IPRO 334
Spring 2007 Final Report

Resource Consumption Awareness in the Home

Advisor: T.J. McLeish

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1.0 Introduction

In the 21st Century we are capable of monitoring our consumption of resources. For example, many cars now contain real time readout of current miles per gallon. However, the means of monitoring energy usage in real time in the home is still unavailable to the consumer. IPRO 334 is set up to evaluate energy consumption awareness in the home and discover what type of system for providing feedback on energy consumption is useful to the consumer.

2.0 Background

Customer: This project attempts to serve people who are interested in reducing energy consumption in their homes. This customer may be interested in our product to save money, because of the new technology, or for the good of the environment.

User problems: We wish to create a system which creates an environment where a user can be made aware of their power consumption without having to adapt to a new or complex set of tools.

Technology: Wireless technologies are infiltrating the homes of average Americans more and more every day. These tools can be leveraged to create a better living experience not only for the comfort of those in the home, but to improve the world’s environment.

Historical success and failure: The mileage monitor on new cars has changed the way we drive. We are now aware moment-by-moment of real time fuel consumption. This has resulted in a cultural shift in the way we think about a car's efficiency, and even how people drive. Some simply see this technology as a status symbol. Others have created personal competitions to drive down their own fuel consumption. With the cost of fuel on the rise and growing fears of global warming, this technology couldn't have appeared at a better time. Why is there no equivalent technology for people's homes? There are few options for consumers to monitor their consumption of energy beyond electric, gas, and water bills. These bills are often so complex it is difficult to discern all the metrics. Some products on the market now, like the Kill-A-Watt, give feedback in a format such as kilowatts which can be difficult for people to relate to. Other programs, like Aware @ Home, are web-based which leaves the program inaccessible to those who are not computer literate. Also, the lack of real time feedback gives customers very little chance of effectively modifying their behavior. Part of our design criteria is to develop an easy to understand product that gives real time feedback and does not require a computer to run.

Ethical and Moral Issues: While wireless networks give people a chance to quickly and easily attain information, they come at a cost. We must be certain to investigate who will have access to the information sent over the networks. We must also make sure security measures are in place so unauthorized users cannot gain access.

Societal Costs: If we are successful in our project, the benefits to society will outweigh the cost. Whatever reason people have for using our system, it will encourage them to lower their energy consumption. This cannot only save people money, but also reduce dangerous greenhouse gas emissions.

Proposed implementation outline: IPRO 334 will address these issues by working as a team to define, prototype, and test an ambient system to provide consumers with information about their personal energy usage.

3.0 Purpose

People are inadequately informed about their energy consumption behaviors in the home. Providing real time feedback at the point of decision-making will enhance consumer awareness of energy consumption, and potentially lead to behavior modification. The purpose of IPRO 334 was to design and evaluate a means of improving energy consumption awareness in the home.

It was determined that in order to evaluate energy consumption awareness it would be necessary to understand what the user considers useful feedback. Therefore, team 334 chose to focus on determining what metrics are most valuable to consumers and the best means to communicate feedback.

Objectives for the Spring 2007 Semester were:

- Study existing technology and similar projects in the areas of energy consumption measuring and awareness
- Develop an ideal user profile, research the users' needs, and find suitable examples in the real world to use as test groups
- Based on user interviews, develop design criteria for the most effective means of communication to people about their consumption
- Design and prototype an interface providing the feedback determined in the design criteria
- Test the effectiveness of the prototype in a residential environment
- Compile data and draw conclusions on the prototype's affect on consumption awareness.
- Project our ideas to future advances of the product including technology, marketing strategies, and business plans

One difficulty in achieving the above objectives was the limitation of time. Therefore, the work of IPRO 334 will continue in the fall semester of 2007. The progress of this semester will create a strong framework for the fall semester. The fall team can use current testing results to modify the prototype and create a user interface that will bring in suggestions for behavior modification.

4.0 Research Methodology

The problems that were focused on during the duration of the semester were determining what the most appropriate feedback would be to provide consumers with regarding energy consumption in the home and determining the best way to provide consumers with that feedback in order to increase awareness on a grand scale in home energy consumption.

The project process proceeded in circles around four stages of research, analysis, synthesis, and implementation throughout the semester, and thus, the teams and their personnel changed accordingly. For the first few weeks, the IPRO was divided into a project planning/deliverable group, a user research group, and a business plan group.

The project planning/deliverable group formed each time a deliverable needed to be completed. This group was in charge of overseeing the production of the Project Plan, the Midterm Report, and the Final Report, as well as keeping track of the budget. After a draft of any report or deliverable was completed, the group would present the draft to the entire team for review and editing.

The user research group was formed in the beginning to create and distribute questionnaires and interviews for the target user type, collect the data from this research, and summarize and analyze the data. This group shortly learned that the data collected from stand-alone questionnaires was not as valuable or useful for informing the design of a prototype as questionnaires and/or interviews in conjunction with a test of a preliminary design idea. The data collected that was pertinent was presented to the entire team after analysis to allow the team to react to the feedback and design the next prototype in response to the data collected.

The business plan group was the only team that formed at the beginning stage and remained constant throughout the entire semester. The group researched marketing techniques and strategies to best market potential products to home owners. The group worked on business scenario plans that were presented to the entire group when formulated so as to help inform the interface and outcome of the design of the prototype. The group looked into what exactly our product needed to do, who the users would be, what price it should be sold at and how to market the finished product.

After the initial research of current devices on the market and user questionnaires, the design group took the information collected and the ideas from the brainstorming sessions and came up with an initial prototype design largely based upon an interface that was created the semester prior from a similar design group.

