# Final Report:

# Assessing a Campus Energy Monitoring System

University of Michigan

ENVIRON 391

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Project Sponsor: Tim Kennedy

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**Executive Summary**

In response to growing concern over the environmental consequences of its energy consumption, the University of Michigan laid out a comprehensive plan for the reduction of its environmental impact over the coming years, seeking to reduce its carbon emissions by 25% with respect to 2006 levels. In conjunction with this effort, the Department of Utilities contracted our Environ 391 class to comprehensively assess the University's energy monitoring system and develop recommendations to make energy use more visible to building occupants. Our goal is to bolster the University's sustainability commitments by making the current energy monitoring efforts of Planet Blue and the Utilities Department more accessible to university members in order to generate a better understanding of energy use and bring about a reduction in consumption.

In this report we describe our methodology and recommendations. We chose to focus on visualization system development in the residence halls, but we believe the information in this report can be applied across campus. We utilized independent research, energy literacy surveying, and user interviews to develop an understanding of what other institutions have done, the current state of energy monitoring at the University of Michigan, and the current desire for such a system amongst the student body. Based on this input, we developed prototypes of an energy visualization system. We then sought feedback on our system from students through a series of ethnographic interviews aimed at determining the effectiveness of our prototypes and how they could be improved. Finally, we determined what it would take to implement such a system through interviews with stakeholders in energy-oriented departments and rough cost estimates based on similar systems.

From our background research we determined that many different forms of energy visualization at other institutions have been effective in reducing energy consumption by equipping users with basic knowledge and incentive to begin changing their behavior. Such systems have been able to generate up to a 32% decrease in energy consumption. At Michigan we found that the University has an extensive Building Automation System (BAS) which can be used to monitor and control environmental and utility use in most general fund buildings on campus. Combined with utilities metering, there is extensive data on energy use that could be used for a visualization system. However, improvements must be made to allow for monitoring not just at the building level, but on the room level. Beyond the technical capabilities of the University, student awareness of energy is narrow, focused mainly on lighting. Moreover, students have little concept of how much energy they use and how they compare to their fellow students, yet the majority desire to know more about and reduce their energy consumption.

The system we developed in response to our findings consisted of three complementary feedback devices. The first, a small touch screen, would replace each residence hall room's

light switch and thermostat and allow students to view their energy consumption, cost savings (or expenditure), and compare themselves to averages of other students. This "dorm dashboard" was well received by students, who liked the personalization of energy use and found it intuitive and "cool," suggesting it would be effective at encouraging them to reduce energy. The second prototype was a floor-level model which displayed average energy use for every room in the hall. While many students were wary of the notion of their energy consumption being made public, they agreed it would be an effective tool in reducing consumption. The final prototype was a building-level device modeled after a light bulb which would glow different colors based on the building's energy consumption relative to its average. Though students liked the design, it was agreed it alone would do little to encourage reduction and could easily go unnoticed shortly after being implemented, thus it should be used in conjunction with the other device and programs such as energy reduction competitions.

After roughly estimating the cost of implementing the system described above, we found that it would cost between $250 and $500 dollars per unit, but has the potential to pay back its development and installation cost within 3 to 5 years.

Based on the information collected throughout this project we recommend that the University perform an extensive cost analysis in addition to implementing a comprehensive pilot program of our energy visualization system in order to test its feasibility and assess its impact on energy consumption. An ideal system would include all three of our prototypes and should be bolstered by an extensive educational campaign to improve the understanding of the information conveyed by our visualization system, as well as other programs such as an energy reduction competition to provide greater incentive to reduce consumption. Through such an effort we believe the University will be able to generate 15-25% reductions in the energy consumption of its building users—bringing the University of Michigan closer to its larger sustainability goals and significant monetary savings.

**VISION:** *A better or new campus energy monitoring system would help foster an ethic of energy conservation among building occupants by connecting users with the impacts of their energy use through high resolution feedback.*

## Introduction

While the University of Michigan has created initiatives to become more sustainable focusing on institutional and structural changes with regard to energy consumption, like the implementation of mandatory LEED-silver certified building construction, few focus on energy consumption at the individual level (see the Office of Campus Sustainability's Final Sustainability Project Report: FY 2012 for a more comprehensive listing of current initiatives). Students living in on-campus residence halls have a significant degree of control over their personal energy consumption with their ability to control lighting and personal electricity usage within their room. Accordingly, these students have significant potential for reducing energy consumption on a large scale—as evidenced by the observed reductions in energy consumption during in-residence energy competitions like Oberlin's Resource Reduction Competition, which incurred a total reduction of 68,300 kWh (Petersen et al., 2007).

However, there are obstacles in reducing energy consumption within the residence halls. Energy usage itself and its environmental consequences are virtually invisible to the residents. The impacts of this consumption are even more obscure to the student living in the residential community than the residential home owner. While energy consumption is equally invisible to both populations, students—who do not directly pay an energy bill—have no monetary incentive to change their behavior and reduce their energy consumption.

One way to foster reduction in energy consumption is to change the structure of information flows. By making energy consumption more visible to users on campus through a visual feedback system, students become more aware of their energy usage, creating more motivation for changes in their energy usage patterns. Many universities and private organizations have begun to implement such energy visualization systems—called eco-visualizations (EVs)—to reduce energy consumption among dormitory residents.

These energy visualizations have been effective in reducing energy consumption and increasing awareness of energy usage, especially when paired with an energy reduction competition as seen in British Columbia's *Do It In The Dark* campaign in which the winning college reducing a total of 29.4% of their energy consumption in three weeks (see http://www.luciddesigngroup.com/casestudies/do-it-in-the-dark.php). After discussing the technologies related to energy monitoring the University currently implements—as well conducting ethnographic research to better understand student needs—we have provided recommendations for the creation of an eco-visualization system within the residence halls. We aim to produce the most effective system for impacting student behavior on campus. This report outlines the psychological foundations of EVs in terms of behavior change, the methodology used to determine feedback designs that resonated most strongly with students, and a comprehensive plan for future project development.

## Behavior Change

When considering the development of an energy visualization system the end goal is to create behavior change with respect to the way people interact with energy. Currently, the behavior towards energy is largely habitual with little consideration of the amount of energy being used or what the larger ramifications of that use are. Before addressing this issue through the implementation of a visualization system it is important to develop a strong understanding of the barriers to behavior change and ways in which they can be overcome. The major barriers to behavior change are a lack of knowledge and the existing social pressures or normative behaviors. In order to have successful and fundamental behavior change, these barriers must be overcome—although progress can be made if only some of them are addressed.

In a case study of differing attitudes towards climate change in Portland and Houston, researchers found that the most fundamental barrier is a lack of knowledge, which can be broken into two categories (Semenza and Hall, 2008). One is a lack of knowledge of the issue itself. Without knowledge of the problem it is impossible for an individual to change their behavior and address the issue (Semenza and Hall, 2008). Many students may be aware of issues such as climate change and pollution, but they may not be aware of how much energy they are using, how their consumption relates to other individuals, or the drain their energy use has on finite resources. The second type of knowledge deficiency is a lack of functional knowledge. Functional knowledge refers to the knowledge required to understand actions and possible ways of changing them, and is fundamental to the development of new behaviors (Semenza and Hall, 2008). In our case, many individuals lack knowledge of how they use energy and what actions may best mitigate their energy use.

While knowledge is important, there are other forces preventing behavior change. The most prevalent are social pressures. We are social creatures and rely on input from our surroundings to decide our next actions (Kollmuss and Agyeman, 2002). By default, we stick to the status quo in order to remain in harmony with those around us (Sunstein and Thaler, 2008). Thus, while satisfying a lack of knowledge is an important aspect of visualization system, it must also work to undo established norms. The final barrier to behavior change is simply a logistical one. When considering any action, individuals generally examine how much time and money it will cost (Semenza and Hall, 2008). In a visualization system, it is important to convey the ease with which energy reduction can be generated. Ultimately, such a system must have enabling or encouraging forces that outweigh the barriers that currently exist.

When addressing these issues there are many possible strategies, but it is important to consider their effectiveness in the short and long term before a particular action is taken. Two of the most well known and most heavily utilized methods for encouraging behavior change are appeals to altruism and incentives, but both have drawbacks when considered in the long term. Appealing to altruism defines behavior change as a selfless act in which an individual is doing something simply for the greater good. The issue here is that most people are inherently interested in what makes them feel better and find truly selfless action difficult (De Young, 2000). Incentives provide some sort of monetary gain or other prize for behavior change that works towards a certain goal. While this method has been shown to be very effective it is hard to maintain in the long term—when an incentive is removed the behavior change is less likely to continue (De Young, 2000).

To overcome these pitfalls, behavior changes must target a more selfish motive and deeper incentives for change. This form of behavior change is known as “intrinsic satisfaction”—the idea that people enjoy certain things regardless of monetary value (De Young, 2000). Intrinsic satisfaction can be broken up into four categories. The first is competence, which centers on the idea that we enjoy improving our own knowledge of a subject and don’t like simply being told what to do. The second is a fundamental inclination towards frugality developed as a result of our reliance on others for survival, leading us to fear taking too much for ourselves. The third is a desire to be part of a community and is the foundation of the power of social norms. Finally, individuals enjoy a certain degree of luxury or innovation which indicates a status symbol (De Young, 2000). Tapping into these “intrinsic motivators” and other values is more likely to yield a more fundamental behavior change.

Based on the above information we can begin to develop an image of what an energy visualization system seeking to reduce energy consumption looks like. Perhaps most importantly it should allow students to develop their own knowledge of these issues by giving them the tools to not only learn about and assess their own energy use, but also determine ways to reduce it. Such a system should also connect students to each other in order to show them how they compare to their peers, allowing them to establish some sort of reference for their own energy use while also fostering a sense of community around energy reduction. In order to connect students, a visualization system must tap into the values and characteristics which users already seek out. These vary tremendously from individual to individual, but commonalities can be formed based on research of prospective users. Following these guidelines we sought to develop a plan for an energy visualization system at the University of Michigan.

## Institutional Case Studies and Current System Capabilities

Prior to designing an eco-visualization system for the University, it was necessary to survey case studies on the effectiveness of feedback systems already in use in the private sector and other college campuses, as well as the capabilities of the current systems available at the University of Michigan.

### Corporate Energy Monitoring Systems

Over the past decade, the corporate world has made an increased effort to improve the sustainability of its facilities (Crawley et al. 2008). Reporting energy consumption data is considered an essential method to improve building energy efficiency (Granderson 2010). Exploring the advantages, disadvantages, and results of large corporations that parallel the University of Michigan in size and infrastructure provides a broad template for possible initiatives on campus.

The main method for monitoring energy in large buildings is through the use of energy information systems (EIS), which are packages of software that monitor performance through data acquisition, analysis, and display (Crawley et al. 2008). These powerful and efficient tools can provide energy use and demand, temperature, humidity, and cost statistics for multi-facility operations over the Internet to users. EIS can be customized to display information pertinent to each site, which would be beneficial to U of M's campus with buildings of different ages, infrastructures, and functions.

Walmart utilizes EIS technology in its High Efficiency Store Series to monitor refrigeration, lighting, gas, and water (walmart.com/sustainability).Through a customized EIS package, Walmart exports data to external software that targets 20-45% energy savings compared to the typical Walmart store (Granderson 2010). One drawback to Walmart's EIS method is that it is not feasible for Walmart to monitor each store to the degree of specificity desired by the corporation (Granderson 2010). The entire staff does not have access to the system, and data is complied every thirty days instead of engaging staff on a daily basis (Granderson 2010). This decreases staff engagement with personal energy use and reduces energy usage from a daily responsibility to a monthly memo, which can easily be ignored.

The lack of daily interaction of EIS technology could potentially decrease the success of such a system at the University of Michigan due to the sprawl of campus and the preoccupation of students and staff with personal agendas. The University has many people and buildings, and a monthly memo or email may not be sufficient to capture the attention of enough people to make a difference in energy consumption. It is to be noted that relaying energy information usage to staff did result in an energy reduction, and a monitoring system with a higher resolution and more accessible interaction produces greater results.

Information dashboards are visual energy feedback systems that provide building occupants with measurable data of personal and building energy use. Dashboards are typically accessed online, but some companies have interactive touch screens that allow for user interaction. Dashboards are meant to engage with many more people than EIS, and allow each respective group to gather information pertaining to their self-interests. For example, building occupants might be more concerned with their energy usage for financial and personal motives, while researchers may use the dashboard information to evaluate the building and improve efficiency.

Founded in 2004, Lucid Design Group, Inc., known as Lucid, is a pioneer dashboard corporation. Lucid's designs are built on the philosophy that making energy consumption data accessible to all will inspire behavior change. Lucid's Building Dashboard Network is the first "social network" for buildings, allowing occupants to view, compare, and share building energy performance on the Internet, while their Building Dashboard Kiosk allows people to access energy usage on a touch screen. The Dashboard works in real time and can search for buildings across a network, set up energy budgets by floor, identify periods of high and low consumption, and check weather forecasts (luciddesigngroup.com). It brings energy saving to the community level through reduction competitions and community-wide comparisons.

DPR Construction Inc. implemented Lucid's Dashboard in their San Diego office in May 2010. All employees and staff can access the Dashboard's data on electricity, water, and natural gas online, and the touch-screen Kiosk monitors usage in a high-traffic area of the office (luciddesigngroup.com). DPR estimates that they reduce 24-48 kilowatt-hours a day based on short-term savings analysis on the Dashboard (luciddesigngroup.com).

Dashboards are a source of instant gratification, which could be appealing on a large, sprawling campus like the University of Michigan's. Different schools and buildings could exchange and compare information instantly, and people could track their day's energy usage across a network of buildings. This could be done between classes, at the library, or even on a smartphone while walking around campus. Dashboards provide a visual energy feedback system, which the University of Michigan currently lacks. Students and staff have no easy, accessible way to track personal or university-wide energy usage without waiting for a university-endorsed assessment every 5 or 10 years. A visible, tangible monitor, like an information dashboard, would enable students and staff to actually see their energy use. Furthermore, the University is not limited to a single building or office, and both EIS and dashboards allow for networking and collaboration among many facilities. Interactive technology would inspire a sense of community and encourage educational opportunities, thus engaging students and staff on a more successful level.

## Collegiate Energy Monitoring Systems

Many universities in the United States have utilized energy reduction competitions in which eco-visualization systems play a large role, such as Indiana University Bloomington's (IUB) Energy Challenge. The Energy Challenge EV was displayed on the school's website as a customized bar graph comparing each residence hall's water and electricity usage. During the one month competition, the website was updated weekly, displaying the amount of kilowatt-hours and gallons of water saved for the whole campus. In addition to the EV, the university provided monetary and prize incentives for the winning residence halls (Odom et al. 2008).

