IMPLEMENTING REAL-TIME RESOURCE USE FEEDBACK TO MOTIVATE AND EMPOWER CONSERVATION

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PROJECT OUTCOMES

Introduction and Summary:

The cumulative decisions made by individuals in the home and workplace are a significant determinant of the ecological health of the Great Lakes basin. The timing and the magnitude of water and electricity use in buildings have direct and indirect effects on the bioregion. How would consumers respond if they were immediately and continuously made aware of the environmental and economic costs of their personal choices? Oberlin College, the development company Sustainable Community Associates (SCA), the software company Lucid Design Group (LDG), and the City of Oberlin, with the aid of additional consultants, propose to develop a novel real-time feedback display technology. Consumers will receive information on their current rates of consumption and on the immediate and cumulative environmental and economic implications of this consumption.

The project objective is to develop, implement, evaluate and begin to disseminate an information technology system that engages, educates, motivates and empowers citizens and small businesses in the Great Lakes to be better stewards of the bioregion. Electricity and water consumption have a profound impact on ecosystems. Our hypothesis, which is well grounded in prior research, is that new feedback will stimulate citizens of the area to make measurable reductions in water and energy use that result in improved water and air quality and lessen regional contributions to climate change in the Great Lakes. During the grant period the project will focus on several pilot implementations within the City of Oberlin. However, our goal is to develop and implement technology with our eyes firmly focused on how this technology can be scaled up for deployment in communities throughout the Great Lakes basin bioregion.

Prior studies by members of our team and others demonstrate that resource use feedback technology deployed in a residential context can result in energy reductions between 5% to 56% [1-3]. Ultimately, we envision relatively low-cost products that seamlessly integrate with existing Internet and mobile phone applications such that little additional effort is necessary for consumers to become aware of and alter personal behavior in response to resource use feedback. In recognition that different people embrace different modes of communication, we will develop a product that allows the user to select multiple pathways for receiving information (e.g., web pages, desktop icons, public displays, email, text messaging, etc.). The goal is a product that can be widely adopted by citizens and small business owners throughout the Great Lakes basin.

With 33 million residents in the basin, even relatively modest reductions in energy and water use stimulated by the technology have the potential to profoundly benefit regional ecosystems. One of the benefits of the proposed approach is that the technology is modular in impact: the first person who reduces consumption as a result of exposure to the technology immediately begins to reduce her impact on Great Lakes ecosystems. Each additional individual who alters his/her behavior as a result of the system will add to the health and ecological integrity of the Great Lakes basin ecosystems. Specific environmental outcomes resulting from implementation of the technology can be measured two ways: by quantifying reductions in magnitude and changes in the timing of consumption and by monitoring changes in the environment that may be attributable to this conservation. Continuous assessment of immediate and cumulative ecological impact of reduced consumption is an inherent and defining feature of the technology that we will develop. Researchers and end-users will have access to a data base that contains one minute resolution records: total water conserved, total electricity saved, pounds of different pollution averted, and coincidence between peak demand and times when local ecosystems are most vulnerable to effects of consumption.

Ecological Context and Problem Addressed:

The Great Lakes contain 20% of the entire world's surface freshwater supply. The 33 million people (10% of the U.S. and 30% of the Canadian population) who inhabit the area that drains into the Great Lakes have a profound effect on ecological health of this critical region. In many ways their ecological impacts are directly related to their rates of resource consumption. The intertwined issues of energy consumption, water consumption, climate change and water quality pose particular challenges to the health of the Great Lakes basin and to its human inhabitants. Climate change is arguably the most significant environmental challenge now facing the region. The well-documented changes now underway are driven principally by the release of CO_2 associated with the consumption of fossil fuels [4]. Greenhouse gasses such as CO_2 are distinct from other pollutants, in that production anywhere in the world has an impact throughout the world. That said, energy consumption by inhabitants of the Great Lakes is responsible for a disproportionate share of the CO_2 emissions now beginning to change the ecology of this region. The six states that border the Great Lakes collectively represent the third largest economy in the world and use 16.5 quadrillion BTUs of energy each year [5]. Consumption in the Great Lakes region is responsible for 17% of U.S. greenhouse gas emissions and over 4% of total global greenhouse gas emissions. Although the effects are mediated through a global climate system, the residents of the Great Lakes basin have a special responsibility to protect the bioregion through personal actions that mitigate their own contributions to climate change.

Documented climatic changes already evident in the Great Lakes basin include: increased air and water temperatures; shorter winters and reduced ice cover; and increased frequency of extreme heat, rain and snow events [6]. Climate models indicate a continuation and amplification of negative environmental trends over the next century including: temperature increases from 5-20ºF, drier summers, wetter winters, declining lake and groundwater levels, increased periods of anoxia, and expanded dead zones [6]. Stream water quality is expected to decrease with increases in water temperature and more pulsed runoff associated with increased variability in precipitation [6]. Increased discharge of untreated sewage resulting from pulsing is expected to result in waterborne disease outbreaks and beach closings [7]. Negative impacts on water quality are likely to be exacerbated by reduced ecological services associated with the smaller extent and stressed state of wetland ecosystems [6]. Climate change will stress Great Lakes ecosystems and reduce ecological services; actions that ameliorate climate change and its impacts are critical to the health of the bioregion.

The ecological health of the area's ecosystems is also critical to the U.S. economy. Crops grown in Great Lakes states account for 25% of the total agricultural production in the U.S. [8]. Extreme heat, drought and flooding events are expected to decrease yield and increase costs of agricultural production across this bioregion [9]. As climate change progresses, pressure to withdraw additional water from the Great Lakes for use within and potentially outside of this region will likely rise in response to irrigation, drinking and other human needs. This will place additional stresses on Great Lakes ecosystems. It is also important to recognize that water and energy consumption are tightly linked in environmental and economic cause and effect. On one hand, the processes of purifying and transporting fresh and waste water are energy intensive; city governments often expend 25% to 50% of their total electricity budget on fresh and waste water treatment (USGS, http://water-energy.lbl.gov/node/12). On the other hand, electrical generation uses water for steam generation and cooling and accounts for 39% of total freshwater withdrawals and 3% of total fresh water consumption (*ibid*). In addition to contributing to climate change, the electrical generation process has environmental impacts on whole-basin ecosystems through production of local, regional and global air and water pollutants including thermal pollution, and deposition of acid particulates, and mercury.

The timing can be as important as the magnitude of consumption. Water consumption and wastewater production have the greatest environmental costs during droughts, when water availability is lowest, and after intense rainstorms and snowmelt, when stormwater infiltration exceeds wastewater treatment capacity. Electricity consumed during peak periods has parallel negative environmental impacts; intense periods of consumption usually occur during heat waves when plant, animal, and human health are particularly sensitive to air pollution generated by electricity generation. We urgently need new models of action that enlist all citizens, rather than a few, as active decision makers in efforts to minimize ecological harm and maximize ecological benefits.

Importance of Individual Behavior within the Built Environment:

The steady expansion in human resource use and its ecological consequences can be partially attributed to activities that take place within the built environment. Americans spend greater than 90% of their lives in buildings [10]. Residential and commercial buildings account for two-thirds of the electricity used in the U.S., 36% of U.S. greenhouse gasses, 9% of world greenhouse emissions, and 12% of U.S. fresh water consumption [11]. Each Great Lakes resident uses approximately 90 gallons of water per day indoors [12], with 30% flushed down toilets and 35% used for showers. During the summer up to 75% of municipally treated water is used to water lawns [12]. Fostering a more sustainable relationship between humans and the rest of the natural world is, in part, predicated on improving the environmental performance of buildings and building occupants.

In residential settings 50% of energy use is typically dependent on lifestyle and management choices, while the balance depends on the inherent properties of the building systems installed [13]. Personal choices, such as how long residents shower, when they do laundry, how they set thermostats and whether they leave lights and appliances on have a very real impact on the natural environment. Both financial and environmental concerns may provide a motivation for conservation. However, a disconnect typically exists between a person's general understanding of the implications of resource use and that individual's understanding of the implications of his/her own resource use choices [14]. Most North Americans report that they care deeply about the environment, believe there is scientific consensus that humans are the principle cause of climate change, and support efforts to join the international community in limiting greenhouse gas emissions [15]. Yet global attitudes are often entirely uncoupled from the short-term behavior of our citizenry. Every minute of every day, citizens and small business owners make short term decisions without understanding or accounting for the economic and environmental impacts of these decisions. The goal of improving the ecological integrity of Great Lakes basin ecosystems can not be achieved without addressing the problem of an information deficit around these everyday decisions.

Role of Feedback in Motivating Environmental Stewardship:

Our goal is to design information feedback technology to reduce and to modulate the timing of energy and water use in homes and workplaces. Feedback is an important tool that can link general knowledge, motivation and personal action. The relevant dictionary definition of feedback is "the return of a portion of the output of a process or system to the input, especially when used to maintain performance or to control a system or process" [16]. "Socio-technical" feedback is a circular information flow that includes both human decision makers and technology. In the context of controlling resource use in buildings, feedback entails making building occupants more directly and immediately aware of their resource use and of the financial and/or environmental consequences of this use (Fig. 1).

