensors were utilized to convert existing analog read-outs to digital pulses that could be interpreted by a custom-programmed microprocessor with wireless-communication capability. The system time stamps the data, stores it, and relays it on wirelessly to a computer. The computer runs AWARE@home software developed during this project, and alerts users via email or pop-up window that cost targets for the month are likely to be exceeded unless the average consumption rate is reduced.

Proposed Phase II Objectives and Strategies

When Phase II of this project is undertaken, we will solicit the input of meter manufacturers and utility companies to understand how best to produce new meters with AWARE@home compatibility. We would also look to develop a similar metering system for gasoline consumption by automobiles. Thus, when the car is parked near the home, it can interact with the AWARE@home system. Phase II of the program would also investigate the impacts that access to AWARE@home information would have on the consumption patterns of users. This would be followed by a market evaluation, business opportunity matrix, and business development plan. Although we are interested in pursuing Phase II within the P³ program, we have determined that the resources available for Phase II do not match the requirements of the technology diffusion plan. We hope that it will be possible to find interested parties who would be willing to leverage available EPA resources, and re-apply to Phase II at a later time.

Publications/Presentations

Two in-depth reports were written as part of the AWARE@home project. The first describes the technological development (developed by students in ME 450) and the second describes the market analysis (performed by MKT 618 students). These can be found on the project website.

Supplemental Keywords

Energy efficiency, conservation, water shortage, public utility consumption, consumer education

Relevant Websites

<http://www.engin.umich.edu/labs/EAST/@home/home.htm>