The 2008 Energy Challenge resulted in an estimated combined avoidance of 33,008 kilowatt hours (KWh) of electricity and 724,322 gallons of water. IUB has since continued the annual challenge, resulting in a total reduction of 3,813,600 gallons of water and 2,578,028 kWh of electricity within the 20 challenge weeks over the past four years. When combined with non-challenge figures over the past four years, these savings jump to 24,465,642 gallons of water and 9,438,986 kWh of electricity suggesting effective long-term behavior change due to the EV-competition system (IU Energy Challenge 2011). While research suggests a large part of the behavior change was motivated by the social incentive of the competition, the feedback provided by the eco-visualization that helped spur the competition with its “Top Ten” competitive format (Odom et al. 2008).

The effectiveness of this the internet-based EV-competition is corroborated by other universities who have implemented similar techniques. Oberlin College participated in a campus-wide (18 residence halls) competition to reduce water and electricity consumption for two weeks in 2007. The researchers who organized the competition focused on two parameters of the EV: the form of “information conduit” and the “degree of resolution” (Petersen et al. 2007). The “information conduit” refers to the way in which data is presented; Oberlin chose to present their data through a University-sponsored website displaying energy consumption in the form of a bar graph (which would later spawn the Lucid Building Dashboard). The researchers were interested in the degree of resolution, or the time intervals and spatial area at which energy consumption is measured, that would be most effective in reducing energy consumption among the student body. They used three levels of increasing resolution to compare effectiveness: data produced and displayed once per week of an entire residence hall, real-time feedback of an entire residence hall, and real-time feedback of the electricity by floor. For the two real-time feedback groups, they also added information kiosks in residence halls that displayed real-time data at all times (Petersen et al. 2007).

Though the reduction in consumption of water was not very significant, the reduction in electricity was quite large, saving 68,300 kWh—a 32% overall reduction. The residence halls with the highest resolution, real-time data reduced their electricity consumption the most: 56%. The researchers also found that the residents in the real-time data groups were more likely to check the website frequently, showing a greater interest in the data. Furthermore, the monitoring system, which was maintained after incentives/advertisements were removed, showed a sustained reduction in energy consumption even after the competition (Petersen et al. 2007). The findings of Petersen et al. (2007) suggest that a high resolution EV with real-time data and a focus on accessible visual displays of energy consumption increases awareness and interest in energy conservation.

While several studies have shown that real-time data is important for effective feedback, some artistic interpretations of real-time data are now being displayed through means of ambient visualization (a visual signal rather than numerical display, such as a change in color or brightness of hue) (Pierce et al. 2008). Many of these visualizations are straying away from the currently-preferred Internet display model to a tangible EV within the context of the building, creating a visual link between the consumer and the source of energy consumption. Alongside their Lucid Building Dashboard monitoring system previously mentioned, Oberlin College has also implemented student-designed “energy orbs” as part of their Campus Energy Monitoring System (Smith 2010). The orbs installed in residence halls display real-time data through an ambient color scheme, changing colors to reflect relative electricity and water consumption. Not only does the color describe energy consumption, but each component, electricity and water, also pulses, with the pulse frequency reflecting an increase or decrease in consumption.

According to preliminary studies, students in halls with these ambient orbs have decreased electricity usage significantly (Smith 2010). These preliminary findings are supported by other studies which have seen a decrease in energy consumption due to ambient EVs, including a study by Seligman et al. (1979) which showed that an ambient light system that flashed when the outdoor temperature was satisfactory to provide cooling rather than air-conditioning created energy savings of 16% over a three-week period .

Like any new technology built to foster sustainability, eco-visualizations face the challenge of motivating and sustaining long-term change in the habits of the populations they wish to impact. Creating awareness of energy usage and promoting energy reduction are difficult goals to achieve, especially considering the large scale of the student body that these eco-visualizations must try to influence. Nevertheless, eco-visualizations have shown promising potential in creating a lasting impact on the energy habits within a university setting. Particularly when paired with a competitive motivation, whether stemming from a social or external incentive, eco-visualizations have the potential to significantly reduce energy consumption within residence halls at the University of Michigan.

## Current U-M Systems

An important factor in the development of a campus energy visualizations system is understanding what currently exists within the University and its current monitoring capabilities. While the University has extensive monitoring capabilities the information has neither very high resolution nor is it conveyed to the students in an engaging and interesting way. Data and information about building functions are currently collected mainly in two ways: through the Building Automation Systems (BAS) or through the utilities billing of the University.

The BAS is part of the University's Facilities Maintenance department and serves as the main avenue through which facilities managers control building functions. Essentially, the system is a series of monitors that track building conditions (Plant Operations). Changes to building operation are made using a system called Direct Digital Control (DDC), which compares current conditions to a set point or desired level. The functions that the BAS monitor and control are numerous. The system is achieved by the cooperation of input points, digital control panels and output points. After the input points collect the data from the buildings, these data are sent back to the panels which are run by local computer programs (Plant Operations). After analyzing the data, the panels calculate the proper output signal and send it to the output points, where regulation takes place. The system monitors the temperature of buildings as well as the composition of the indoor air, which factors into the management of heating/cooling programs and air mixing units that provide fresh air to buildings. Outside of air regulation, the BAS monitor chilled and hot water systems, lighting, university cooling towers and free-cooling systems. The BAS are also being improved to increase control conditions in individual rooms. Additionally, building usage patterns are factored into the above data to develop more comprehensive programs for building operations (Plant Operations).

Thus, the University tracks a tremendous amount of information about its facilities and can use this information to control many of their functions. Though the University is making improvements to allow for more individual control many of these systems continue to be controlled at the building level and occupants have little input. Furthermore, the information itself is collected at the building level so there is little information about individual room usage or individual occupant usage. Information is collected and utilized internally and is not presented to students and other users of the facilities. Another issue with the BAS is that it is not extensively used in the student housing, though as they are renovated more buildings are being brought online.  Nonetheless, this places a limitation on the information available for a residence hall-based system.

In addition to the BAS, the University collects a tremendous amount of data on its utility consumption.  This information is collected through the Utilities & Plant Engineering department of the University and is used in verifying the billing of the University by its various utility providers. It is important to note that the university provides 45MW of its own electricity and heating through the Central Power Plant with the remainder provided by vendors such as DTE (Plant Operations).

All buildings on campus are monitored for electricity use, but differences arise depending on who monitors them and how they are read.  The Utilities & Plant Engineering Department monitors buildings receiving power and heating from the Central Power Plant, but on many portions of campus such as North Campus, the North Campus Research Complex, and South Campus buildings are supplied and monitored solely by DTE. Buildings can further be divided by whether they are manually or electronically read.  Buildings read manually are limited by how frequently the University or DTE is willing to send someone to read them--typically once a month (Wells 2011).  Many buildings on campus, however, are monitored electronically.  Thus, they can be monitored from a remote location and information about the buildings' energy usage can be viewed over different timescales as small as every second.  These systems can essentially real time information about the energy use of buildings on campus.  Regardless, electricity is only monitored for the entire buildings or large sections of building and cannot currently be used for more detailed monitoring (Wells).   Moreover, individual variances in building monitoring as described above would have to be removed before one all inclusive system can be utilized.

The information from the monitoring of utilities is made available to members of the University through various websites and programs.   The most commonly identified venue is through the Planet Blue education seminars.  At these events Planet Blue displays information collected by utilities monitoring.  Furthermore, building level information is made available on the Utilities and Plant Engineering website under Energy Management. This site provides monthly data, as well as annual sums of the electricity, steam, gas, and water usage of many buildings on campus.  Additionally, a more comprehensive break down of utilities use can be found on the Utilities Department eDNA Billing system site.  Utilizing these sites students can determine the utilities consumption of the University on the building level by month, but no more detailed information is available.  The information provided makes little effort to engage with the viewer.

Ultimately, the University has a tremendous about of monitoring capability, but lacks more detailed, higher resolution information on a room by room or real-time basis. Furthermore, there is little incentive or encouragement for students to explore the information that is already available.

**Primary Research**

While much of the literature on behavior change and energy conservation influenced the direction of our project, the majority of fruitful data that shaped the functionality of our recommendations came from user and ethnographic research.  This research was conducted through multiple design tools such as surveying, customer journey mapping, observing and interviewing prospective users, and rapid prototyping.

Energy Literacy Survey

In order to gauge general interest in energy consumption and the average energy "literacy" (knowledge of units, relative energy consumption of household appliances, etc.) on campus, we distributed a survey to a random sample of 5000 students via email. Of the 626 respondents, 53.8% "agreed" and 27.0% "strongly agreed" that reducing their personal energy use was important. Moreover, 80.2% of respondents said they were interested in knowing how much energy they consume, 82.4% were interested in how much their energy consumption costs, and 74.2% were interested in the total consumption of where they live. In terms of energy literacy, 73.8% correctly identified kilowatt-hours as a unit of energy use, suggesting technical units might not be *universally* recognizable to users. Respondents were more divided on relative comparisons of energy usage with 58.5% correctly recognizing a MacBook as using less energy than a hairdryer and 49.7% correctly recognizing an electric oven as using more energy than a LCD television, which supports the notion that users can be largely unaware of the energy consumption of their appliances.

Overall, the student body demonstrated considerable interest in learning the specifics of their energy use as well as a strong consensus on the importance of reducing energy consumption. Literacy-oriented responses reinforced the concept of easily comprehensible units and revealed areas for educational opportunities (i.e. the energy demand of everyday appliances). The complete survey results are listed in Appendix A.

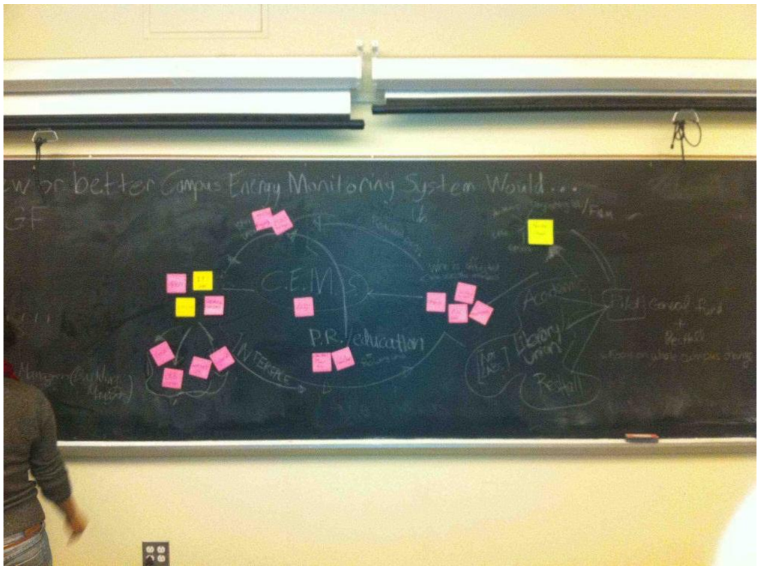
User Mapping

After developing a better understanding our initial population's thoughts on energy, we still needed to synthesize our findings further and also refine the scope of our project. We used the customer journey map tool as a medium to do this.

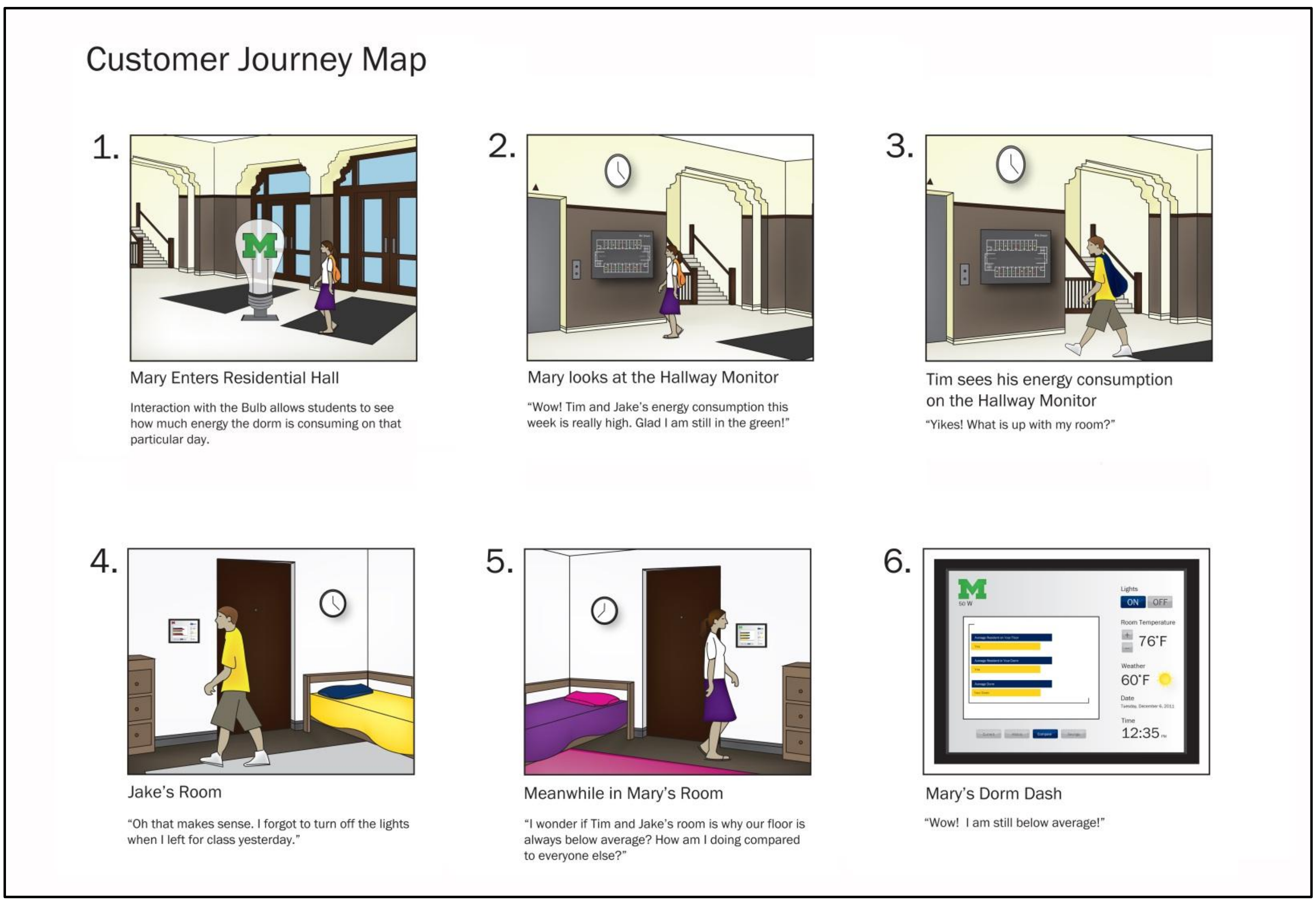
Customer journey mapping is a method of visually representing the actual, everyday user experience of a service. The customer journey map will plot touch points, service interactions and gestures of users having experienced a service. The method helps designers understand the intentional and unintentional aspects of the customer journey. The map is humanized with personal insights, anecdotes and photos, using the user's language, their successes and even failures as a very user-centered visualization of the customer journey (http://www.enginegroup.co.uk/service_design/m_page/customer_journey_mapping).

Our original and refined ideas for our eco-visualization journey map are illustrated below.