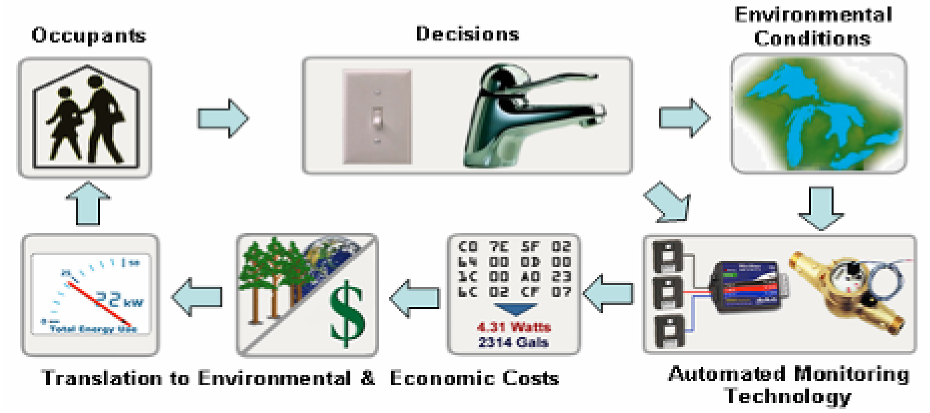


Figure 1. Arrows indicate the feedback pathway envisioned for this project. Residential and commercial building occupants are provided with real-time feedback on their electricity and water consumption in the context of real-time measures of community-level resource consumption and the environmental conditions affected by this consumption.

The premise of the proposed work is that real-time feedback on resource use, made possible through sophisticated information technology, can provide an incentive that positively alters both attitude and behavior of building occupants in ways that improve Great Lakes basin health. Prior peer-reviewed research conducted by members of this team and other scholars demonstrates that real-time, socio-technical feedback on resource use can reduce both electricity and water use. For example, a comprehensive review of 38 separate studies concluded that feedback on electricity use increases awareness and stimulates conservation [1]. Simple feedback devices displaying total electricity use and/or cumulative electricity use to rate-paying consumers typically result in electricity savings of 5% to 15% [1, 2]. Yet it is important to recognize that the studies just cited emphasized relatively basic modes of feedback delivery, generally in the form of simple digital displays or paper communications quantifying use in currencies of kWh consumed and financial costs. We believe that the potential of feedback as a tool for motivating conservation can be substantially enhanced by taking advantage of sophisticated display graphics, user interactivity, socially comparative data, and multiple modes of feedback delivery. For example, in a study that joined socially comparative feedback on electricity and water use with educational programming and resource reduction competitions, we documented up to 56% reductions in electricity use and 11% reductions in water use during a two-week "dorm energy competition" [3].

We believe that there is an enormous and as yet unrealized potential for harnessing sophisticated feedback to stimulate resource use conservation to benefit Great Lakes ecosystems. We propose to develop and implement a suite of technological approaches that utilize and enhance the impact of real-time feedback. The research team assembled for this grant is uniquely qualified to develop and test the technology to accomplish this. With the knowledge and experience gained through pilot programs, we will design a scalable approach so that proven technology and approaches can be implemented in residences and businesses throughout the Great Lakes bioregion.

Anticipated Outcomes: Ultimate Results

What follows is an implementation scenario that anticipates a variety of changes in resource costs and legislation:

1) The technology is developed, tested and refined in Oberlin residences and businesses. Applications developed prove effective in reducing and modifying patterns of energy and water use in ways that benefit ecosystems and save consumers money. (Mechanisms for disseminating knowledge and technology are described below.)
2) As more communities adopt the technology, hardware and software advances render the technology less costly and more effective. Hardware advances, including broad-scale deployment of real-time utility meters for both water and electricity, enable low-cost deployment of feedback displays in free-standing, single-family residences.
3) Costs of energy and of delivering and treating water continue to rise. Feedback technologies are increasingly recognized for their capacity to save money as well as to conserve environmental resources.

4) Price increases in water and energy are followed by wide adoption of demand-based pricing; consumers pay higher consumption rates at times when costs of delivery are highest (i.e., when the ratio of demand/available supply is highest). Two important developments substantially increase variability in both supply and demand. First, increased reliance on renewable energy creates a situation in which electricity pricing (and water processing costs) are weather dependent; electricity is most available and least expensive when wind within the regional grid is blowing hardest. Second, climate change enhances variability in weather. Heat waves and droughts rise in frequency and intensity, creating extended periods when the demand component of the ratio of demand/supply is high. The psychology of consumption changes such that consumers use feedback to synchronize personal resource use with variability in pricing.
5) National and regional legislation is passed that addresses the environmental costs of resource use. Real-time monitoring is used to create variable rate tariffs to discourage resource use during times when negative effects on human and ecological health are most severe. This provides a strong incentive for residents and businesses to reduce water use during periods of flooding and drought and lower energy use when pollutant byproducts are most likely to damage health.
6) A critical mass of users is achieved for social networking. It becomes common for users of MySpace, Facebook and other online social networks to insert graphics that allow them to publicly display and compare their resource use with others, to set public conservation goals and to challenge others to friendly resource-use reduction competitions. Individuals who participate in these social networks improve their personal behavior and participate in advancing a culture of environmental stewardship.
7) Feedback technology becomes ubiquitous. Lucid Design Group and new complementary and competing firms develop a range of real-time feedback technologies deployed in a majority of the residences and businesses within the Great Lakes. People become aware of and continuously adjust their resource-use behavior in the same way that they currently choose and modify attire based on weather conditions and forecasts.
8) Real-time feedback helps to transform human views of nature. Thoughtfully implemented socio-technical feedback stimulates greater connection to and concern for the environment, and motivates people to modify their lifestyles. Citizens who are initially motivated and empowered to take greater responsibility for their personal energy and water use in the home and business begin to recognize the impact of consumer and political choices that they make outside of utility consumption. They learn to think and behave differently and in ways that align personal and ecological benefits.

Anticipated Outcomes: Interim Results

The immediate goals of the project are to develop and implement a prototype feedback technology (described in sections that follow) that engages, educates, motivates and empowers those who experience it to reduce their resource use. Environmental benefits will be a direct result of this reduced consumption and include cleaner water, lower consumption during times when ecological implications of consumption for the Great Lakes basin ecosystems are greatest, and reduced contribution to climate change. Although it is unlikely that development will precisely follow the scenario described in the section immediately above, we are certain that the process of developing and implementing the technology in a pilot study will provide critical insights that advance the potential success of the product and approach. As described in the sections that follow, a key goal of the pilot project will be to test the efficacy of multiple approaches (modes) to delivering feedback, ranging from sophisticated data-rich graphical displays, to shared data in online social networking communities, to text messaging on cell phones. We fully anticipate that some components of this project will be more successful than others. The modularity and diversity of approaches that we are proposing in terms of both the situations in which we will deploy the technology and the modes of feedback we develop reduce the risk of failure. We have a high degree of confidence that the development and testing conducted as part of the prototype will enable us to build a robust product that is effective, scalable and ready to be deployed broadly in other communities. Hypotheses tested are described in detail in sections that follow.

PROJECT RATIONALE

Team Strategy:

Members of the team assembled for this work already have an established track record of developing successful feedback technology to motivate pro-environmental behavior. We seek to advance this work and apply it specifically to Great Lakes ecosystems by developing, deploying and testing a multi-scale information feedback system in several distinct residential and commercial settings. The feedback systems we develop will deliver four levels of environmentally contextualized information to end-users: 1) the monetary and environmental costs of electricity and water consumption in individual residencies and small businesses; 2) average consumption of multiple residencies and businesses within a shared facility (e.g., apartment buildings, condominiums, dormitories, and businesses that share building spaces); 3) aggregate electricity and water consumption at the scale of the entire city in which consumer monitoring occurs; and 4) water flow rates and water quality in the catchment basin (above and below wastewater treatment facilities) for the city in which monitoring occurs. The success of our project in reducing ecological impacts, and the specific features that lead to success, will be assessed by tracking conservation in water and electricity relative to baseline consumption and by quantifying changes in consumers' attitudes and psychological connection with nature after experiencing the technology.

Target Audiences:

As described in the first section of this proposal, we aim to develop a product and approach that can be deployed in communities throughout the Great Lakes region. Consumers will be motivated to use the technology because it will allow them to save money on utility costs and will provide information that enables them to become better stewards of the environment. City governments and utilities will find the technology desirable because it has the potential to modulate the time of resource use in ways that reduce the costs of electricity delivery and the effectiveness of water treatment.

The primary end-user audiences for the new technology will be individual households and small business owners and their customers. Within the residential community the system will provide unit-specific information for apartment residents, homeowners, and those living in institutional contexts (e.g., college students residing in dormitories and seniors in retirement communities). For businesses, we can distinguish between feedback intended to allow managers to directly reduce consumption and public displays that provide customer relations value by conveying to patrons that the business is a good environmental steward. A final target audience will be the general public; people who do not live in monitored buildings can still take advantage of real-time information on aggregate consumption and local environmental conditions to make decisions that benefit the environment.

In terms of marketing, we envision that the feedback hardware and software or more likely the services provided by the hardware and software will be sold to interested residences and businesses. Data depicting current environmental conditions and aggregate consumption by the entire community will be made available free of charge to the public. We will, however, investigate the potential to subsidize this public display on the website and on public computer monitors through sponsorships and advertising space.

Different Modes of Feedback for Different People:

Creating and testing new approaches to real-time data visualization and communication will be a central component of the proposed project. A suite of communication technologies and venues, including email, text messaging and online social networking have developed over the last several decades. Our approach recognizes that different people embrace different modes of receiving and transmitting information. Effective communication to diverse audiences and successful adoption of feedback therefore require that end-users have a range of options that allows them to customize information delivery to suit their desires (Fig. 2).

Figure 2. Modes of feedback. Different people (bottom) prefer different methods of receiving information feedback. The system developed will allow users to configure and customize feedback so that it is delivered in forms to which they are most receptive.

We propose to develop a system that allows users to select among eight modes of information delivery (Fig. 2):

1) Consumer Dashboard websites: Each monitored entity (i.e., household or small business) will be provided with its own "dashboard" interface on a password protected website that provides a real-time visualization of that entity's current resource consumption patterns. The dashboard will contextualize these patterns by displaying: a time series depicting past resource consumption by the particular entity over a variety of user-selected time scales; comparative resource consumption of similar monitored entities expressed on a standardized basis (e.g., per person or per square foot); aggregate water and electricity use within the entire city at a moment in time; current environmental conditions that inform decision making regarding resource use; and environmental implications of resource use on local, regional and global scales.