*Original Rough Draft*



*Final Draft*



By mapping out a few hypothetical situations we came to realize that the system with the highest behavior change capacity would be one that influenced students in their dorm settings. This was due to the fact that the residence halls are:

- the most effective setting for a high resolution system, i.e. where individual feedback is most feasible and appropriate
- the easiest setting to monitor (most residence halls are uniform in layout, making metering easier and the most cost effective solution)
- the most effective population to induce behavior change due to the natural social network in place and potential for this behavior to transfer to life outside of the residence halls
- easier to measure success or failure rates from energy behavior change, i.e. how can someone really know whether reduction patterns were due strictly to behavior change? If a pilot were to be run in the dorms results could be easily measured from floors/rooms with an eco-visualization juxtaposed with those who do not. This is in comparison to general fund buildings, where measuring feedback could be less feasible due to the non-uniformity of building layouts and habits of building users, i.e. how can we measure electrical data from users who have no liability for their energy use?

User Interviews and Personas

*"Conducting a great interview isn't only about asking the right kinds of questions; it's also about the attitude with which you approach the conversation."* - Kim Goodwin, Designing for the Digital Age: How to Create Human-Centered Products and Services, p. 119

The most specific and possibly most important data from our research came in the last stage of our project. Here we focused on gaining what users thought about the idea of having an energy visualization system in the residence hall setting, and, from these conversations, we created prototypes that were then presented to a new student audience.

We chose to conduct our initial set of interviews in three separate dorm settings: Mary Markley, South Quad, and North Quad. By selecting residence halls with varying student population type (class, co-ed, community based, etc.) we thought we could gain a better picture as to where different types of students vary their opinions about their energy use. Questions were drafted on the basis of being similar to a conversation. Our initial greeting and overview questions were intended to have students walk us through their average day in the dorm and also have them explain what kind of websites they liked and used most often. By getting students to talk about their habits, we could extract more specific questions about energy habits without being too direct. Below is an outline of the questions used to frame our user interviews.

Overview Questions

- Can you walk us through your average day in your room, what do you do first? What about when you walk into the dorm?
- Can you tell us what website you visit frequently, what takes you here, what makes this website cool? How frequently?

- If you use social media (facebook, twitter, etc) which website do you use? Why? What do you like about them? (versus inconveniences like facebook interface changes)
- What do you like about the dorms? About your dorm room? Where do you spend most of your time?

Living Context

- How do you feel like you have control of your dorm space?
- Do you feel like you have control over your energy? How so, thermostat, lights, what aspect?

Motivations

- Do you ever think about your resource use during these activities/in these places?
- Do you care about energy consumption? Do you actively try to conserve energy?
- If yes, what are the barriers to your energy conservation?
- If not, Is there anything that would make you try to conserve? friends? competition? Money?

Visualization

- When you think of energy, what comes to your mind? Can you draw it?
- How do you think of energy, what would make you want to think about it?

Goals

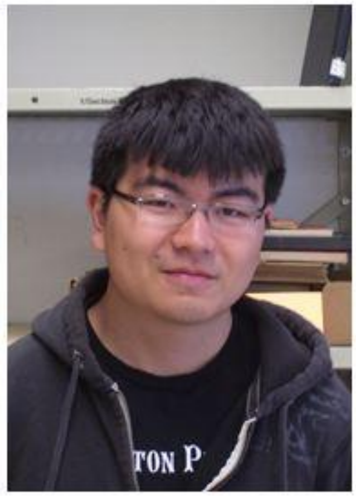
- What makes living in the dorms fun, or a good experience?
- If there was something in your dorm that displayed energy, what would it look like? What would it tell you?

When we began to synthesize our findings we used personas to help make our data have meaning. Personas are a specialized type of composite model resulting from cross-case analysis, using primarily inductive reasoning. A persona encapsulates and explains the most critical behavioral data in a way that designers and stakeholders can understand, remember, and relate to. Unlike simple lists of findings or other types of models, persona use storytelling to engage the social and emotional aspects of our brains, which helps each team member either visualize the best product behavior or see why the recommended design is good.

Several personas developed after the user interviews are displayed below.

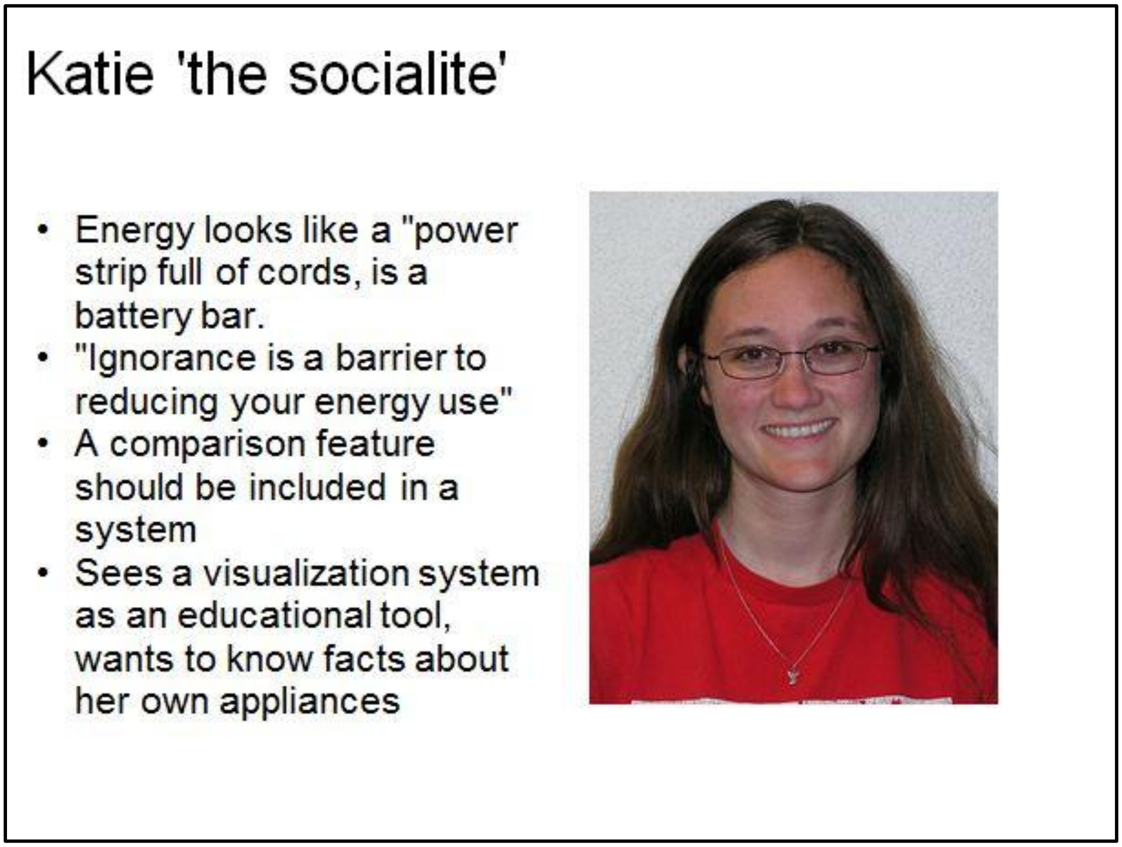
# Jimmy

- Experienced User
- "Energy looks like a bunch of electrons"
- "Energy savings just makes sense"
- Motivations for saving energy
  - enforced rules
  - ex. blue bins for recycling
- Ideal device would:
  - have graphs
  - compare consumption between dorms




# Alex

- RA who knows his stuff
- Wants highly individualized, real-time feedback
- Device should be unavoidable
  - "It should confront you"
- Consumption should be compared with tangibles: coal burned, gas used, etc.
- Engagement will come from enforced monetary incentives




The major findings from our synthesis of these personas were:

- Dorm residents tended to act as if they know their energy consumption.
- Comparisons would be the most helpful feature in helping students grasp their energy usage.
- Confrontation from a device is necessary and surprisingly welcomed by students.
- Students see a ‘payback’ system as an inherent part of the system’s functionality.
- Lighting is the most common form of energy use with regards to how students feel they control energy.
- Dorm residents view community differently from dorm to dorm.

Perhaps what was most interesting about the results of our interviews is that each residence hall had a wide variation of responses, highlighting the differences of each shared community. For instance, residents in South Quad seemed more receptive to an eco-visualization that could be community based, such as a device with competition and social-media aspects. Residents in Mary Markley responded similarly, with a lot of conversation revolving around the social aspect of being able to see your neighbors energy use on the floor level. However, users in other dorms—especially North Quad—responded in quite the opposite manner. These residents, advocating for more privacy, liked the idea of having a device that was individualized and showed them their personal energy use habits. Other contrasting preferences among residence halls are listed below in our summary diagram.

| | North Quad | South Quad | Mary Markley |
|---|---|---|---|
| Student Population | Upperclassmen | Mixed: freshmen sophomores and athletes | Freshmen |
| Sense of community | Very limited, individualistic | Yes, honors and athletic communities | Limited |
| Interested in energy consumption | Somewhat | Yes | Yes |
| Monetary Incentive | Beneficial | Beneficial but not necessary | Beneficial but not necessary |
| Social media and competition features | No | Yes | Yes |

Rapid Prototyping and User Interviews

In the last part of our primary research we designed prototypes based off of our initial user interviews. Using inspiration from Lucid Design's and Oberlin's Orb products, we drafted a product line consisting of three separate (but complementary) eco-visualization devices—collectively known as the Interactive Energy Visualization System (IEVS). The idea of having a product line came from the variation of student's preferences. As discussed above, some students favored customizable features, where others enjoyed having the ability to view information in a public setting.

The three products we developed were:

1. "The Dorm Dash": A touch screen LCD that replaces a room's thermostat and light switch, while also displaying multiple types of energy information.

2. "The Hall Monitor": A hallway or elevator lobby panel that displays a floor's average weekly energy usage on a per room basis

3. "The Bulb": A residence hall's central node for conveying how the building's energy use is doing with respect to its average. All three devices are listed below with an in-depth analysis of their original functionality and design.

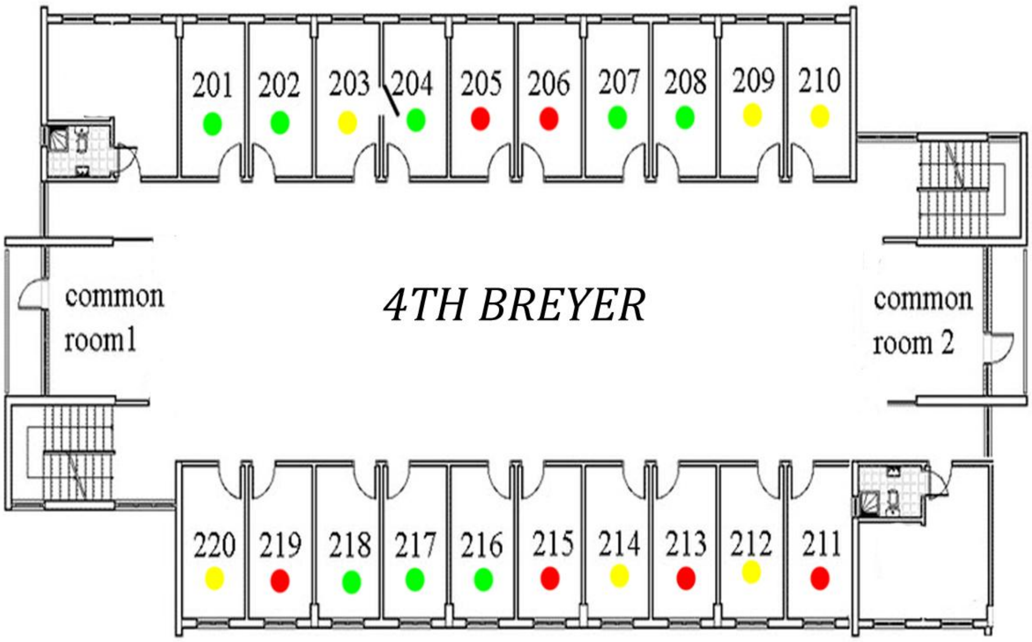
# “The Bulb”

*Ideally it would be placed on a pedestal or on the wall of the main lobby of the building.*

*The Incandescent Block M glows red, green, or yellow based on the average energy consumption of the entire resident hall.*

*Dimensions would ideally be around 4 to 5 feet tall, and smaller if attached to a wall mount.*

# "The Hall Monitor"



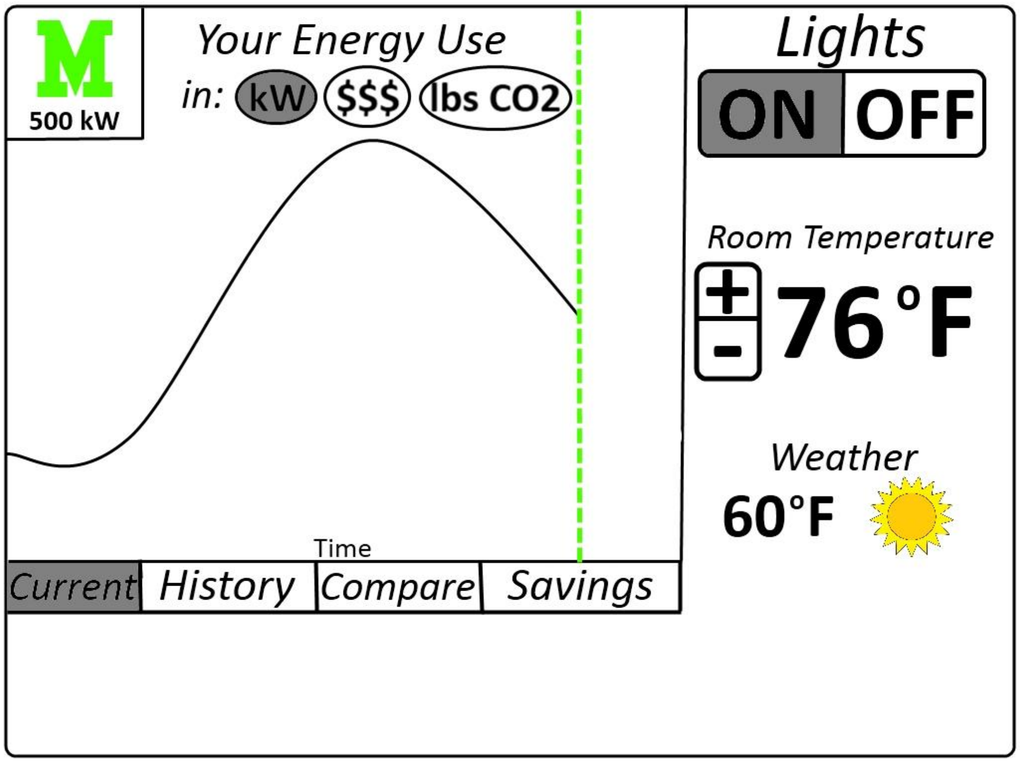

*Each room's average energy use would be represented by a color changing LED.*

*The background medium would be a sheet of stainless steel metal with the room outlines engraved, similar to a modern elevator dashboard.*