   Like the dashboard of a Toyota Prius, the home page interface will give the user a snapshot of immediate performance, while additional menu choices allow users to develop a deeper understanding of how choices and environmental conditions are affecting environmental performance. Figure 3 provides examples of the Consumer Dashboard. People have different learning styles. Different ways of displaying the monetary and environmental costs of resource use will therefore be made available. A key feature of the Consumer Dashboard will be the capacity for consumers to select from a wide variety of alternative environmentally contextualize energy and water currencies to show resource consumption. For example, for electricity end users will be able to select from units such as kWh, gallon of gas equivalents, CO_2, SO_2, NO_x mercury emissions and ecological land footprint. For water they can choose among units that include gallons, swimming pools, toilet flushes and water footprints.

   The Consumer Dashboard will be the most information-rich and interactive mode of engaging with the data. A competition module will allow users to compare their own resource use to that of others (see more complete description under social networking sites). We anticipate that the more abbreviated information communicated through the modes described below will stimulate users to visit their Consumer Dashboard for deeper investigation. The Consumer Dashboard will also contain comprehensive consumer tips and links to resources and sites that provide consumers with tools for reducing their resource use, for example to sites that allow consumers to evaluate the impact of upgrading or purchasing less resource consumptive appliances.

2) Bioregional Dashboard websites: This website will feature current environmental conditions and aggregate consumption trends within the city as a whole (Figure 4). This broader-scale feedback will allow all residents of the City of Oberlin to understand how the timing and magnitude of personal consumption choices contribute to and can ameliorate ecological impacts. Site visitors will receive current information about when water or energy use curtailment would most benefit the Great Lakes ecosystems. Conditions depicted will include water flow and water quality at fresh and wastewater treatment plants and within local river systems as well as the current rate of total electricity consumption within the local electrical grid. For monitored entities, the Bioregional Dashboard will be viewable as a seamless component of the Consumer Dashboard. For the general public the Bioregional Dashboard will be accessible as a stand-alone website.

3) Desktop screen gauges: Many computer users choose to display real-time news or events on their computer screen while conducting daily business. For example, weather forecast and stock prices are displayed on computer desktops as "widgets" or "gadgets" that provide updated information to computer users while they engage in other computer tasks. We will develop components of this type to display current resource use by an entity relative to typical use by that entity, use by others, or current environmental conditions. Users will be able to select one or more screen gauges from a predefined set (see sample small gauges in Figure 3).

4) Social networking websites and the competition module: Prior studies indicate that public commitments and socially comparative data displays are generally more effective at motivating behavioral change than private commitments and that social networking websites are a useful tool for motivating environmental commitment [17]. Sites like Facebook and MySpace already allow the insertion of third party display applications. We propose to develop a Facebook application that will enable a social network member who lives or works in a monitored entity to insert a range of simple real-time graphics on their Facebook profile. These will display the monitored entity's: current consumption, high and low consumption during a defined period, and consumption relative to a selected set of other entities in the online community who choose to share their performance data.

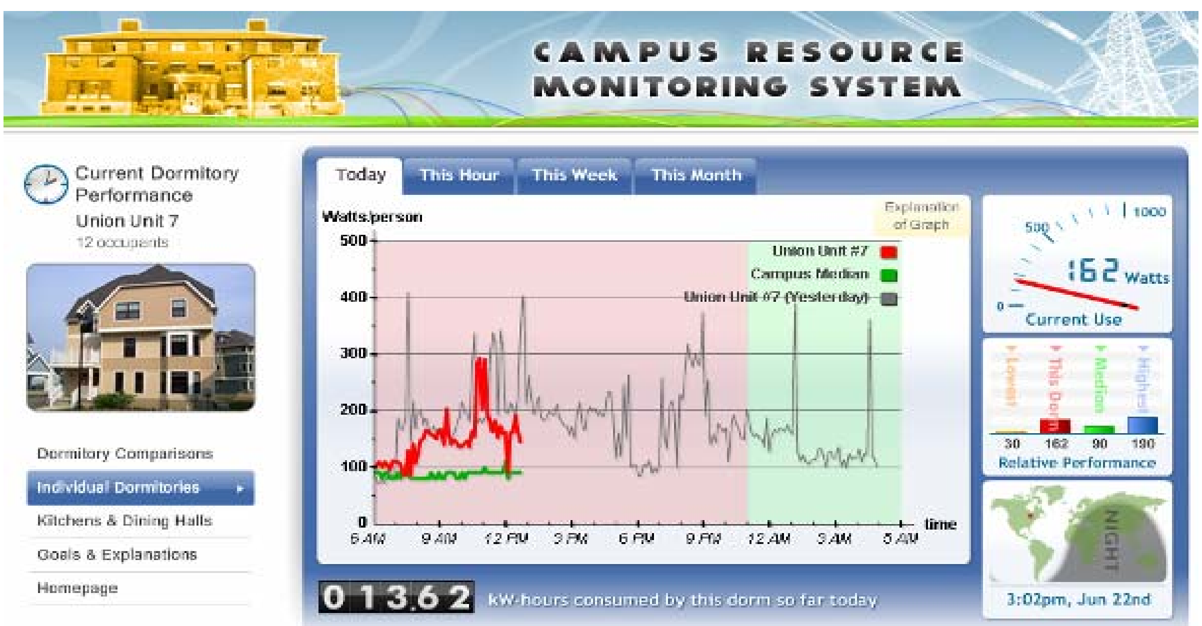
   The competition component of the Consumer Dashboard web site will allow individuals within a monitored entity to select a community of users with whom they wish to share and compare performance data. Users will be able to define groups (e.g., individual households or businesses, or groups of households and businesses) and to challenge others to friendly resource-reduction competitions. Competitors will strive to see who can reduce their resource use by the largest percentage over a defined time period. Prior research by team members indicates that competitions of this kind can result in substantial resource use reduction [3].

5) Email notifications: Viewers will have the option of specifying conditions that will trigger emails. For instance, a person in a monitored entity might choose to have an email message sent when rates of water or electricity use exceed set rates. Alternatively, a person could have messages sent at a specified interval (say once per day) with a summary of consumption data since the last message, or when conditions within the environment or electrical grid indicate that conservation is most warranted.

6) Text messages: The text message function would operate in a manner similar to the email notification option, although the text messages would necessarily be shorter.

7) "Environmental orbs": A number of researchers (including members of this team) have begun testing "ambient feedback" devices. Ambient feedback is delivered as a passive sensory experience and does not depend on interpretation of voice, text or visual graphics. For example, a device called an "ambient orb" (www.ambientdevices.com) can be programmed to displays different colors as a function of a condition. The Oberlin team is already experimenting with this technology and recently developed and deployed "energy orbs" in the lobbies of six Oberlin dormitories. The orbs are programmed to shift from bright green to yellow to red to signify electricity consumption below, equal to, or above typical electricity consumption for that time of the day. As part of this grant, we propose further development and testing of ambient orb technology as a mechanism for stimulating conservation in residential and commercial settings.

8) Public kiosks and large screen displays: Displays of information in public gathering places provide a final and important means of delivering information to both monitored entities and to general audiences. Here we envision large screen displays in downtown public spaces, such as storefronts or bus stops. Displays would cycle through a sequence alternating among information of general interest to a diverse audience (e.g., a local events calendar, weather forecasts and potentially advertisements of local businesses as a mechanism for underwriting the display), displays of current environmental conditions (water flow, water quality and total electrical use data) and aggregate data associated with the consumption of monitored facilities to highlight commitments to environmental stewardship. Although the majority of individuals seeing these public displays may not live or work in a directly monitored entity, we hypothesize that exposure to typical patterns of consumption by others may stimulate citizens to consider more carefully their own consumption choices. We will generate two versions of the public display, one which operates as a fixed sequence for large screens, and a second touch-screen version for use in the lobbies of monitored buildings. The touch screen version will provide for interactivity.



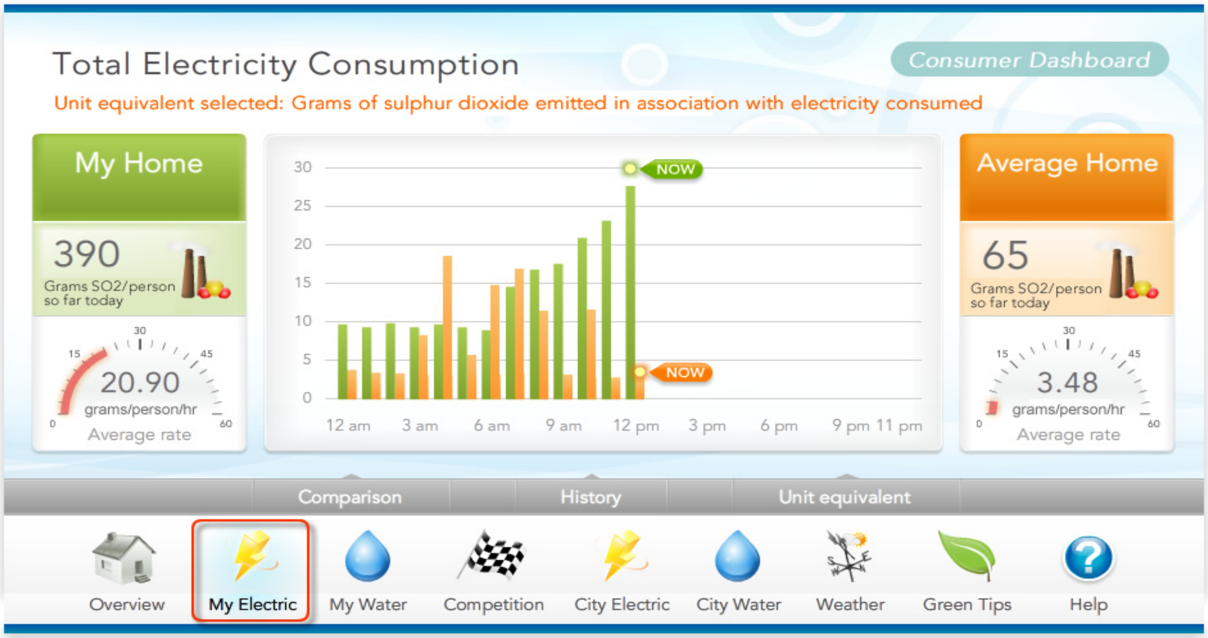


Figure 3. Examples of Consumer Dashboard website. The first panel (bottom of previous page) is a screen shot of a dashboard that Lucid Design Group and Oberlin College previously developed for displaying real-time resource use in college dormitories (current performance right now can be viewed at www.oberlin.edu/dormenergy). The second panel (immediately above) is a mock-up of the type of display that we envision creating for the current project. On the page depicted, the user has selected to view the environmental performance of her apartment or house in terms of sulfur dioxide emissions associated with electricity generation over the last day compared to average emissions for other monitored residences during the same period.