*At this stage LED color was based off real-time energy use.*

## "The Dorm Dash"

*Current Screen*



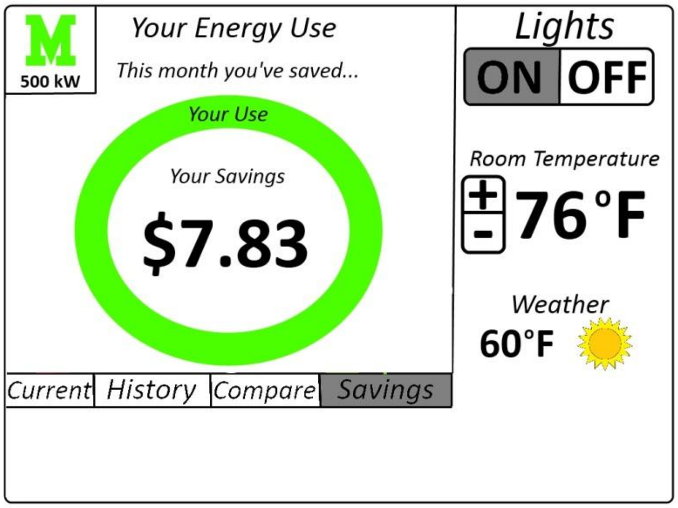

*The medium for viewing would be a touch screen LCD to maximize interaction between user and device.*

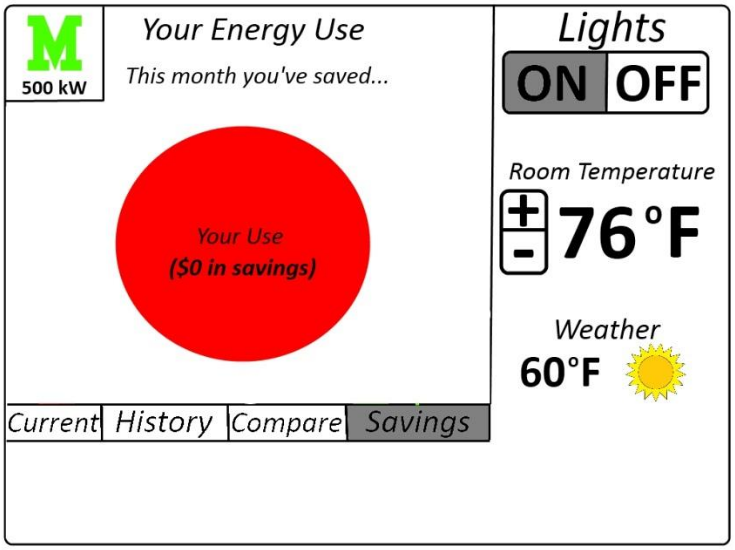
*Both lighting and temperature of the student's room could be controlled via the dash.*

*The home screen would display the real-time status of the room's energy use in units of the user's choice.*

*The Block M's color corresponds to the user's consumption relative to the dorm's real-time calculated average (similar to "The Bulb's functionality).*

*Savings Screen*

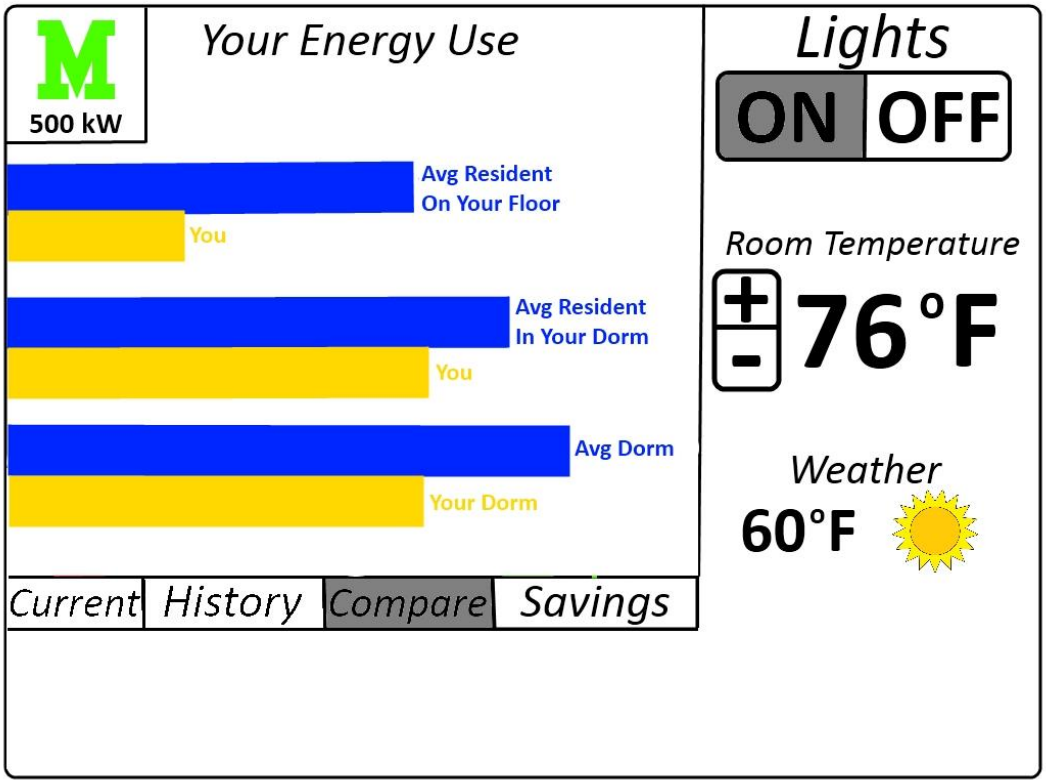



*The savings screen would be used to allow students to see their energy savings in $ based off of their monthly bill (if the university was to change billing from semester to monthly allotments).*

*The circle changes based off your use for the month. If at the end of the month the user has gone over is allotment, the green on the circle disappears and is replaced by a red circle. The goal is to keep your circle empty; maximizing the savings amount.*

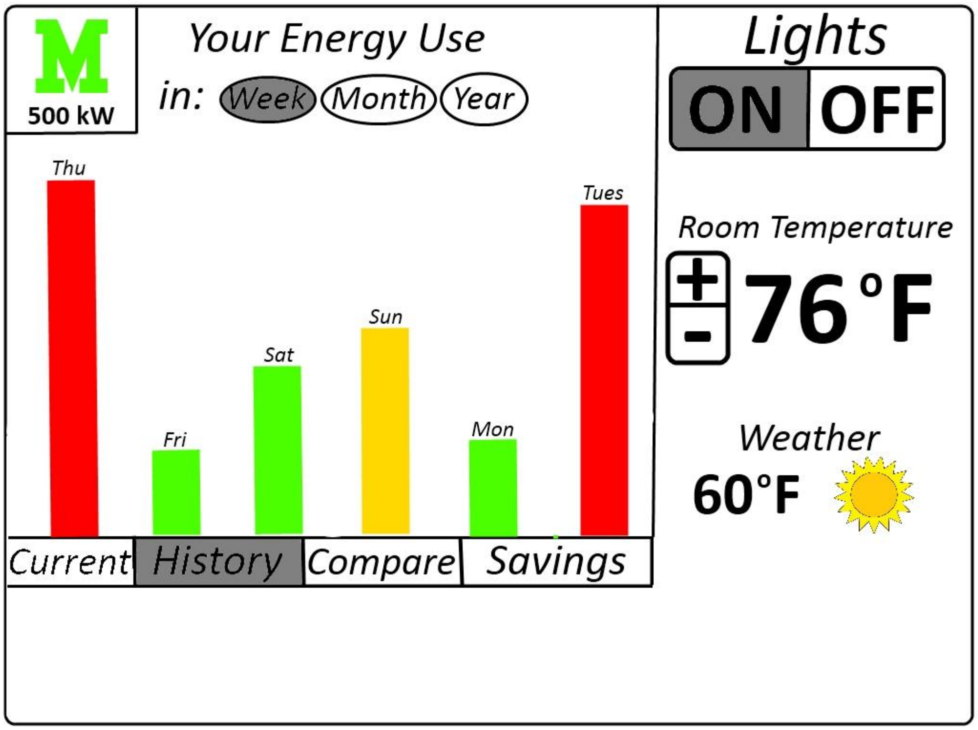
*Compare Screen*




*The compare screen would allow users to benchmark their consumption vs. an average person on their floor, and resident hall. Other comparisons would be listed under a select menu such as your dorm versus the campus' average dorm p/resident usage, and you versus the average student in all campus resident halls.*

*Comparisons would be visualized in a relative manner; whereby 'your' consumption would be compared against an average metric whether it is at the hall or building level.*

*History Screen*




*The history screen would allow users to benchmark their consumption history against their average. The user would be allowed to select the unit of time over which his/her energy consumption would be compared.*

*Each bar in the graph would be colored based on that day/month versus the average of the selected time unit.*

## Back to the Residence Halls

We returned to the residence halls (East Quad, North Quad, and South Quad) to determine whether our prototype design fit our users' preferences, and if not, we inquired as to how they could be improved. Even though our prototypes were crude card board cut-outs, users generally understood and could also interpret each prototype's functionality. Each user was selected at random in either their room or a study lounge and was asked to guess what our prototypes were and what they thought of them based on first impressions. Later we explained how our devices might be used and asked each user if they had questions with regards to each device's functionality and design.

One of the most reoccurring improvements suggested was the need for information that explains "what is going on" with the device. This was especially prevalent in comments concerning "The Bulb." If a device similar to "The Bulb" were to be placed in the lobby, residents desired supplemental information describing how it works and why it is important. Some even suggested having a Planet Blue plaque, similar to the ones located next to water refill stations around campus. "The Bulb" made sense to users; however, most residents only thought it would be effective if it was to be linked to the other two devices. This meant that residents saw "The Bulb" not as a stand-alone device, but more of an essential complement that would foster a shared ethic of conservation among dorm users.

The floor plan was one of the most controversial among residents as it drew a lot of attention in terms of being "confrontational." Many thought that even though some students might not like the idea of having their energy usage displayed to public, it would ultimately be very effective at changing students' behavior. Students pointed out a few flaws in the way that energy would be visualized. For instance, Sam in South Quad mentioned that if each LED was to represent a student's current real-time usage, the data could be redundant or useless. If a student were to leave his room and everything was turned off, he/she would already know that his usage would be in the green. A solution that was proposed involved having the room LEDs display data that was benchmarked against a time-based average. For example, if Sam were to see his room LED display red, he would understand that his use for the week was higher than average.

Other potential users, like Steve from North Quad, highlighted the topic of monetary savings. These users saw monetary savings as an inherent part of the system, and thought that a device such as the "Dorm Dash" could be most efficacious at gaining the attention of students if it were to offer such features. However, we must note that there were others who said that even though savings were important, just having access to visualize their energy use was enough to elicit a response.

There were many other functionality improvements to the "Dorm Dash" that users suggested. Among the most mentioned were improvements to the scale of the block M. Users for the most part wanted to have an enlarged average indicator in comparison to the tab sections. Users also wanted to have more options in choosing which time unit to compare against in the current tab. It made more sense to them to see their current usage benchmarked against hourly, monthly, and weekly logged data. Other minor additions included adding a time feature at the bottom of the screen.

Below is a summary of findings from our interviews.

| | | |
|---|---|---|
| 1) "The Bulb"<br>+ fosters a community ethic<br>+ symbolic<br>- not motivating to individual users | 2) "The Hall Monitor"<br>+ fosters competition and accountability among students<br>+ socializes energy use<br>+simple and intuitive<br>- invasive | 3) "The Dorm Dash"<br>+ individualized feedback is essential<br>+ "cool", the touchscreen aspect in convenient and attractive for users<br>+ confidential |

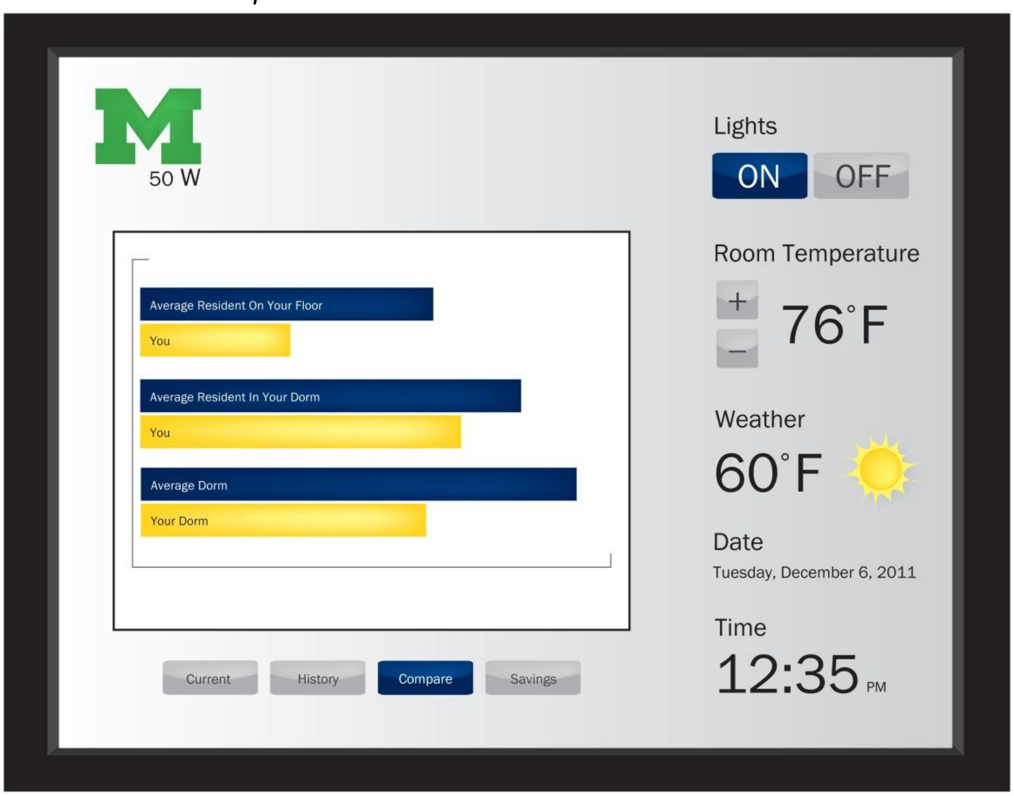
The following diagrams showcase the finalized prototypes based off of our user input. Comments highlight modifications and edits.