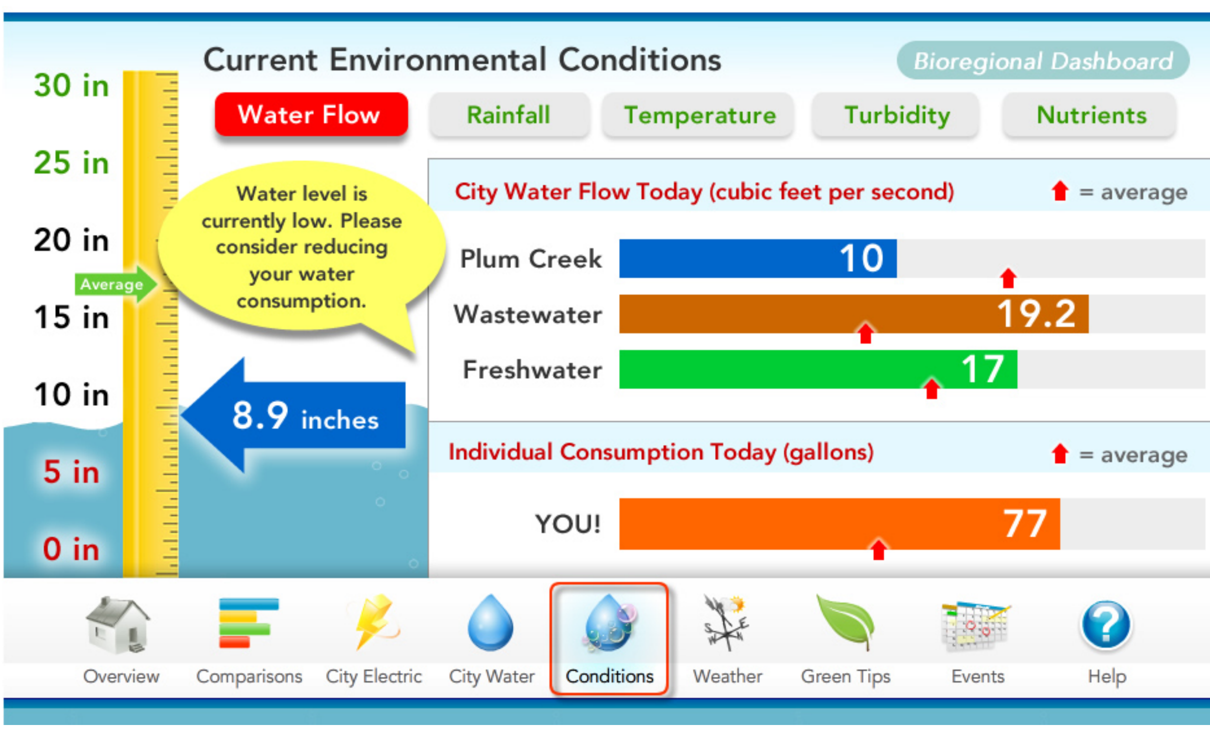


Figure 4. Mock-up of the Bioregional Dashboard displaying environmental conditions that inform resource use. The selected page features personal water use in the context of real-time measures of water flow through fresh and wastewater treatment plants. Because stream water levels are below an alarm level, a tip is displayed to encourage water conservation. A series of other pages within the Bioregional Dashboard would provide information on water quality parameters and on patterns of aggregate electricity consumption within the City.

A simple web interface will be developed that allows those living in monitored entities to configure communication choices so that they receive only the types of feedback that they actively select (Fig. 2). In addition to specifying desired modes of communication, end-users will be prompted to provide information that allows their unit to be compared with other units. Such information will include housing type (e.g., apartment, condominium or free-standing house), number of residents or employees in the monitored entity, square footage of space, and business type (restaurant, retail, manufacturing, etc.). Individuals will be asked to specify whether they wish to share performance data on their entity and with which other entities (or online communities) they wish to share data.

Data Acquisition:

The capacity to display real-time data is obviously contingent on the availability of that data. Our objective is to provide citizens of the Great Lakes bioregion with visualizations of personal consumption in the contexts of larger patterns of use and its direct effect on the local environment. Technological developments on several fronts are rendering data of this kind more readily available:

1) Resource consumption data for buildings: There are a variety of conduits through which data can be collected from residential and commercial consumers. Modern commercial buildings (including many apartments) often incorporate sophisticated building automation systems for the purpose of tracking and regulating heating, cooling, ventilation, lighting and other systems. Sensors that are unnecessary for control purposes but are useful for environmental feedback can be easily added to building automation systems. Where no building automation system exists, water and electricity flow sensors can be installed and wired to independent Internet-enabled datalogging devices that render these data available to a password protected server. Finally, an increasing number of utilities (including water and electricity utilities in Oberlin) are moving towards automated reading of both electricity and water meters via radio signals broadcast from each consumer's utility meter to collection stations. Lucid Design Group, a partner on this proposal, has developed IRIS™, a software product designed to communicate with independent data loggers and building automation systems. IRIS™ has been well tested and is commercially available for use in this environment. Initial discussions with several meter automation companies including Itron indicate that it may be possible to modify IRIS™ to capture utility data collected by radio signal and then make these data available for residential display. Although there are challenges associated with obtaining sufficiently fine scale resolution data through this conduit, it is worth pursuing because it would enable data display without the need for new hardware installation.

2) Resource consumption data at the whole-city scale: Municipal water treatment plants (fresh and waste water) and municipal electricity companies are excellent potential sources for tracking real-time consumption at the whole-city scale. Advances in data monitoring and management facilitate use of this information in a new context to educate and motivate citizens. For example, many water treatment facilities now have automated sensing technology that provides an ongoing record of ecologically important variables such as flow rate, pH, turbidity, conductivity and dissolved oxygen. New technologies are becoming available to monitor inorganic nutrient concentrations and total organic carbon on a continuing basis. Water and power utility facilities are being upgraded with "Supervisory Control and Data Acquisition" (SCADA) systems that allow data to be accessed over the web in real time. Lucid's IRIS™ software has the capacity to access, store and post process data from modern SCADA systems.

3) Local environmental quality data: Both fresh and wastewater treatment facilities often include monitoring of water quality in the stream from which water is extracted or delivered. Even if stream water is not currently monitored, existing SCADA infrastructure typically allows for relatively cost effective incorporation of additional sensors to assess or enhance assessment of stream water quality. Increasingly, weather feeds are also available that provide ready access to local weather conditions in real time. Temperature and precipitation can be incorporated into displays to provide users with additional context for interpreting the environmental implications of their resource use.

Oberlin as a Venue for Prototyping:

The City of Oberlin, Oberlin citizens, Oberlin College and Oberlin undergraduates offer an ideal environment for prototyping the proposed feedback technology. Both the City and College are recognized for their environmental initiatives. The College is nationally known for its environmental studies program, and it was one of the first institutions of higher education to adopt a comprehensive environmental policy, commit to climate neutrality, and adopt a LEED Silver or better requirement for all new construction. The City of Oberlin adopted a comprehensive sustainability policy in 2001, has endorsed climate stewardship and is an active participant in the International Council for Local Environmental Initiatives (ICLEI). At the instruction of City Council, Oberlin Municipal Light and Power has aggressively pursued green energy and currently includes green hydroelectric, landfill gas and wind power in its portfolio. In February 2008 Oberlin was one of only three communities participating in AMP Ohio to vote down a 50-year investment in a new coal-fired power plant. This context of environmental consciousness and policy suggests that the Oberlin community has promising potential for success as an “early adopter” of innovative real-time display technology. Successful examples of early adoption are critical to the future success of a new technology.

Yet despite their forward-thinking policy and actions, the City and College suffer from many of the over-consumption and pollution challenges that face other communities in the Great Lakes region. Over 80% of the City of Oberlin’s electricity is currently produced by burning coal. Coal produces more greenhouse gasses per unit of electricity generated than any other fuel source and is responsible for the release of sulfur dioxide (see Fig. 3), mercury, particulates, radionucleotides, and other pollutants that damage the health of Great Lakes ecosystems and its human inhabitants.

With respect to water quality, the City of Oberlin is located within the watershed of Plum Creek, a tributary of the West Branch of the Black River. The Black River is one of 43 river systems in the Great Lakes that the EPA has termed “Areas of Concern” and is the only system in which the entire drainage basin has been designated an Area of Concern. Thus, much more needs to be done to mitigate the environmental impacts of the community. The proposed system will provide the necessary feedback to motivate residents and small businesses to modify their behaviors in ways that increase the health of the Great Lakes ecosystems. The Mayor of Oberlin and other members of City Council as well as the President of Oberlin College have expressed strong support for the project (see letter from Mayor Sonner in attachments). Successful pilot implementation of the technology in Oberlin will draw considerable regional attention and will provide an excellent model for other communities.