# The Dorm Dash

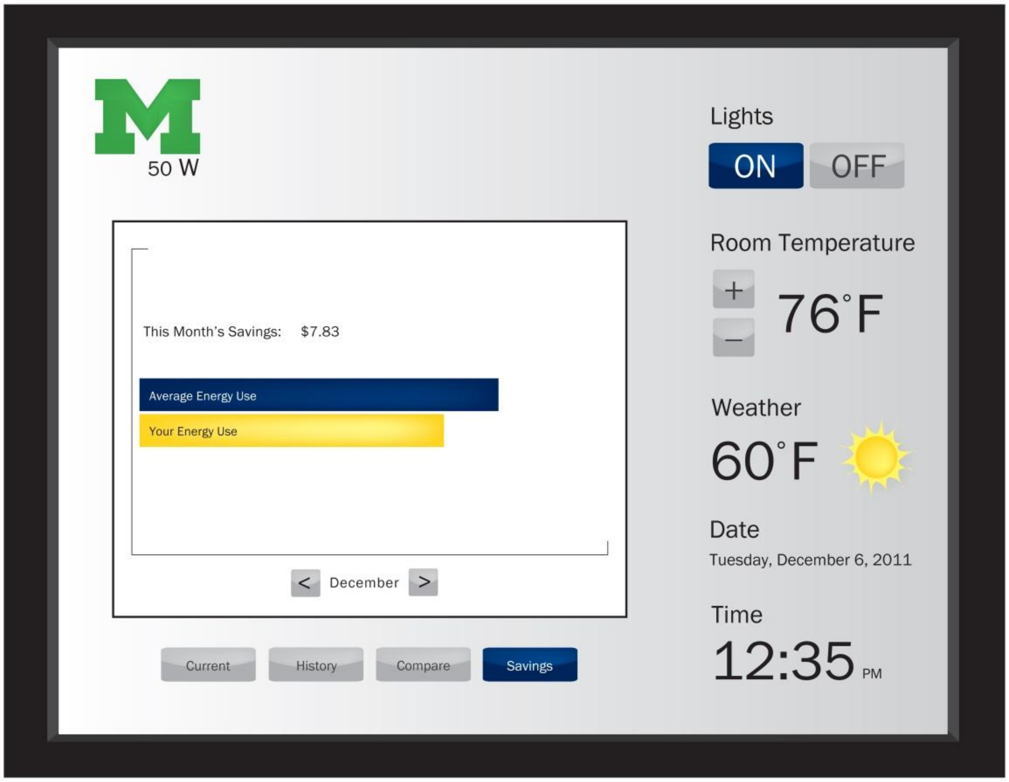
*Current Tab*

*History Tab*

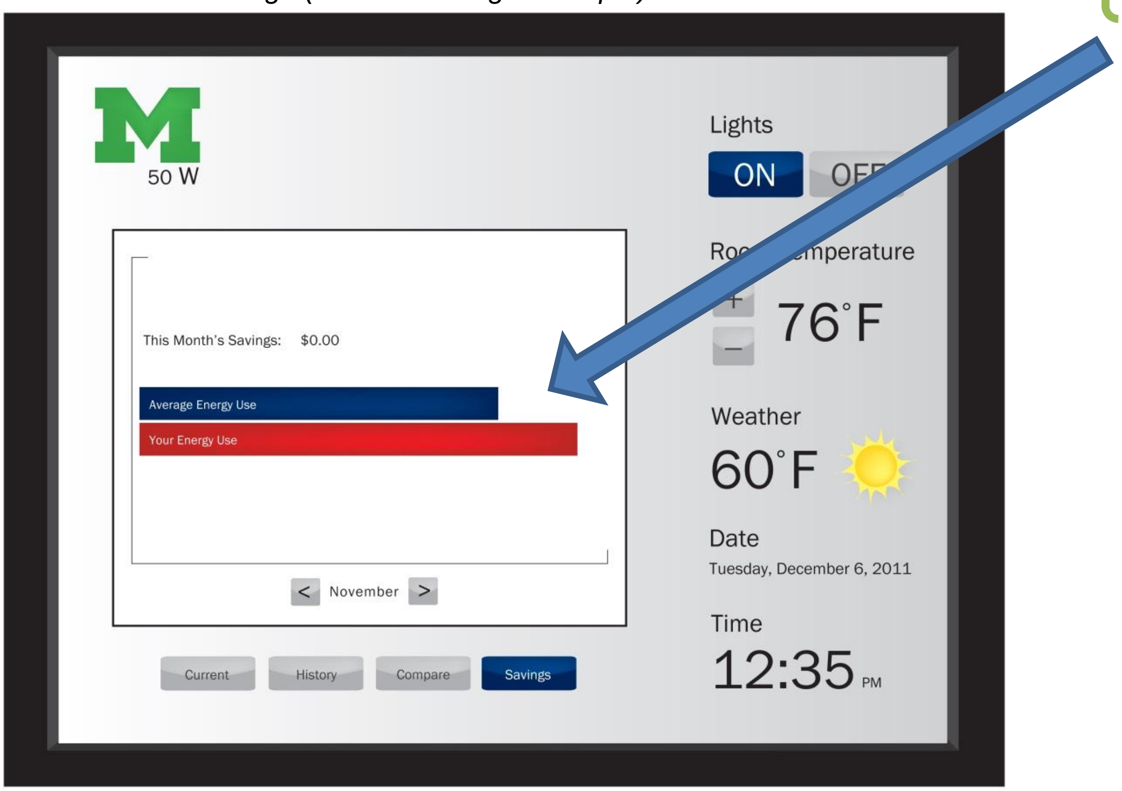

*Compare*



*Savings (user savings example)*




*Savings (no user savings example)*

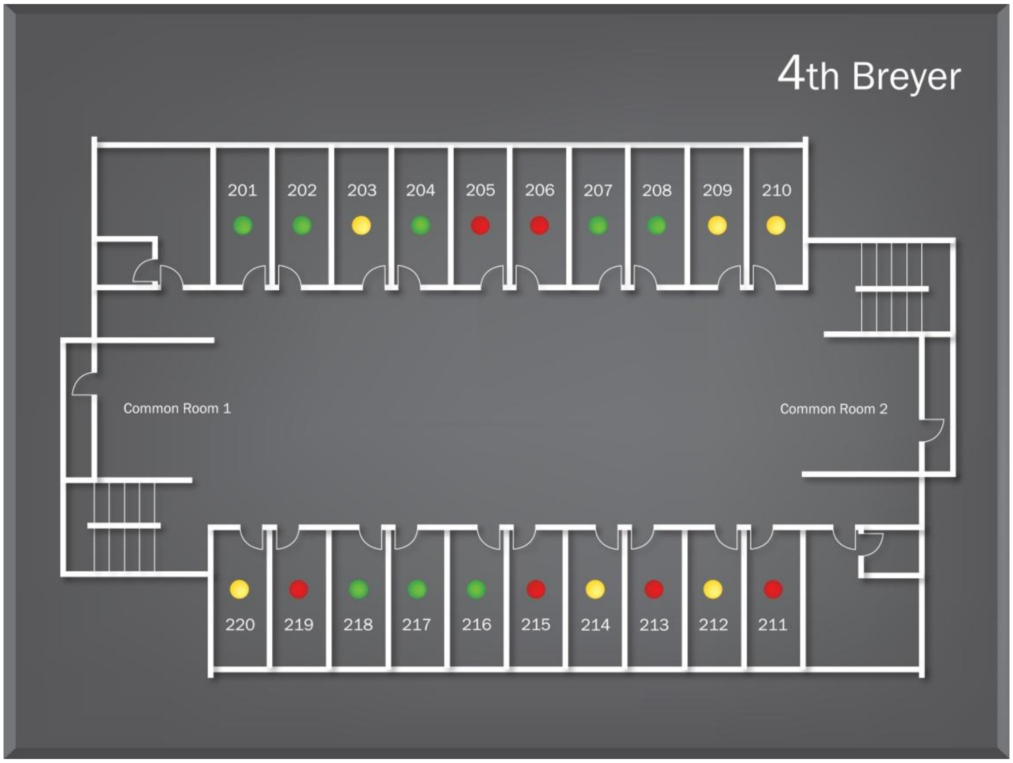



*New bar graph layout is more intuitive to users*

*The "Dorm Dash" in Context*

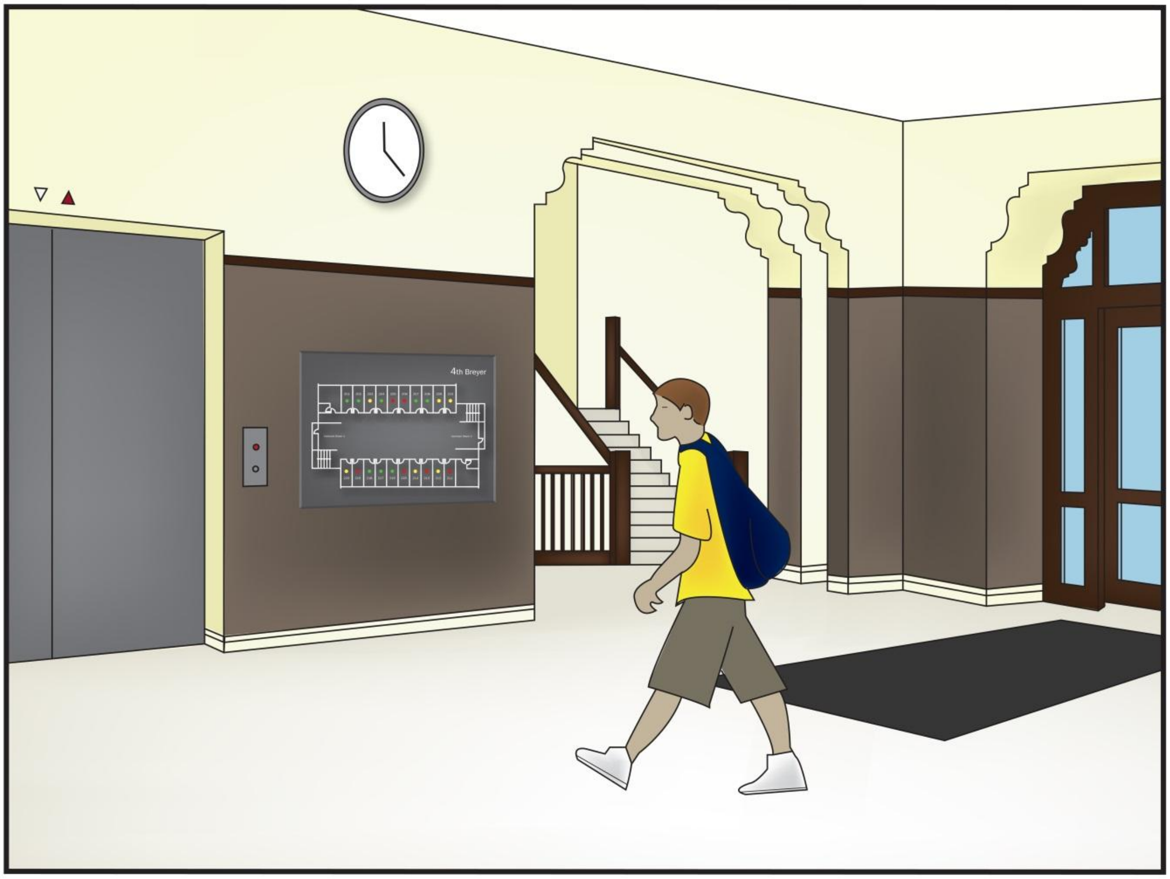
The Dorm Dash

# The Hall Monitor



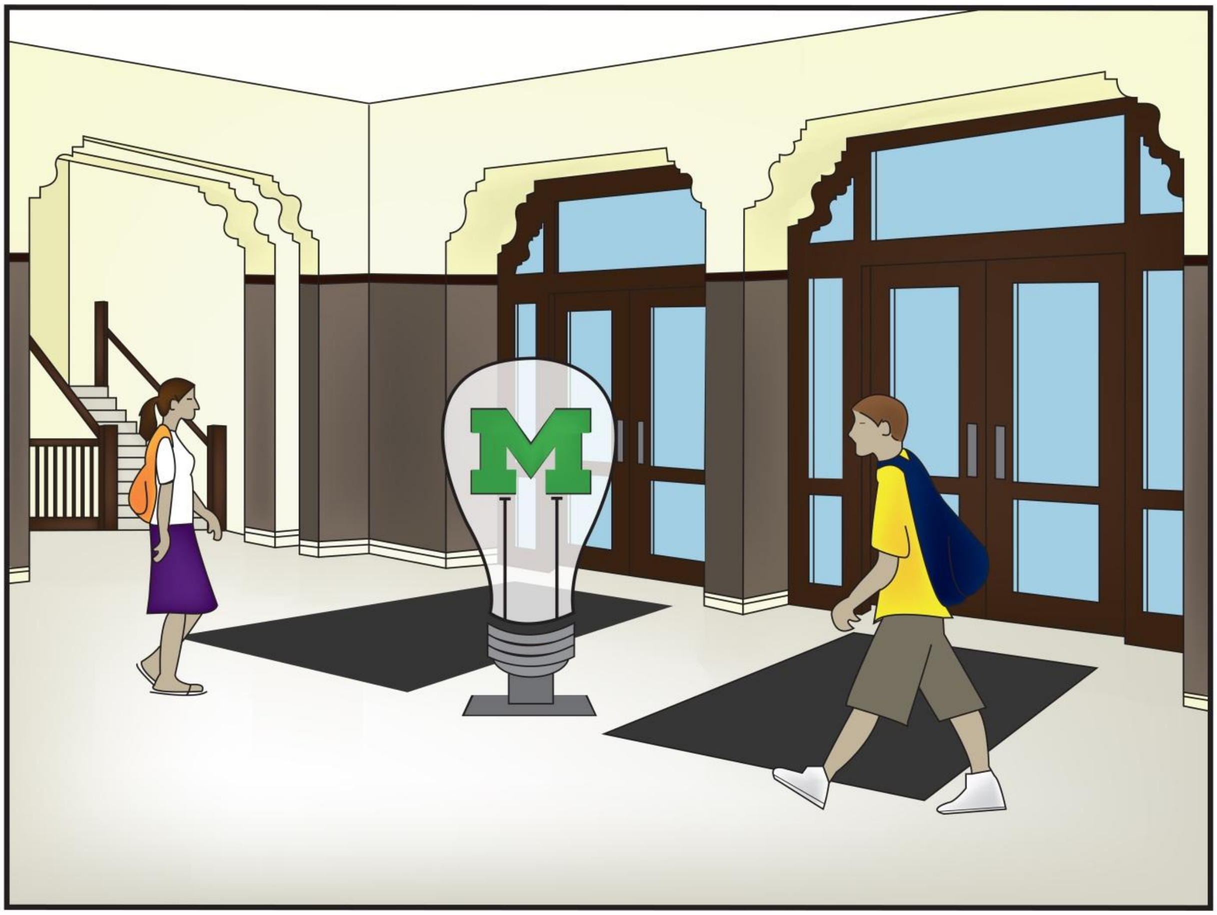
*“The Hall Monitor” in Context*

The Hall Monitor



*“The Bulb” in Context*

The Bulb



**Potential Systems and Feasibility Assessment**

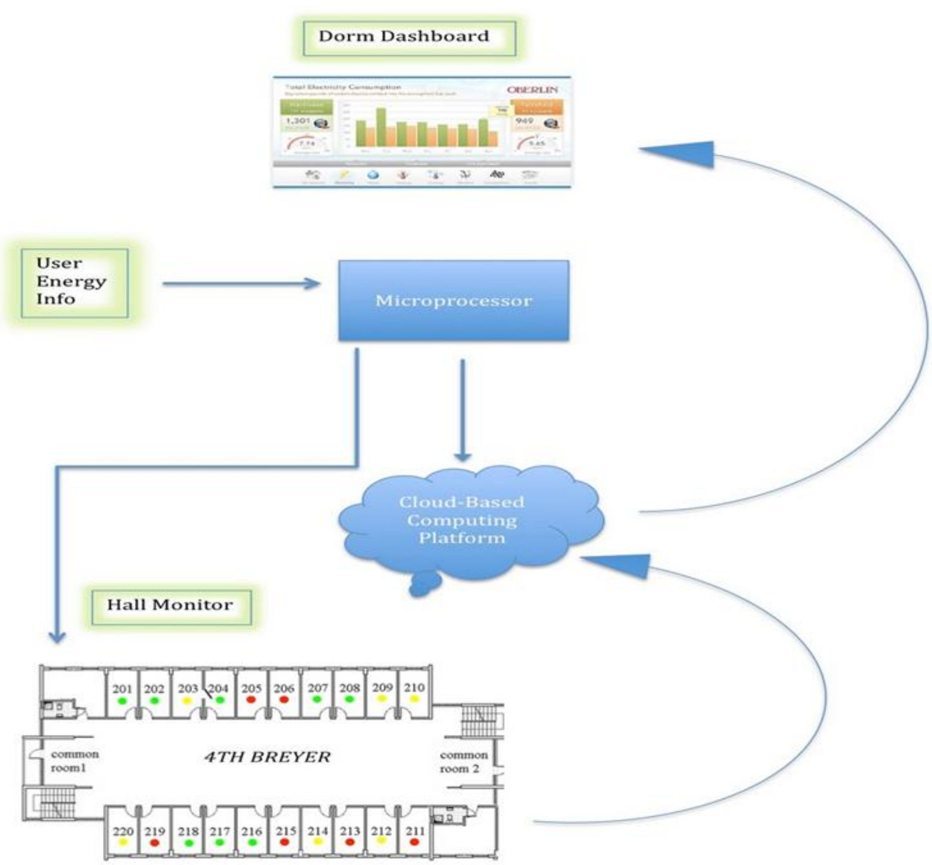
If the University of Michigan were to develop a campus energy visualization system there would be two avenues it could take: (1) development of its own system via open source hardware and software, or (2) buying rights to operate a system from a third party. The largest issues determining which approach the University should take revolve around monetary, human resource, and ownership factors.

A system in line with our recommendations would require many man hours put towards the development of both hardware and software platforms. In order for the University to understand what such a system would require we must first describe the functionality in a holistic manner.

Any energy visualization system requires, at the minimum, three functionality pieces:

1) Metering of electrical data
2) A collection of this aggregate data
3) A medium that can relay this data to end-users

The diagram below highlights the type of technological resources needed to make such functionality points work.



Starting from a user's room, energy use is calculated via current transformers and other circuit components. Afterwards, all electrical consumption is calculated in a small microprocessor unit that can send its data to other devices, such as "The Hall Monitor," and also to the web where all aggregate data is compiled and sent to the visualization system's web page and users' dorm dashboards. From an engineering standpoint, regardless if such a platform is developed in-house or is outsourced, there will have to be considerable work put into installing new metering hardware in dorm resident's individual rooms and hallway corridors. Other factors that might limit the success of implementation will come from building layout constraints which will be discussed further in our recommendations section. The following section discusses the costs and benefits of creating our system in-house vs. outsourcing the production.

In-House Development

As the most comprehensive solution, developing an energy visualization system in-house would have the largest impact in giving dorm residents the highest resolution of feedback possible. By not contracting out to third parties the University would have the flexibility in choosing how (what it looks like, how to access, etc.) students would view their energy usage. This is an important factor because presently there is no system that has room to room visualization displays, which was a crucial component from our user feedback. Below is a list of other various costs and benefits associated with in-house development.

Benefits

- Customizable web interface
- Customizable floor, building, and room visualization mediums (not just LCD monitors)
- Less expensive hardware costs

Costs

- Human resources spent towards building a cloud based data storage unit with an accompanying web interface
- Construction costs to implement sub-metering (although third party-systems would also require this at some scale)
- Supervision and maintenance by one or multiple units of the University (hardware and software upkeep by Plant Operations, Housing, and ITS)

Outsourced Development

Lucid Designs

As mentioned above, one of this market's most well-known producers is Lucid Designs. Lucid's integration with other universities' BAS systems is its highest selling point. By integrating with the BAS, the University does not have to create a new way of making electronic measurements at the building scale. However, the current BAS does not scale down to room-sized measurements, so there would have to be additional purchasing of sub-meters in order to have full metering.

In addition to its hardware offerings, Lucid offers institutions a full set of web applications and widgets specifically designed for energy visualization. By eliminating both web page and data storage elements, Lucid's web services are a huge savings in terms of product development and data storage costs.

### People Power

As more of a mobile-based system, People Power gives users real time energy information to their Internet based devices. Much like Lucid's features, People Power's apps and 'Energy Services Platform' give users the ability to monitor, control, compare, and compete with respect to their energy usage. The main advantage People Power's solutions have over Lucid's is that their applications have the ability to be scaled to a per-device level, making it extremely easy for the university to integrate energy monitoring on a dorm room level. This in turn would also enable the ability to have students be able to control their lighting from the system, which is included in our recommended design.