A number of existing and planned developments within the City and College provide an exceptional opportunity for broadly testing the efficacy of real-time monitoring and display. Ultimately we envision a marketing model in which consumers pay a modest fee for monitoring and display services while the Bioregional Dashboard is sponsored through advertising. However, our intent is for grant money to fund product development and the delivery of feedback services throughout the period of prototyping. As described below, grant funds would allow us to test the system in five diverse settings.

1) <u>Sustainable Community Associates:</u>
SCA (described in partner section) will break ground in fall 2008 on a new development that will combine mixed-income housing with retail space. Businesses and residents within this new development will provide a key testing ground for the technology to be developed. Electricity and water flow sensors will be installed in each of the 53 apartments and six commercial spaces of the development. These will be wired to datalogging equipment, data will be sent to a central server for post-processing, and feedback on use will be delivered within one minute of being collected. For the duration of the grant the user community will have full and free access to all modes of data delivery described above. After this period, residents and businesses will have the option of continuing to receive the monitoring information at the standard service rate. A large flat screen display will be installed in a storefront window facing a bus stop for public information display, and a touch screen will be included in the lobby.

2) <u>SEED House</u>:
As recently featured in a front-page story in *The New York Times*, Oberlin College renovated a residential house in the City of Oberlin to serve as a showcase for environmentally sensitive living. A goal of this project is to demonstrate home-scale technologies and behavioral changes homeowners can employ to reduce substantially the ecological footprint of residential living. As part of initial renovations, the house has been instrumented with an ultra-high resolution monitoring technology; each individual room in the duplex is separately monitored for electricity use and temperature. Hot and cold water and natural gas are monitored independently on each side of the duplex. The building has also been wired to accommodate “environmental orbs” (see description above) as a mode of feedback. The monitoring system already installed in SEED house provides a unique opportunity to explore an end-point in terms of assessing the efficacy of high-resolution socially comparative feedback technology. The capacity exists to compare the electricity consumption of each individual member of the household. Technology installed enables what we believe will be the first instance in which the total combined carbon footprint of all utilities can be provided in real-time in a residential complex. Although the monitoring infrastructure has been installed, a data display system has yet to be developed for this facility and is not currently funded. A grant from the GLPF would allow us to develop a sophisticated feedback interface that is

consistent with that employed in the other installations, but will take advantage of the ultra-high resolution data. The grant would also allow us to assess the full range of feedback modes described above, but in the context of ultra-high resolution of feedback. Research on SEED house will provide critical insight into application of the technology within free standing houses, the efficacy of environmental orbs as a mode of feedback the degree of resolution in feedback that is most effective in motivating behavioral changes.

3) Other residential houses and apartment buildings occupied by students:
Twelve other residential houses occupied by 144 Oberlin students are already outfitted with a data tracking and display system (e.g., Fig. 3). If funded, we would redevelop the current feedback system so that it can be used to assess the efficacy of environmentally contextualized data and multiple modes of feedback as a mechanism for improving the health of the Great Lakes ecosystems. In 2002 Oberlin College purchased the 67-unit "Firelands" apartment complex in downtown Oberlin that previously housed senior citizens. We propose to instrument this building with sensors and datalogging equipment that allow for monitoring and display of electricity use in each individual apartment. This would provide a valuable parallel to the SCA complex with greater flexibility for experimental control to assess different approaches to feedback.

4) Oberlin College dormitories:
The College's "Campus Resource Monitoring System" (www.oberlin.edu/dormenergy), designed and built as a collaborative effort between the College and Lucid Design Group, has received awards from the U.S. EPA and the National Wildlife Federation and considerable national attention as a model of real-time feedback technology as a mechanism for stimulating environmental stewardship. Currently a majority of Oberlin students live within dorms that provide real-time feedback on whole-dormitory scale electricity consumption. Prior research with the feedback system documented that during a two-week resource reduction competition students used the feedback technology to: conserve 68,000 kWh of electricity and 20,500 gallons of water, save $5,100 on these utilities and reduce emissions by 150,000 lbs of CO_2, 1,400 lbs of SO_2 and 500 lbs of NO_x [3]. As part of the GLPF program we propose to expand this system to monitor electricity and total water consumption in all dormitories on campus and to redevelop the display system to allow assessment of efficacy of the different modes of feedback described in this proposal. The diversity of students and housing types provides a phenomenal situation for testing the efficacy of the technology.

5) Residential houses via automated remote utility meter reading:
As discussed, new technology is emerging and being deployed for residential water and electricity meters in Oberlin homes that allows for remote meter readings. Since this proposal was originally submitted, our research team has actively engaged in discussion with Oberlin City personnel and with metering manufacturers to explore the feasibility of accessing data from this system for real time display to residences. The City of Oberlin has already installed transmitter devices that allow residential and commercial electrical meters to be read automatically from a distance with a radio receiver. The City is currently planning installation of water meters that transmit readings via radio signal. This transmitter technology appears to hold great promise of eventually enabling real-time feedback displays that build on planned improvements to infrastructure, with no additional hardware cost to the home owner. However, there remain some critical unknowns regarding technology, costs and the timing of installation in Oberlin. As part of this grant, we therefore propose to do a relatively modest scoping work to further assess the feasibility of this technology to determine how it might be employed to render feedback more cost effective.

6) Aggregate consumption and environmental effects data:
The city of Oberlin is a critical partner in the proposed work. Existing and enhanced municipal infrastructure and monitoring equipment would be used to collect data on aggregate city-wide consumption and real-time conditions in the watershed for display on the Bioregional Dashboard. Oberlin's Municipal Wastewater Treatment Plant (WTP) is located on Plum Creek at the downstream end of the City of Oberlin. We have verified that the WTP's SCADA system, which was upgraded over the last three years, can be made accessible to Lucid's IRIS™ software to make available real-time data on the monitored variables that are used to assess water flow and quality within the treatment system. With funds from a GLPF grant, we would add additional sensors immediately above and below the outfall from this plant to provide additional data on the ecological health of the watershed. Water quality parameters monitored will include water flow rates through Plum Creek and the wastewater treatment plant and dissolved oxygen, pH, conductivity, turbidity, ammonium (NH_4) and total organic carbon (TOC). Depth would be monitored upstream of the water treatment plant, and a rating curve will be developed to convert depth to stream flow volume. Flow rates in the river and through the treatment plant will

provide an important reference variable for informing domestic water consumption; the Bioregional Dashboard will inform consumers of conditions that warrant extra vigilance with respect to conservation (e.g. Fig. 4). Oberlin's freshwater treatment plant is scheduled for a SCADA system upgrade in 2009. When this occurs, data on total freshwater consumption will be accessed and displayed as part of the Bioregional Dashboard. The SCADA system used to monitor electricity consumption within Oberlin is scheduled for an upgrade in 2009. If the GLPF grant is successful, Oberlin Municipal Light and Power has committed to specifying an upgrade that will provide data that can be accessed by Lucid Design Group's IRIS™ software for display on the Bioregional Dashboard.

Oberlin as a Prototype and Model for Implementation:

The implementation described above targets multiple contexts for technology deployment that include a range of residential settings (apartments, free-standing houses and dormitories) and a range of end-users (high- and low-income apartment-owners and renters, small businesses and students). This diversity provides the team with the capacity to broadly assess the conditions necessary for successful application of the technology within Great Lakes communities. We view the monitoring and display system developed and tested in the Sustainable Community Associates facility as a particularly important component of the study because it provides a test of the technology in a traditional residential and business setting. Deployment of the technology in SEED house, the Firelands apartment complex and in other Oberlin College residential settings are equally vital to advancing the development of technology that improves ecological health.

The role of students and college dormitories as an audience and venue in this prototype deserves special consideration. Although representing a relatively small percentage of overall housing within the Great Lakes, we believe that the living environment experienced by students represents an important venue and market for feedback technology. For many citizens of the Great Lakes, college dormitories are their first experience living away from home. As such, the environmental consciousness and behaviors that our citizens develop in this context inform the development of the decision making process that they will employ for the rest of their lives. In surveys, a majority of students exposed to real-time resource use feedback in the context of Oberlin dormitory living reported that this experience allowed them to teach themselves new conservation strategies that they intend to employ in the future and outside of the college environment [3]. Thus, behaviors learned in college may have a profound impact on the health of the Great Lakes region. There is also a demonstrated market for feedback technology in dormitories; over 9,000 students live in dormitories served with displays designed and managed by Lucid Design Group.

In addition to representing an important audience for feedback, student housing is an ideal venue for rapid development of feedback technology for a number of reasons. First, students are a relatively captive audience that is generally receptive to participating in research. In prior work our team has obtained a very high response rate to surveys used to measure changes in knowledge, attitude and behavior in response to feedback. Second, students typically change residency once per year, and approximately 25% of the total student population is replaced each year. This provides a unique opportunity for controlled studies that assess different approaches on a regularly refreshed audience of participants. Third, in many cases the housing units that students occupy (houses, apartments or dormitories) consist of nearly identical units that allow a high degree of control and replication in experimental design. Fourth, the student community has been ahead of the larger population in understanding the considerable environmental challenges faced at this moment in history. Fifth, the fact that students typically do *not* receive utility bills for their residential consumption allows us to isolate environmental concern as a sole motivating factor for conservation. Finally, students are inherently experimental and are very often early adopters of new technology and modes of communication that later become pervasive within society as a whole (e.g., email, Internet, cell phones, text messaging, social networking, etc.). For these reasons we view college students as an enormously valuable resource for testing the technology that we hope to implement within the larger citizenry of the Great Lakes bioregion.

Public and private decision makers and analysts also represent a key audience for research on the technology's efficacy and potential for dissemination. This sector includes government officials; the directors and managers of local utilities; developers, architects, and engineers; institutions of higher education that can coordinate and disseminate research and serve as early adopters; business leaders; and regional environmental organizations. The project team includes individuals from all of these constituencies, and their qualifications are described below and in the attached resumes and letters of support.

Research Questions and Methods of Assessment:

The overall hypothesis we will test is that real-time environmentally contextualized feedback motivates changes in attitudes and behavior that improve the health of the Great Lakes ecosystems. The sections above discuss how the timing and magnitude of resource use can negatively affect ecological health. Reductions in consumption and modulation in the timing of consumption that reduce impacts will be the direct target of the work we do. As such, we will quantify impacts on ecological health by comparing the magnitude and timing of consumption with and without the presence of real-time feedback. The two approaches used to accomplish this will be a comparison of changes in consumption before and after feedback technology is provided and a comparison of experimental units (apartments, houses and dorms) that receive feedback with similar units that do not receive feedback. The monitoring technology employed creates a high resolution database that will provide a comprehensive one-minute resolution record of resource consumption in monitored entities with which to precisely quantify resource-use changes and reductions.

In addition to assessing actual resource-use conservation, we recognize that full evaluation of the technology will require accurate quantification of the different modes of delivery as well as an assessment of the psychological mechanisms that motivate stewardship in response to feedback. The following questions and techniques will be employed to assess the technology:

1) *How effective are different modes of data delivery? How can they be made more effective?* This will be assessed through focus groups, surveys and analysis of data quantifying the utilization of the different modes of feedback provided (e.g., web traffic to different pages of the site, number of text messages and emails sent, etc.). Lucid Design Group has already created a software component that generates a detailed database that records visitation to different components within Building Dashboard^{TM} websites. The new feedback modes will be developed in a way that uses the same database to track utilization.

2) *What is the effect of this interactive feedback technology on attitude, on psychological connection with nature and on behavior?* The "Connectedness with Nature Scale" (CNS), developed by team members Frantz and Mayer [18], will provide one critical measure of the psychological impact of exposure to the technology. The effects of behavioral changes will be directly quantified as actual reductions in resource use. Before and after surveys will be used to determine the behavioral changes that people employ to reduce resource use in response to feedback.

3) *What is the effect of prior attitude towards the environment on receptiveness to the feedback technology?* This will be assessed by relating CNS to resource consumption data. Receptiveness has important implications for the wider dissemination of feedback systems. For instance, if unreceptive individuals demonstrate little to no behavior change, then wide-scale implementation should strongly target receptive demographic categories first.

4) *What is the relative effectiveness of resource-use feedback in the context of individual and community-based data presentation?* As discussed, residents of monitored entities will be able to join groups whose members voluntarily share and compare their own resource use data with others. Patterns of resource use and CNS among groups that receive feedback in individual contexts and in group contexts will be assessed.

5) *How effective are competitions and other possible incentives in motivating conservation?* We will create voluntary groups that receive different incentive treatments and directly compare resource-use behavior among these groups.

6) *How do different degrees of data resolution affect attitudes and behaviors?* We will assess this by comparing patterns of resource use and survey responses of individuals residing in entities that have different levels of resource use. SEED House will offer ultra-high resolution feedback, apartments and houses will provide a high-intermediate level, monitoring at the level of whole dormitories will give a low-intermediate level, and aggregate consumption by the entire city will be the lowest level resolution.

Risk Minimization:

Given members' significant experience developing and assessing socio-technical feedback systems, the project team is well-positioned to undertake the proposed work. A suite of different modes of delivering feedback is intentionally proposed, with the recognition that some methods will prove easier to develop and more successful than others. We will take an adaptive management approach to the project, assessing progress throughout to identify and develop the most successful technological approaches and strategies. Faculty from the University of California, Berkeley (Edward Arens) and Carnegie Mellon University (Jen Mankoff) with expertise in the fields of architecture, resource-use display and human-computer interactivity will serve as consultants for the project, providing independent perspectives on progress during and at the end of the grant.

PLAN OF WORK

Major Tasks:

The text and timeline (table 1) below detail the sequence of tasks necessary to accomplish the goals and objectives outlined above. The project manager, Dr. John Petersen (Oberlin College), will monitor progress on all components. If the project is funded he will take a leave from teaching and chairing Oberlin's Environmental Studies Program for the 2009-10 academic year to oversee rapid progress on technology development, research, implementation and any early-course corrections that prove necessary.

1) Sustainable Community Associates Monitoring:
In preparation for this application, SCA, its architects and engineers for the development, and Lucid Design Group have had detailed discussions. Changes have been made to the design to accommodate the addition of water and electricity monitoring equipment for each apartment and for each business in the complex. Bid documents are being prepared that would allow for installation should funds be available. Contractors supervised by SCA engineers with additional oversight from Petersen will ensure appropriate installation of flow meters with funding from the grant.

2) Oberlin College Monitoring:
Expansion of the Campus Resource Monitoring System will entail surveying the wiring of un-monitored residences on the Oberlin campus and production of bid documents necessary to hire contractors to install monitoring equipment. This would be accomplished by Petersen working with College facilities planning personnel. Costs for this component will be covered by Oberlin College. An electrical contractor will be hired to complete installation under the supervision of College facilities staff and Petersen. The product will be a completed monitoring system in the remaining dorms. Funding is requested for labor and materials for the installation of sensors, with estimates based on previous installations.

3) City of Oberlin Monitoring:
This work will involve close cooperation between Lucid Design Group technical staff and personnel at Oberlin's municipal water and power facilities. Preliminary discussions indicate that data monitored through the SCADA system for the waste water treatment plant will be relatively easy to access with Lucid's IRIS™ software, and this will be one of the first tasks accomplished as these data will be necessary for development of a beta version of a Bioregional Dashboard that will display water flow through the waste water treatment plant. The director of the wastewater treatment plant will work with Petersen to finalize selection of the water quality monitoring sensors which plant personnel will then install. Scheduled upgrades to the SCADA systems for fresh water treatment plant and the electrical distribution system will allow for data access in 2009 or early 2010, at which point sensors will be added. Further discussions will elucidate opportunities that exist in association with the City's new automated meter reading program as the City's plans develop.

4) Lucid Design Group Software and Display Development:
Lucid will work closely with faculty at Oberlin College and with consultation from Jennifer Mankoff to design and develop the dashboard components and other tools necessary to provide different modes of feedback. Since the "Consumer Dashboard" and the public displays will essentially be implementations of Lucid's "Building Dashboard™" software, this will be a relatively easy component to begin developing. Because of differences in aggregation, the dashboards for SCA, SEED House and Oberlin dorms will be somewhat different. The social networking module and the email and text messaging modules will be new software, and Lucid Design Group will require significant development time.

5) Research, Assessment and Dissemination:
The overall research questions and approach are described in the preceding section. Assessment will focus on quantifying energy and water savings, changes in the environment and changes in attitude and behavior. Oberlin faculty, in consultation with the consultants, will take the lead on developing surveys and other research instruments to evaluate specific changes in attitude and behavior in response to user experience with the different content, different currencies of resource use and different modes of data delivery. Several of the protocols we will employ are described in prior research by the Oberlin team [3, 18]. Research will begin separately in the different user groups as soon as necessary display components have been completed. Data analysis will also begin early in the process, with publishable results from early components of the research anticipated by 2010. As described below, all members of the team will play a role in disseminating findings.

Lucid Design Group will take the lead in marketing the successful technological approaches developed. Through prior market research conducted as part of its award winning business plan, Lucid has already determined that substantial commercial, institutional and residential markets exist for real-time feedback of environmental performance. The research and technology developed as a result of the proposed research will provide the ammunition needed in Lucid's sales process to make a compelling and defensible case to potential customers. Lucid’s marketing efforts will focus first on its existing sales venues which include universities, corporations, energy service companies and developers. We anticipate that the research will open up two new potential markets, municipal electric utilities and home owners. Lucid will work with utilities, corporate partners and non-profit partners to explore marketing approaches that will allow for broad dissemination of the technology to the residential market through OEM relationships.

Regular engagement with desired end-users will be a critical component of steps number 4 and number 5 above. In previous research we have found that meetings with a relatively small but diverse focus group of end-users and potential end-users at multiple stages in the process of designing user-interfaces results in efficient display design. Given the value that SCA customers are likely to place on environmental stewardship, we anticipate that it will be easy to recruit apartment owners, renters and business owners to participate in focus groups. We have had no difficulty attracting student focus groups.