People Power's energy visualization platform, like Lucid's, would make data storage off site, allowing the University to save resources. Furthermore, their ability to tie social media and utility billing info would be an important aspect to consider. Having such features available would be a large asset to the success of the ROI of this project if further initiatives to change utilities billing to students' responsibility and initiative like Kill-A-Watt were to be expanded.

Both Lucid and People Power's current product lines only cater to displays with LCD touch screen interfaces. Although this will be needed for the dorm dashboards, not all aspects of the campus energy visualization system will require such extensive tools. For instance, our current design for our floor monitor system will be displaying energy information via LED lights. The energy information needed to operate this monitor would have to come from the metering devices in each dorm room. If the university were to purchase metering tools from a third party supplier such as Lucid or People Power, there would have to be an option to integrate with both university made devices and third party developers. If such an option is possible, the most advantageous route would be for the University to outsource much of the software, but develop most of the hardware in-house. Below lists the costs and benefits from third party development.

Benefits
- Less human resources spent on web development and data storage
- More web-based features
- Less software upkeep
- Pre-built apps for People Power

Costs
- Annual fees for software and data usage
- Limited room for customization of visualization devices

## Initial Cost Analysis

In order to recommend our campus energy visualization system to University departments, we first and foremost need to highlight the costs of such as system. Currently our group has received one bid from a third party developer (Lucid), and has also calculated hardware costs for a one hundred room pilot program. Hardware costs are based off of current market prices for each needed component.

In-House
- Microprocessor units @ $50 X 100 = $5000
- Sub-metering units @ $50 X 100 = $5000
- LCD displays @ $100 X 100 = $10,000
- DATA acquisition @ $ 200
- Software development and data storage *
- Total apx. = $20,000 or $200 per room without software

Lucid

- $25,000 to $50,000 without quote for individual LCD displays
- 10% of initial investment for data monitoring per year

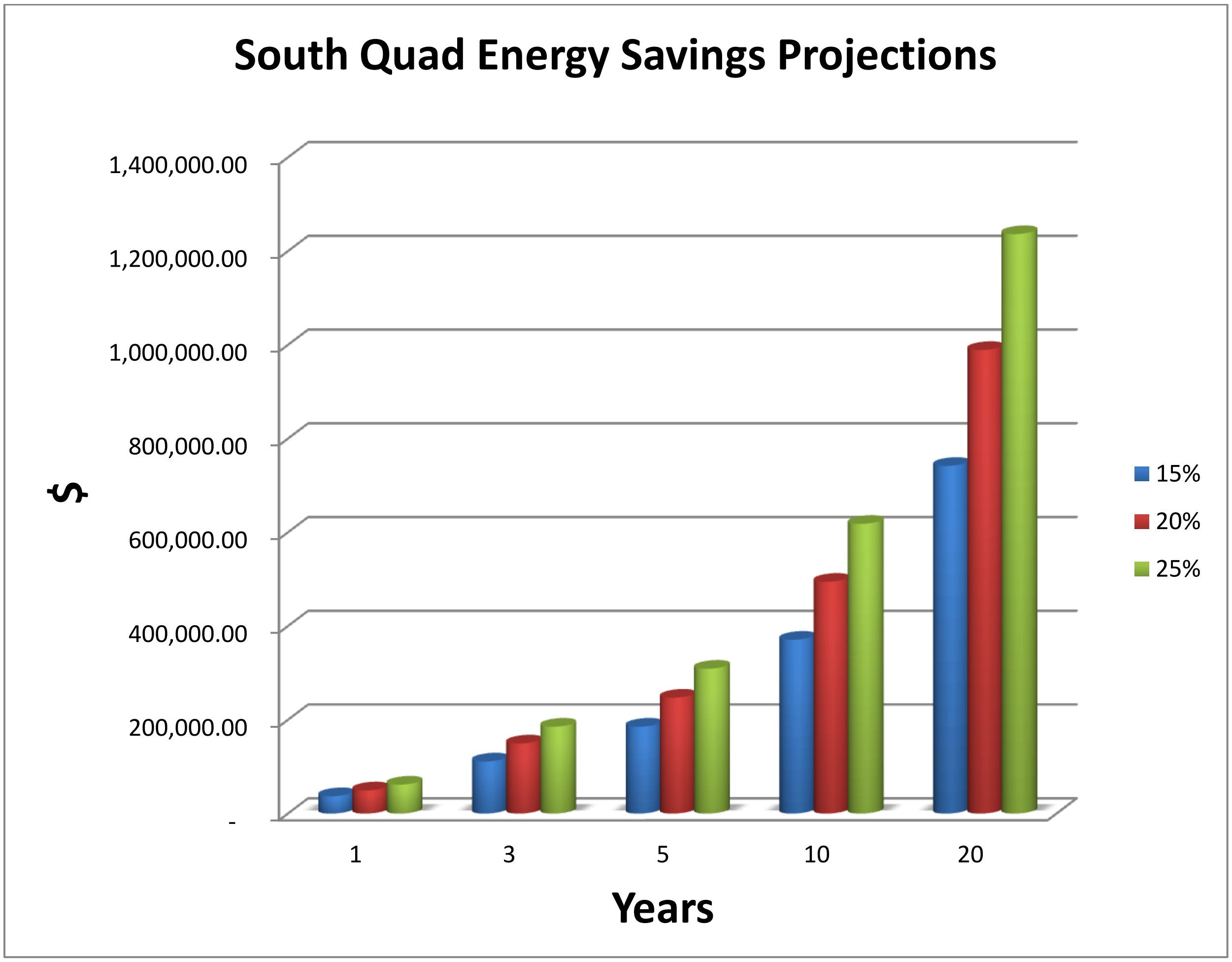
*Software has been left blank because there was no quote received. However, Bill Verge from plant operations gave our group an estimate of software his department uses for both metering and display purposes was approximately $10,000.

Return on Investment

Using the estimated costs for a one hundred room pilot, we drafted a rough return on investment to highlight the potential cost savings from eco-visualization-influenced energy reductions. The following assessments take the initial or start-up costs of our proposed system and calculate time frames in which money could be recovered. These rates were based off of numbers derived from similar pilots, such as Oberlin College's eco- visualization system (32% reduction off of baseline usage).

Actual metering and billing data was generated from a report compiled by the University of Michigan Housing Director of Business & Finance Michael Dennis. We must note that all reduction rates, both monetary and energy related are formulated from buildings as whole units. This means that each residence hall's net potential energy reduction rate is calculated under the assumption that non-student influenced usages, especially auxiliary systems such as kitchen, HVAC, and offices, have no influence. We could not include a building's specific contribution from student electrical energy use because (1) student contributions to an entire residence hall's energy use vary too widely, and (2) because of the variation in individual contribution, data is difficult to extrapolate, especially since sub-metering is not currently available. These two reasons give further credence as to why a pilot program would be necessary prior to wide-scale implementation.

South Quad Assessment




The above projections (with tabled values on the next page) show energy savings in $ units based off of reduction rates of 15, 20 and 25% values. From the estimated pilot hardware costs, we deduced that on a per unit (room) basis, each eco-visualization would cost approximately $200. Scaling this for an entire residence hall such as South Quad, we would expect a total initial cost to calculate around $116,000. The combination of the two cost analyses produced a return of investment to vary between 3 to 4 years (depending on the rate of reduction from the residence hall's calculated baseline energy use).

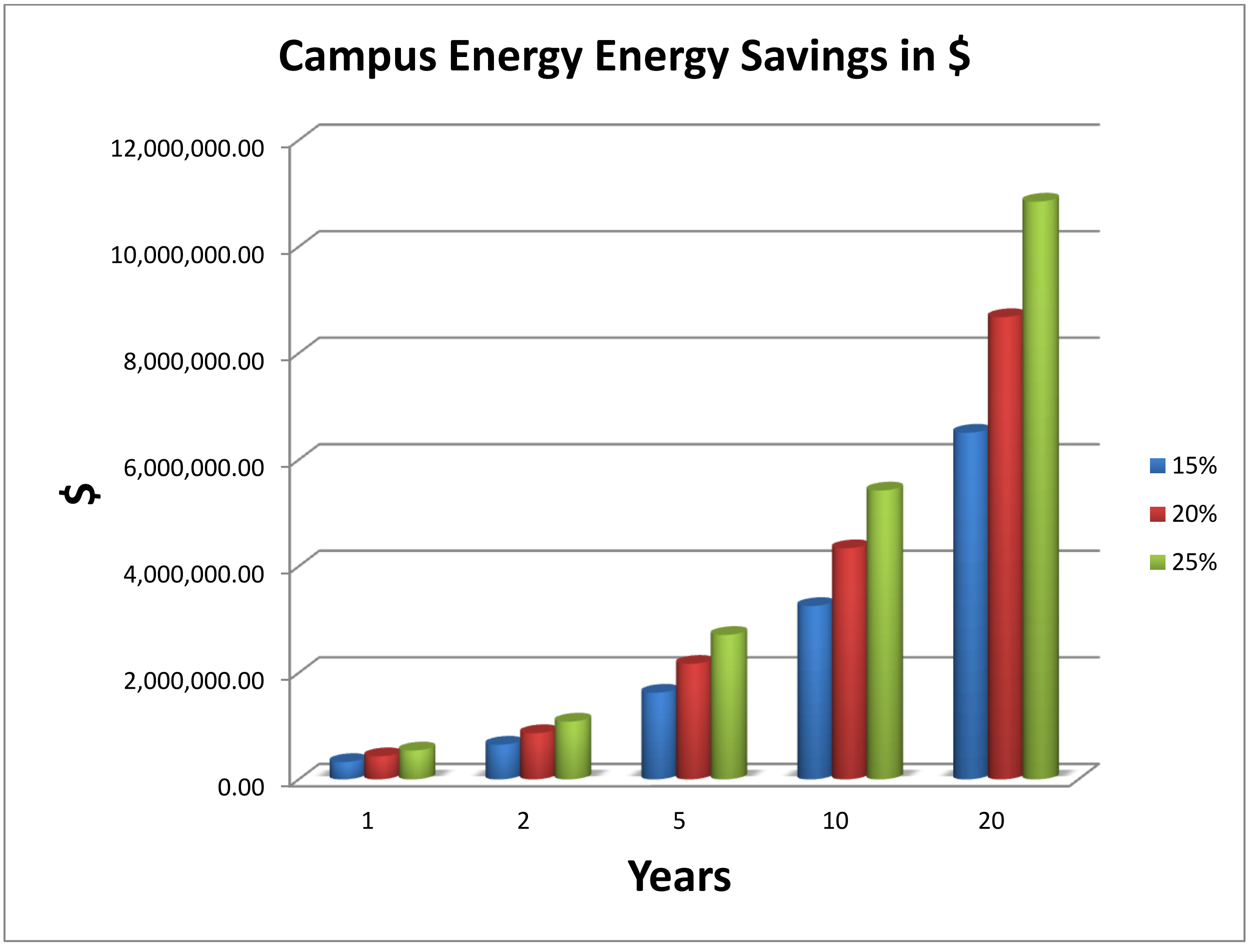
Table I

| Year | kWh | $/yr | Res Hall Baseline ($) | Number of Rooms | Avg Cost per room ($) | Initial Cost ($) |
|---|---|---|---|---|---|---|
| 2005 | 3,267,840 | 271,230.72 | 247,299.68 | 580 | 200 | 116,000.00 |
| 2006 | 3,176,480 | 263,647.84 | | | | |
| 2007 | 3,083,270 | 255,911.41 | | | | |
| 2008 | 2,969,874 | 246,499.54 | | | | |
| 2009 | 2,893,712 | 240,178.10 | | | | |
| 2010 | 2,874,890 | 238,615.87 | | | | |
| 2011 | 2,802,656 | 232,620.45 | | | | |
| 2012 | 2,767,392 | 229,693.54 | | | | |