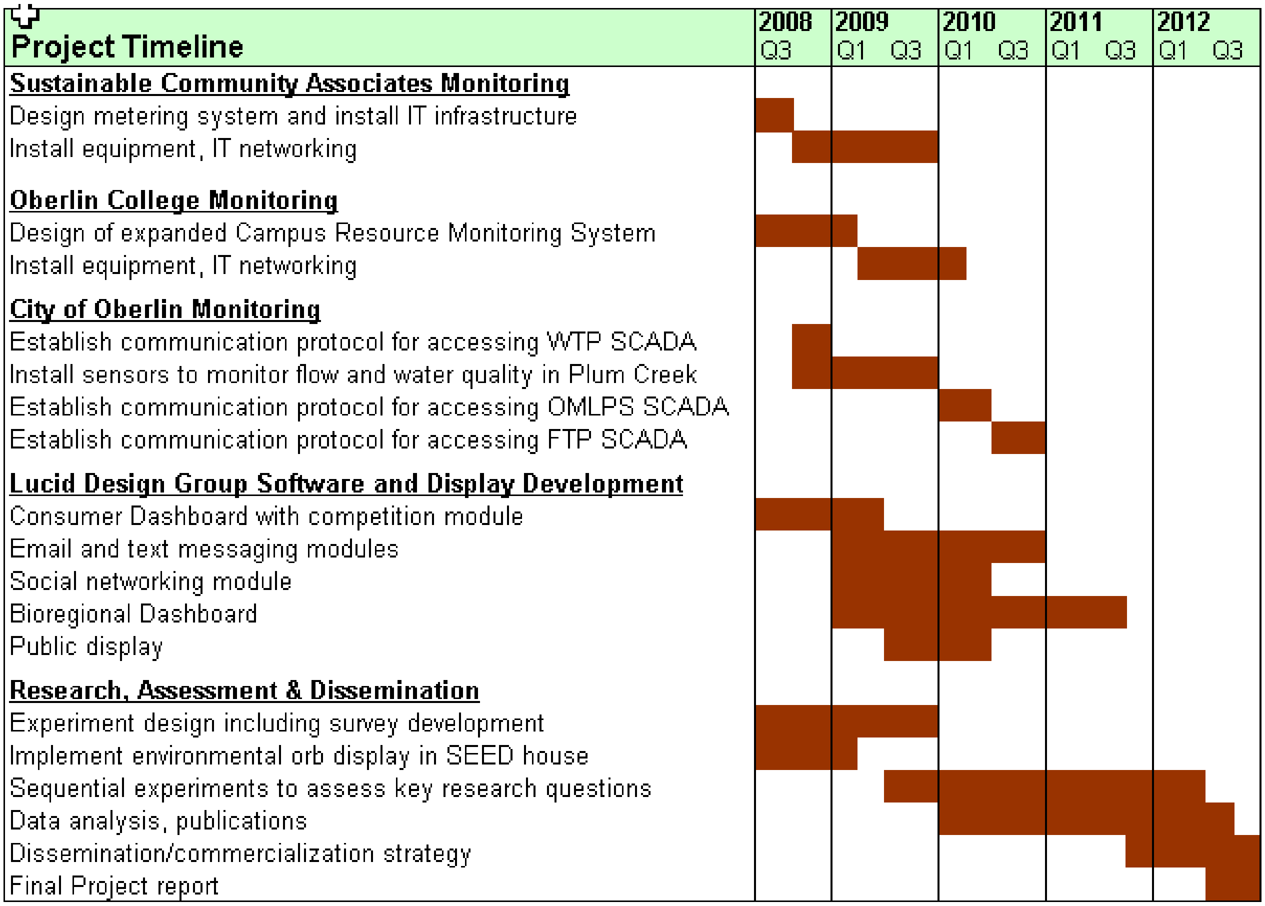


Table 1. Abbreviations: IT = Internet technology, WTP = waste water treatment plant, FTP = fresh water treatment plant, OMLPS = Oberlin Municipal Light and Power, SCADA = Supervisory Control and Data Acquisition system.

Dissemination:

In addition to the marketing efforts discussed above, dissemination of successful feedback products and knowledge developed through the Oberlin prototype will involve two key components: 1) promotion of awareness, interest and adoption of the technology among the community of end-users; and 2) sharing of research on the efficacy of the technology with decision makers and others who might build on the knowledge generated through this project. In both cases, our goal is to ensure that what is developed and learned has a lasting impact and benefits the health of the Great Lakes basin ecosystems.

As discussed, Lucid Design Group will provide a critical conduit for marketing effective approaches developed in the Oberlin prototype throughout the Great Lakes states. Lucid is already widely recognized as a leader and an innovator in developing real-time displays of resource use and has the capacity to market feedback technology broadly within the bioregion. Indeed, Lucid has existing relationships with a number of university customers and potential customers in the Great Lakes states including Ohio University, DePaul University, Kent State University, University of Toronto, and numerous others. Lucid also has relationships with a number of energy service companies (ESCOs) that could potentially serve as venues for wide distribution of a successful technology.

The Oberlin City officials and managers on this project and their established professional relationships with counterparts and civic organizations also offer a valuable conduit for disseminating lessons learned. One critical relationship is with the International Council for Local Environmental Initiatives (ICLEI). ICLEI is an international membership organization that provides technical assistance to cities and counties in promoting environmental stewardship. With a broad network of local governments across the Midwest, ICLEI has a well-developed infrastructure for disseminating innovative environmental protection tools and strategies that its members have designed and implemented. Preliminary discussions with Amy Malick, the Director of ICLEI's Midwest Regional Center, indicate that the proposed project may have potential for broad replication and adaptation in other ICLEI member cities and counties in the Midwest and beyond. In late 2007, ICLEI opened an office in Chicago to provide direct and customized climate protection and sustainability support to Midwest members. This office is poised to work with the City of Oberlin to design a program that could be adapted elsewhere in the Great Lakes Region. Ms. Malick indicated that the tool we plan to develop aligns closely with ICLEI's climate protection methodology and is very much in keeping with the innovative strategies that allow its local government network to thrive.

As indicated by their *curriculum vitae*, the academic members of the team all have strong publication records and are active in regional and national conferences. We are confident that information on the efficacy of the approaches taken within the proposed research will be broadly disseminated in academic and non-academic settings.

Edward Arens, Professor of Architecture at the University of California, Berkeley, has agreed to serve as external evaluator of the research conducted through the grant. Rather than waiting until the project is completed, we have asked Dr. Arens to commit to providing periodic independent feedback on our progress and to asses the following questions: Is the project on a pathway leading to larger scale implementation? Are behavioral changes having a measurable effect on Great Lakes ecosystems? In what areas do we appear to be making the greatest progress and in which areas do we need to rethink our strategy? He will also provide an independent evaluation of information presented in the final report presented to the GLPF.

BACKGROUND OF APPLICANT

Oberlin College, General Background:

Founded in 1833, Oberlin combines a distinguished undergraduate college of arts and sciences with a preeminent music conservatory. Oberlin's medium size allows it to offer an unusually rich academic program without losing the close faculty-student interaction that is the hallmark of a liberal arts college, and excellence in teaching and research and engagement with the broader community are emphasized. The academic program at Oberlin is of exceptional quality and since 1920 Oberlin has led all private undergraduate institutions in the number of graduates who have gone on to earn doctorates [19]. Oberlin is a private, non-sectarian institution that holds 501(c)(3) status. Its operating budget for fiscal year 2008 is $139,937,000.

Prior Role in Great Lakes Activities:

Oberlin faculty have undertaken a variety of research on the Great Lakes and its tributaries, particularly the Black and Vermillion River watersheds. In the 1970s Professor of Biology David Egloff collaborated with the NASA Lewis Research Center and the Northeast Ohio Areawide Coordinating Agency to develop water quality and pollution monitoring techniques applicable throughout the Great Lakes. The project involved remote sensing of water quality on Lake Erie and focused on the use of municipal water intakes as a source of water for water quality analysis, which is quite relevant to the current work. Associate Professor of Biology Roger Laushman has conducted extensive research on *Vallisneria americana* in Lake Erie since the early 1990s. His research on the ecology and population genetics of stream fishes, crayfishes, floodplain forests, and aquatic plants is conducted on six Ohio rivers that drain into Lake Erie. Limnologist Eddie Herdendorf, who is currently an affiliate scholar in Oberlin's Environmental Studies Program and will serve as a consultant on this grant, is one of the foremost experts on the ecology of the Great Lakes ecosystems. John Petersen, who will serve as project manager for the proposed work, manages an experimental wetland restoration project composed of six hydrologically isolated quarter-acre constructed wetlands in the Black River watershed that are being used to examine the effects of different restoration management practices on species diversity and ecological function. He also manages a water quality monitoring program on the Plum Creek, a tributary of the Black River. In addition, faculty in Biology, Environmental Studies, Geology, and Rhetoric & Composition engage students with the local watersheds in their teaching. The Environmental Studies Program offers two courses in watershed education.

Prior Work Related to the Proposal:

Since 2000, through his work on the nationally recognized A.J. Lewis Center for Environmental Studies, Petersen has developed a research program focused on monitoring resource consumption in buildings and displaying this in real-time to the public as a means of engaging, educating, motivating and empowering environmental stewardship. In 2004, Petersen and colleagues began applying the concept of real-time resource use feedback in a residential context as a mechanism for stimulating conservation. Oberlin has received two grants from U.S. EPA's People, Prosperity and the Planet program and one from the Ohio Foundation of Independent Colleges to develop Oberlin's Campus Resource Monitoring System. Combined with education and incentives, this socio-technical feedback technology has proven to significantly reduce resource use by students in college dormitories. The results of this work have been published in a peer reviewed journal [3] and presented and published in the proceedings of numerous regional and national conferences (e.g., Greening the Campus 2005, 2007, Association for the Advancement of Sustainability in Higher Education 2006, American Solar Energy Society 2006, Ecological Society of America 2005, 2007). Two Oberlin students have completed senior theses related to feedback systems. Dr. Cindy Frantz and Dr. Stephan Mayer in Oberlin's Psychology Department are collaborators on the second EPA grant, and they have developed a research tool that quantifies people's psychological connectedness with nature [18] that will provide a critical metric for evaluating the efficacy of the feedback technology. Dr Rumi Shammin, who joined the Oberlin faculty in 2007, is an expert on resource use in the home and its impact on climate change. Dr. Shammin has expertise in footprint analysis and in the use of other environmental currencies to quantify and to communicate environmental impact.

In 2004 John Petersen and three Oberlin alumni who had worked on this project founded the company Lucid Design Group, which then developed IRIS™ and Building Dashboard™, software products used to acquire, manage and display resource use data in a format that is designed to be easily accessible to a non-technical audience. Oberlin College and Lucid Design group have received a number of national awards and recognition including the P3 grants from the U.S. EPA, and a "ChillOut" award from the National Wildlife Federation.

PROJECT TEAM

Oberlin College:

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MD Rumi Shammin, Assistant Professor of Environmental Studies. Email: rumi.shammin@oberlin.edu, Phone: (440) 775-8747, Fax: (440) 775-8946.
Cynthia McPherson Frantz, Associate Professor of Psychology: Email: cindy.frantz@oberlin.edu, Phone: (440) 775-8499, Fax: (440) 775-8356.
Stephan Mayer, Professor of Psychology: Email: stephan.mayer@oberlin.edu, Phone: (440) 775-8067, Fax: (440) 775-8356.
Address: Oberlin College, Departments of Environmental Studies and Psychology, Oberlin, OH 44074

Oberlin is recognized nationally for its sustainability efforts, including the Campus Resource Monitoring System, and last year was rated the "coolest school" by *Sierra Magazine*. Working with Lucid, Oberlin has been at the forefront in the development of real-time information feedback technology and testing the ways in which this technology can be used to alter attitudes and behaviors related to resource consumption. Faculty in Oberlin's Environmental Studies and Psychology departments are experienced and well qualified to design the studies and assess the impacts of the proposed technology on attitudes and behaviors. This group also consistently engages undergraduate students in cutting-edge research that results in peer-reviewed publications on similar projects. Oberlin's faculty will take principle responsibility for the design and execution of research that assesses the impact of feedback technology on human attitudes, psychological connection and behavior. Research undertaken during the academic year will be supported by Oberlin College as part of the faculty members' regular effort. Funding is requested for one month of summer salary for work on the project for all four faculty and for one semester of leave for project director Petersen to focus full time on design and implementation.

Petersen's extensive management experience includes ten years of service on the Research Coordinating Council of the Multiscale Experimental Ecosystem Research Center (MEERC), a $10 million EPA funded research project at University of Maryland. He served as the Principle Investigator of two previous EPA grants focused on feedback research. He was a founding partner of Lucid Design Group and currently serves as Director of Oberlin's

Environmental Studies Program and Chair of Oberlin College's Committee on Environmental Stewardship, which oversees development and implementation of environmental policy. He has been an active participant in City politics and negotiated the College's green energy purchasing agreement, which has resulted in contracts to purchase over 50% of the College's electricity from green energy sources. Through these and other experiences Petersen has demonstrated the ability to effectively coordinate diverse groups that include decision makers, facilities managers, contractors, students, academic researchers and citizens.

Because of his affiliation with Lucid Design Group as a financial partner, Petersen has agreed to accept no payment from Lucid Design Group and to accept no profits from Lucid Design Group that are associated with work conducted for Oberlin College or associated with this grant; any time he spends directly on Lucid Design Group business will be donated to this project.

Sustainable Community Associates:

Partners: *Naomi Sabel* (contact), *Ben Ezinga* and *Josh Rosen*. www.sustainableca.com
Email: naomi@sustainableca.com, Phone: (740) 591-7715, Address: 138 Hollywood Street, Oberlin, OH 44074

These young, environmentally minded developers were featured in a front page article in the real estate section of *The New York Times* in 2007 for their pioneering and innovative work in developing mixed-use, mixed-income green housing and retail space. Their Oberlin project was recently accepted by the U.S. Green Building Council as a national pilot project for the new LEED Neighborhood Development certification and, in addition to seeking LEED-NC Gold, will likely be one of the first developments in the country to receive LEED-ND Gold Status. By fall of 2008 SCA will break ground on its development in downtown Oberlin that will features a broad range of fresh water, storm water and energy conservation innovations. Naomi Sabel and Ben Ezinga will work with their architects, with Lucid Design Group, and with John Petersen to incorporate data monitoring technology into the building design so that the data display component is readily available to all residents and retailers who occupy the space.

Lucid Design Group:

Michael Murray, President (contact), *Vladislav Shunturov*, Chief Technology Officer, *Gavin Platt*, Creative Director.
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Address: Lucid Design Group, 484 Lake Park Ave, Suite 600, Oakland, CA 94610

Lucid Design Group was incorporated in Ohio in 2004 and has since developed IRIS™ and Building Dashboard™. These software products are designed to collect, store and process resource consumption use data and translate these data into compelling real-time visual presentations. The company goal is to engage, educate, motivate and empower non-technical building occupants to conserve resources to the benefit of the environment and their pocketbooks. In 2007, Lucid Design Group was the grand prize winner of AMD's $100,000 Smart Power Award in the California Clean-Tech Open, often dubbed the "academy awards" of high-tech green business. Lucid has designed feedback technology for a variety of high profile higher education and corporate campuses including Harvard, Ohio University, Yahoo! Inc., and the universities of North Carolina, Pennsylvania, and Vermont.

Lucid will play the principle role in overseeing the technical implementation of the project including development of new software and new modes of feedback. Michael Murray , Vladi Shunturov, Gavin Platt and John Petersen will oversee this development. Shunturov will take principle responsibility for software development and for facilitating the integration of data from the multiple different data sources and setting up the IRIS™ database that will process and deliver this data to building occupants. Gavin Platt will work to implement multiple version of the multi-scale display that will convey these data to the public. If the prototype multi-scale feedback system developed through this project is successful, Lucid is well positioned for rapid dissemination of the approach to other communities within the Great Lakes region and beyond. Lucid actively markets in Canada as well as the U.S., so the potential exists for applying information learned from an Oberlin model to installations in the Canadian region of the Great Lakes. Lucid is a member of the U.S. Green Building Council.

Lucid Design Group has been selected as a partner for the proposed work because of its significant prior experience in designing Internet-based real-time feedback displays. We are not aware of the existence of any other firm with the experience or existing data management software that would allow for either access to the range of different data sources required for this project or with the capacity to develop the multiple modes of feedback envisioned.

City of Oberlin:

David Sonner, Mayor and Chair of Oberlin City Council, Email: DSonner@cityofoberlin.com
Steve Hoffert, Superintendent, Oberlin Municipal Wastewater Treatment Plant, Email: shoffert@cityofoberlin.com
Steve Dupee, Electrical Director, Oberlin Municipal Light and Power System, Email: sdupee@omlps.org

Oberlin City Hall, Phone: (440) 775-1531 Fax: (440) 775-7208, Address: 85 South Main St, Oberlin Ohio 44074

As discussed earlier, the City of Oberlin is a recognized leader in environmental stewardship. In 2006 the City established one of the first Stormwater Task Forces to serve as standing committee of its Public Utilities Commission. This task force is charged with addressing the implications of stormwater on the ecological health of the catchment basin. Further, the City Council enacted forward-thinking conservation development regulations that encourage responsible water management practices including innovative on-site storm water management. In terms of energy and air quality, Oberlin is a participant in the ICLEI *Climate Protection Campaign*. OMLPS has aggressively pursued and added green energy to its portfolio, including river-run hydroelectric, landfill gas electricity and wind power. OMLPS sponsors a variety of energy and water conservation programs that include free home energy audits for all citizens, compact fluorescent light bulb giveaways and a variety of ongoing educational programming for schools and the general public.

On behalf of the City of Oberlin, Mayor David Sonner is committed to developing Oberlin as a model for environmentally sustainable Cities. All four City officials will participate in the quarterly meetings discussed under Team Coordination. Steve Dupee will function as the point person who will facilitate necessary discussions with and actions by OMLPS engineers to make data accessible in the planned upgrade to the facilities SCADA system. Steve Hoffert will oversee installation of additional sensing equipment that will allow for water flow and water quality to be monitored above and below treated water discharge and incorporated into the SCADA system so that it can then be accessed for real-time online presentation. The time that Hoffert invests in the project will be covered by the City of Oberlin. However, the new equipment for monitoring stream water conditions and the time that his personnel spend installing and maintaining this equipment will be covered by the grant for the duration of the grant. If the work proves successful, the City has committed to maintaining the equipment beyond the duration of the grant period. Hoffert will also work to coordinate interactions with the fresh water treatment plant so that the upgraded SCADA system for that facility can deliver data.

Other Collaborators:

Jennifer Mankoff, Associate Professor, Human Computer Interaction Institute, Email: jmankoff@cs.cmu.edu, Phone: (412) 268 1295, Fax: (412) 268 1266, Mail: School of Computer Science, Carnegie Mellon University 5000 Forbes Ave, Pittsburgh, PA 15213

Edward Arens, Professor Department of Architecture, Director Center for Environmental Design Research, Email: earens@berkeley.edu, Phone: (510) 642-1158, University of California Berkeley, Department of Architecture, 232 Wurster Hall #1800, Berkeley, CA 94720

Eddie Herdendorf, Emeritus Professor of Limnology and Oceanography, Ohio State University. Email: herdendorf@aol.com, Phone: (440) 934-1514, Address: 4921 Detroit Road, Sheffield Village, Ohio 44054

As described earlier, the team members listed above will function as advisers and evaluators on key components of the project and all three will participate in the quarterly evaluation meetings to provide independent review and guidance. In addition, Jennifer Mankoff will participate in early brainstorming sessions in which we design the modes of feedback. She and her graduate students will provide feedback on display graphics and will play a key advising role on the design of the social networking module. Eddie Herdendorf will advise on the design of the Bioregional Dashboard such that it accurately represents the implications of conservation on Great Lakes ecosystems. Edward Arens will play a key role as a third party evaluator of effectiveness of the project as a whole in bringing about desired outcomes.

Team Coordination:

We will initiate this project with a full day meeting involving all grant participants and with representative users of the technology (future apartment owners and business owners from the SCA facility and Oberlin College students). Team partners from out of state will participate from their remote locations via interactive conferencing. The objective of this meeting will be first to review and clarify team member roles and responsibilities and timelines and second to conduct a design charrette in which we consider the full range of opportunities and constraints associated with the modes of information delivery. After this initial meeting, the group as a whole, with stakeholder representatives, will meet on a quarterly basis throughout the four-year duration of the grant to review progress and make mid-course corrections. Lucid Design Group and John Petersen will meet separately and regularly with SCA, Oberlin facilities and the City partners to coordinate on implementation of data monitoring technology. The faculty members of the team will work closely with Lucid Design Group in the design of the various modes of delivering information. Faculty working on the project will coordinate with Lucid Design Group in the development of experimental designs for the research associate with the project.

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ATTACHMENTS (separate file)

- IRS record of tax exempt status and contact person
- Audited financial statements (FY06 & FY07)
- Institutional Program Budget (Environmental Studies)
- Board of Trustees Affiliations
- CVs and letters of support for key participants