Table II

| ROI in $ | 15% | 20% | 25% |
|---|---|---|---|
| Years | | | |
| 1 | 37,094.95 | 49,459.94 | 61,824.75 |
| 3 | 111,284.55 | 149,579.40 | 185,474.25 |
| 5 | 185,474.25 | 247,299.00 | 309,123.75 |
| 10 | 370,948.50 | 494,598.00 | 618,247.50 |
| 20 | 741,897.00 | 989,196.00 | 1,236,495.00 |

All Residence Halls




Similar to the South Quad cost and savings projections, we also conducted an analysis on all residence halls on campus. From the estimated pilot hardware costs, we deduced that on a per unit (room) basis, each eco-visualization would cost approximately $200. Scaling this for the entire campus, we would expect a total initial cost to calculate around $960,000. Similar to the South Quad analysis, we expect a return on investment to vary between three to four years (depending on the rate of reduction from the residence hall's calculated baseline energy use).

Table III

| Year | kWh | $/year | Res Hall Baseline ($) | Number of Rooms | Avg Cost per room ($) | Initial Cost ($) |
|---|---|---|---|---|---|---|
| 2005 | 20,102,618 | 1,668,517 | 2,169,486 | 4,800 | 200 | 960,000.00 |
| 2006 | 20,531,684 | 1,704,130 | | | | |
| 2007 | 19,281,433 | 1,600,259 | | | | |
| 2008 | 18,943,149 | 1,610,168 | | | | |
| 2009 | 22,146,449 | 1,912,606 | | | | |
| 2010 | 21,711,785 | 2,062,620 | | | | |
| 2011 | 23,913,829 | 2,415,297 | | | | |
| 2012 | 25,415,786 | 2,287,421 | | | | |

Table IV

| ROI in $ | 15% | 20% | 25% |
|---|---|---|---|
| Years | | | |
| 1 | 325,423.00 | 433,897.00 | 542,371.50 |
| 2 | 650,846.00 | 867,794.00 | 1,084,743.00 |
| 5 | 1,627,115.00 | 2,169,486.00 | 2,711,857.50 |
| 10 | 3,254,229.00 | 4,338,972.00 | 5,423,715.00 |
| 20 | 6,508,458.00 | 8,677,944.00 | 10,847,430.00 |

*All Electrical Energy Baseline Benchmarks were calculated from the standardized mean of energy use from years 2009 to 2012

**Recommendations**

After synthesizing both the primary and secondary research sections of our project, we recommend three key steps be taken for future development of the Interactive Energy Visualization System (IEVS): (1) exploration of a more detailed cost analysis and return on investment, (2) implementation of a pilot program, and (3) development of partnerships with complementary organizations or relevant stakeholders. We offer these recommendations to any future groups—whether this is another ENVIRON 391 or external group—as a guide to fundamental questions that will need to be answered in order for a campus energy visualization system to be successfully constructed.

Detailed Cost Analysis

Our present cost information shows that funding such a pilot would be feasible under a scope of fifty to one hundred rooms. As mentioned above in the cost analysis section, a one hundred room pilot with eco-visualizations constructed in-house would cost approximately $20,000, i.e. without estimates for labor and software costs. And from a third part supplier (as quoted by Lucid Designs) eco-visualizations would vary between $25,000 and $50,000. Ruling out Lucid, due to the fact that presently they are unable to customize individual room displays, we recommended that further return on investments fully investigated out in order to determine more precisely how much eco-visualizations made in-house could save both housing and the university as a whole. We believe with a more detailed return on investment, departments such as Planet Blue and Housing could be more apt to fund such a project.

The Pilot

From our initial findings we have deduced that a comprehensive pilot program is necessary to assess actual energy reduction rates from residence halls with installed eco-visualizations compared to those with none. Before a pilot is to be run in a residence hall, the following group should look to answer the following questions:

- How many halls, floors, rooms, will be metered?
- How will this data be analyzed and by whom?
- How do we quantify successful reduction rates? 10, 15, 50%?
- Who will manage the software and hardware components during the pilot?
- And if a pilot is successful, how will departments such as Housing or Planet Blue purchase and operate the campus visualization system? Will it be purchased from Plant and Operations and if so will they maintain the system?
- In which residence hall(s) should the pilot be run in?

In order for a pilot to be enacted, it will need to be funded by an external source. All parties that were interviewed in the initial stages of the project (namely Housing, the Office of Campus Sustainability, and Planet Blue) commented that although eco-visualizations are probably beneficial and helpful towards reducing our campus' carbon footprint, their budgets would not be able to fund a pilot.  We recommend that the next group look at the following sources of grants to fund a pilot program:

- PBSIF (Planet Blue Sustainability Initiative Fund)
- EPA's P3 (People, Prosperity, and the Planet) Grant
- White House "Champions of Change" Challenge
- Clinton Global Initiative University

Partnerships for Success

The campus energy visualization system will not be a standalone system.  Its success depends deeply on auxiliary groups and departments.  We have identified three specific areas in which the IEVS can be incorporated:

- Education
- Funding and Purchasing
- Construction and Maintenance

Education

The success of our proposed campus visualization system will depend heavily on education components.  We have identified the Kill-a-Watt program to be an essential component social aspect of our system.  We recommend that components of the "Dorm Dash"—specifically the savings and compare sections—be related and tied into Kill-a-Watts semester based competition.  Other important relationships include Planet Blue Ambassadors.  Planet Blue Ambassadors could be critical introducing and informing students about the system's functionality.

Funding and Purchasing

Housing has expressed interest in seeing the campus energy visualization system come to fruition.  We have identified them as a major source of funding for initial implementation of the CEVS. We recommend that Housing and Plant Operations (Planet Blue) work together in both the construction and implementation steps.

Construction and Maintenance

We recommend that Plant Operations (Planet Blue) develop the initial pilot designs.  If a pilot proves successful we recommend that Planet Blue also mediate the implementation of the IEVS in residence halls. It will be between Housing and Planet Blue to agree to terms of ownership and operating and maintenance responsibilities.

## Conclusion

Information flows can be vital tools for encouraging behavior change. As a form of feedback, eco-visualization systems seek to provide building occupants with the functional knowledge necessary for users to adopt energy-saving behaviors and reduce their environmental impact. The effectiveness of these systems is corroborated by numerous case studies in both the private sector and college campuses. By comparison, the University's current information flows with regards to energy consumption are numerous, but too broadly focused and not widely distributed. The Interactive Energy Visualization System outlined in this report hopes to foster an ethic of energy conservation within the University by connecting users with the impacts of their energy use through widely accessible, high resolution feedback. By partnering with complementary student organizations and relevant stakeholders, the IEVS stands to produce both significant economic savings and a more sustainable student body. While we acknowledge that the IEVS alone is insufficient for addressing all aspects of resource consumption, we believe the implementation of such a system represents an invaluable step towards realizing the University of Michigan's broader sustainability goals.

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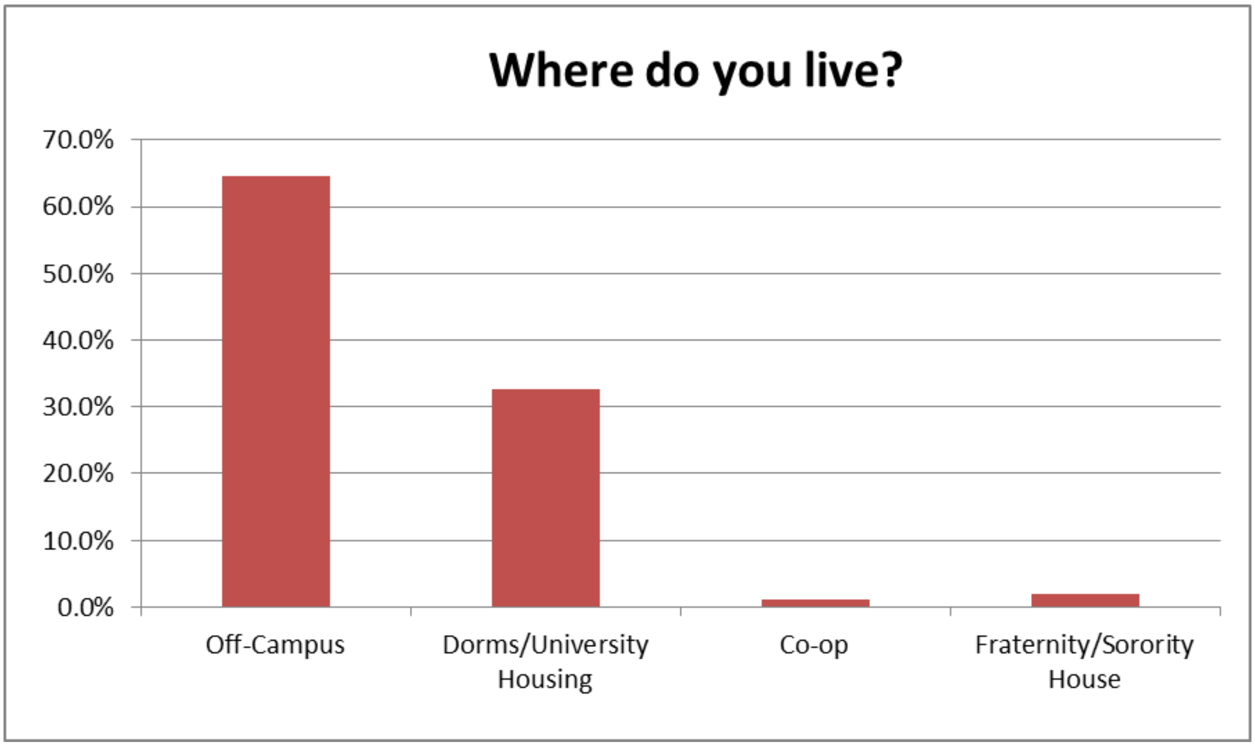
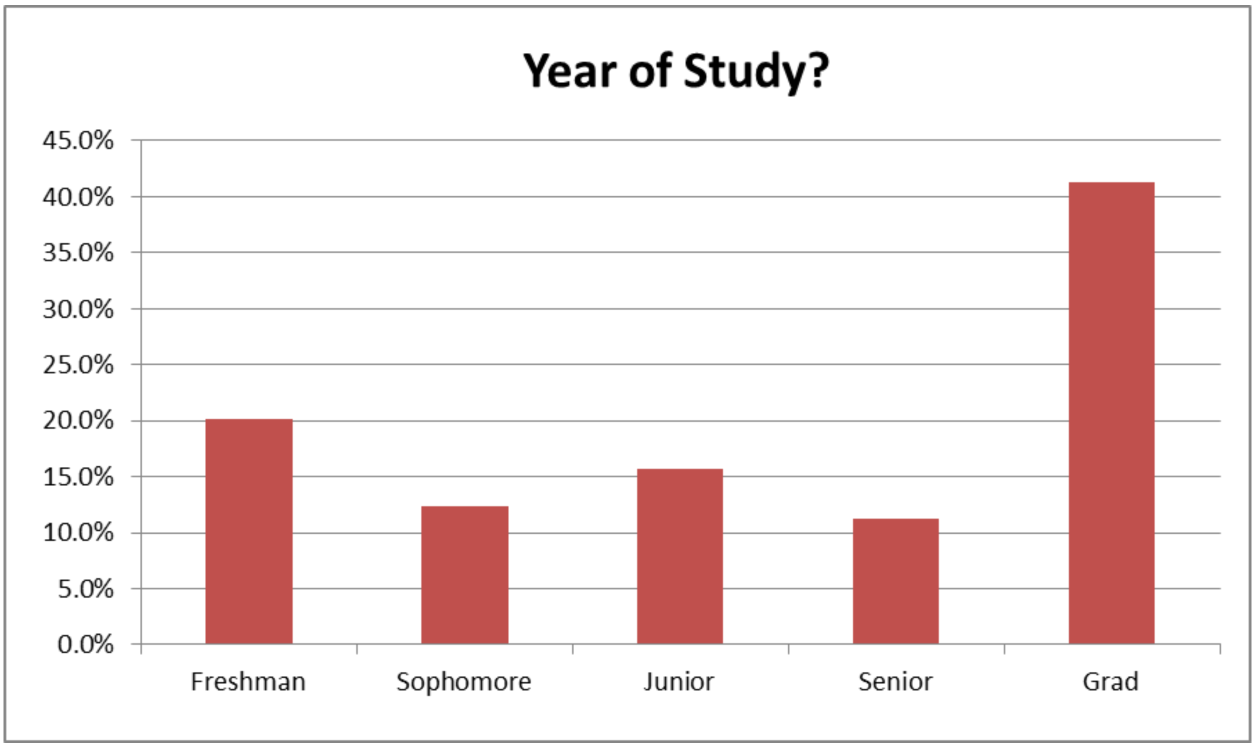
## Appendix A: Energy Literacy Survey Results

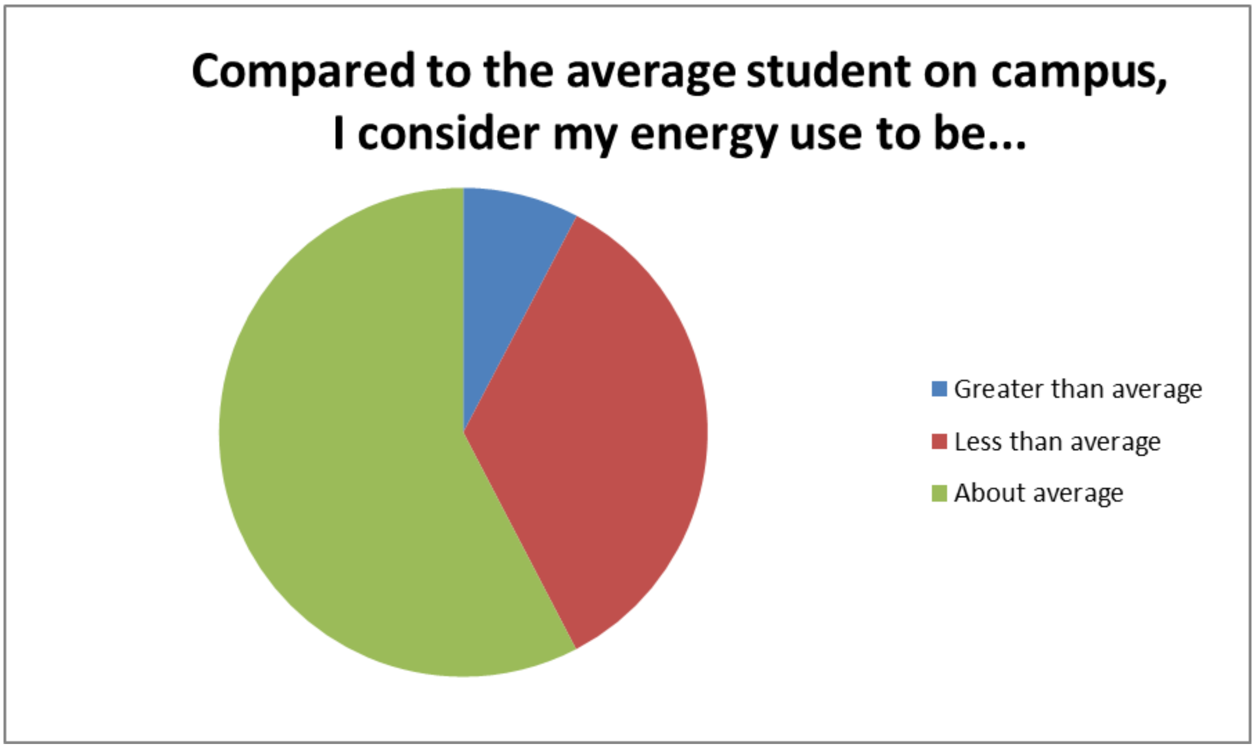
| Where do you live? | | |
|---|---|---|
| **Answer Options** | **Response Percent** | **Response Count** |
| Off-Campus | 64.6% | 424 |
| Dorms/University Housing | 32.6% | 214 |
| Co-op | 1.2% | 8 |
| Fraternity/Sorority House | 2.0% | 13 |
| | *answered question* | 656 |
| | *skipped question* | 3 |



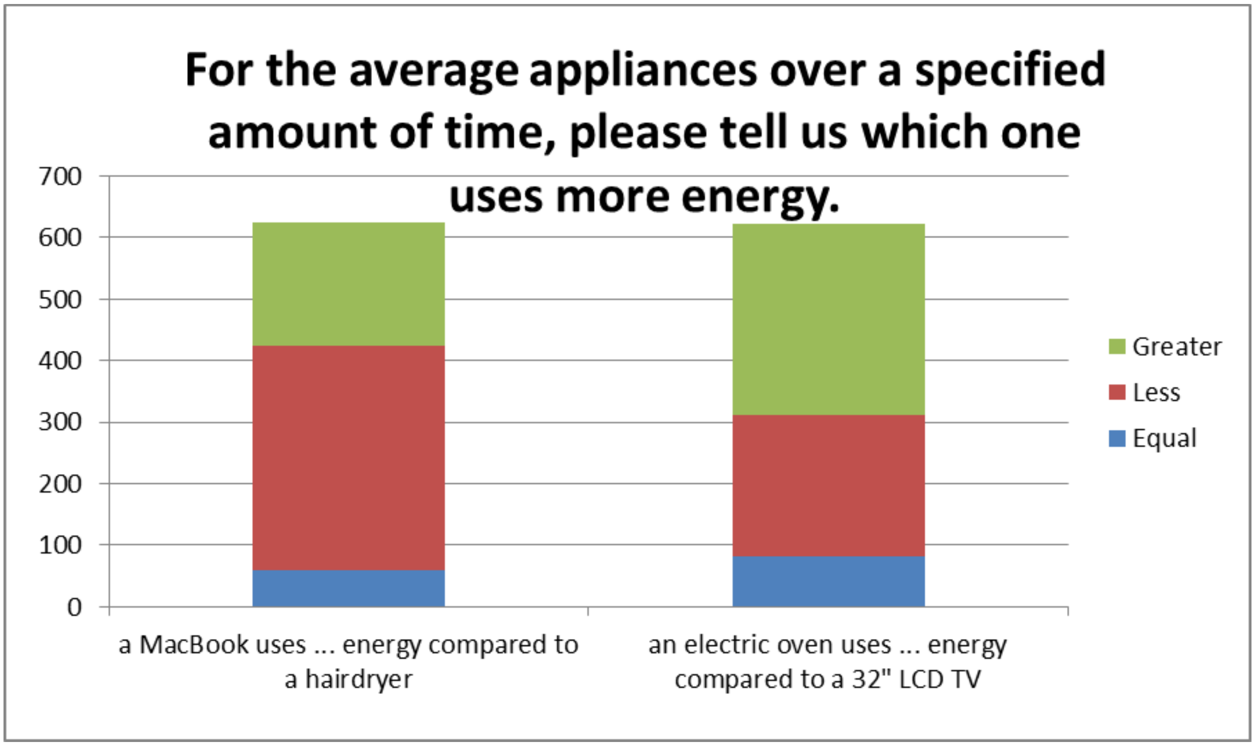
| Year of Study? | | |
|---|---|---|
| **Answer Options** | **Response Percent** | **Response Count** |
| Freshman | 20.1% | 132 |
| Sophomore | 12.3% | 81 |
| Junior | 15.7% | 103 |
| Senior | 11.3% | 74 |
| Grad | 41.3% | 271 |
| | *answered question* | 656 |
| | *skipped question* | 3 |



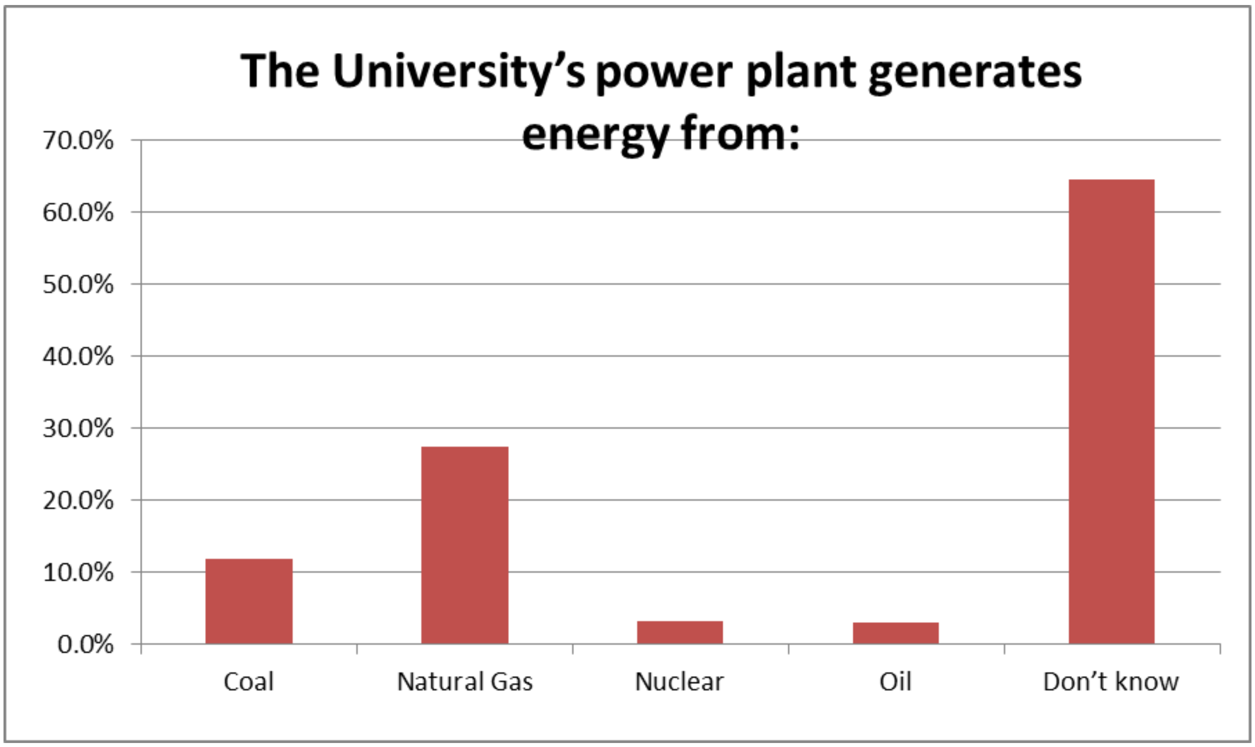
| Compared to the average student on campus, I consider my energy use to be... | | |
|---|---|---|
| Answer Options | Response Percent | Response Count |
| Greater than average | 7.7% | 48 |
| Less than average | 34.7% | 217 |
| About average | 57.7% | 361 |
| | *answered question* | 626 |
| | *skipped question* | 33 |



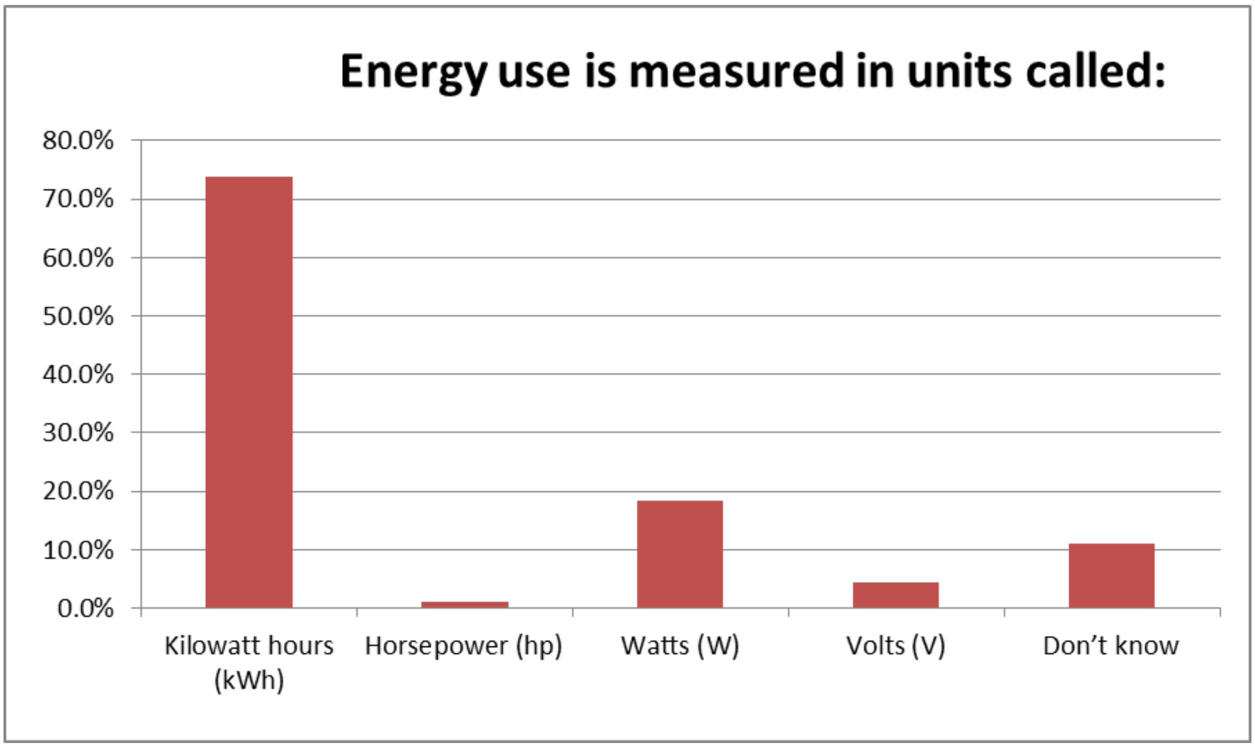
| For the average appliances over a specified amount of time, please tell us which one uses more energy. | | | | |
|---|---|---|---|---|
| Answer Options | Greater | Less | Equal | Response Count |
| a MacBook uses ... energy compared to a hairdryer | 200 | 365 | 59 | 624 |
| an electric oven uses ... energy compared to a 32" | 310 | 229 | 83 | 622 |
| | | | *answered question* | 624 |
| | | | *skipped question* | 35 |



| The University's power plant generates energy from: | | |
|---|---|---|
| **Answer Options** | **Response Percent** | **Response Count** |
| Coal | 11.9% | 75 |
| Natural Gas | 27.4% | 172 |
| Nuclear | 3.2% | 20 |
| Oil | 3.0% | 19 |
| Don't know | 64.5% | 405 |
| | *answered question* | 628 |
| | *skipped question* | 31 |



| Energy use is measured in units called: | | |
|---|---|---|
| **Answer Options** | **Response Percent** | **Response Count** |
| Kilowatt hours (kWh) | 73.7% | 463 |
| Horsepower (hp) | 1.1% | 7 |
| Watts (W) | 18.3% | 115 |
| Volts (V) | 4.3% | 27 |
| Don’t know | 11.0% | 69 |
| | *answered question* | 628 |
| | *skipped question* | 31 |



| How strongly do you agree or disagree with the following statements: | | | | | | |
|---|---|---|---|---|---|---|
| Answer Options | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree | Response Count |
| Reducing my personal energy consumption is | 12 | 23 | 86 | 337 | 169 | 627 |
| I am interested in knowing how much energy I use | 14 | 26 | 85 | 324 | 179 | 628 |
| I am interested in how much my energy consumption | 13 | 20 | 77 | 314 | 202 | 626 |
| I am interested in knowing the energy consumption of | 14 | 30 | 119 | 315 | 149 | 627 |
| U of M should reduce their energy consumption even if | 35 | 92 | 198 | 201 | 100 | 626 |
| | | | | | *answered question* | 628 |
| | | | | | *skipped question* | 31 |