As the project process went on a design team, a synthesis team, and a production team was needed. As an entire group we came together to determine how the research would specifically inform the ideal user, as well as what information that user would find meaningful in order to impact their energy awareness. These conclusions informed the design of a product that we tested in homes.

The Synthesis Team analyzed the data collected to form design criteria, as well as collected data from prototype testing and analyzing results.

The Design Team developed designs and created prototypes that accomplished the appropriate feedback for the determined user and addressed all the specific design criteria and parameters. They also tested the prototypes on a variety of people in three diverse home settings. The design team, dependent on what stage the testing process was, split into smaller sub-groups to accomplish all aspects of testing prototypes and acquiring data from them. These sub-groups included the orientation/introduction group, the feedback group, the installation group, the prototype group, and the data analysis group.

The orientation/introduction group came up with a simple way to explain the project and how the device works to the user that will be testing the prototypes. When the product was installed in the test users' home, a group member was there to introduce them to the devices, explain the process and answer any questions they might have.

The feedback group brainstormed ideas to figure out how best to give feedback to the test user and how to change the feedback in between tests to make it more affective/useful for the next test.

The installation crew consisted of various members depending on availability and confidentiality of test site, who went into the test users' home and installed the devices on electronic equipment and set up the feedback devices. After the testing period had concluded, they would go to the users' home and uninstall all equipment and feedback devices.

The members of the prototype group actively participated in buying supplies/materials and designing and building various feedback prototypes to be used during testing.

The members of the data analysis group deciphered data collected by the computer during testing and figured out how it related, how useful and how it could help us further the design of the device.

The Production Team compiled all data and designed the final material used for presentations on IPRO day.

The specific breakdown of the project process:

- Research: business, market, people
- Analysis and Synthesis of collected information
- Develop design criteria informed by research
- Determine specific parameters to inform product design from the created criteria
- Develop designs that address specific design criteria and parameters
- Create prototypes that accomplishes the appropriate feedback for the determined user and addresses all the specific design criteria and parameters
- Test the prototypes on a diverse group of people in diverse home settings.
- Conduct research according specific to the homes and people within the homes that the prototypes were tested in
- Analyze the test results and research
- Determine the results found from the analysis of the testing

5.0 Assignments and Designation of Roles

While the teams we created in the Project Plan are still valid, we have added other sub-teams to address specific problems that have arisen with the design of the prototype and testing phases.

<u>Team Descriptions</u>

Planning/Deliverables: Team leader – Jessica Henson

The Planning/Deliverable team put together the project plan, midterm report and final report as well as taking on the responsibility of turning in all final products to the IPRO office for IPRO Day.

Business Plan: Team leader – John Kestner

The Business Plan Team researched marketing techniques and strategies and determined the best way to market the product to the intended user.

User Research: Team leader – Jordan Fischer

The User Research Team created and distributed questionnaires and interviews for the target users, collected the data, and summarized the data.

Synthesis: Team leader – Nick Perry

The Synthesis Team analyzed the data collected to form design criteria, as well as collecting data from prototype testing and analyzing results.

Design: Team leader – James Pierce

The Design Team developed a design and created a prototype that accomplished the appropriate feedback for the determined user and addressed all the specific design criteria and parameters. They also tested the prototype on a variety of people in diverse home settings.

Production: Team leader – Sarah Jones

The Production Team compiled all data and design the final material used for presentations on IPRO day.

Sub-Team Descriptions

Orientation/Introduction: No assigned leader.

The purpose of the Orientation/Introduction Team was to come up with a simple way to explain the project and how the device would work to the user that would be testing the system. When the product was installed in the test users' home, a team member would be there to introduce them to the devices, explain the process and answer any questions they might have.

Feedback: No assigned leader.

The Feedback Team brainstormed ideas to figure out how best to give feedback to the test user and how to change the feedback in between test to make it more affective/useful for the next test.

Scenario Plan: No assigned leader.

The Scenario Plan team was looking at what exactly our product would do, who the users would be, what price it should be sold at, and how to market our finished product.

Installation/Uninstall Crew: No assigned leader.

The Installation Crew consisted of various members depending on availability and confidentiality of test site, who went into the test users' home and installed the devices on electronic equipment and set up the feedback devices. After the testing period has commenced, they went to the users' home and uninstalled all equipment and feedback devices.

Prototype: No assigned leader.

The members of the Prototype team actively participated in buying supplies/materials, designing and building various feedback prototypes to be used during testing.

Data Analysis: No assigned leader.

The members of the Data Analysis Team deciphered data collected by the computer during testing and figured out how it related, how useful it was, and how it can help us further the design of the device.

Construction: No assigned leader.

The Construction Team was in charge of buying supplies, designing and building the exhibit space for IPRO Day.

Interiors: No assigned leader.

The Interiors Team designed, collected and decorated the exhibit space for IPRO Day.

Last Name	First Name	Major	Year	Skills	Attributes	Team/Tasks
Cawvey	Jessica	Architecture	4	Autocad Microsoft Office Suite Adobe Illustrator Adobe Photoshop	Organized Creative Hard-working	Planning/ Deliverables, Feedback, Prototype, Collection of Materials and Supplies, Presentation, Install/Uninstall Crew, Interiors
Christensen	Carissa	Architecture	3	Autocad 3D Studio Max Microsoft Office Suite Adobe Photoshop Rhino Dreamweaver	Organized Happy Creative Visual Hard-working	Planning/ Deliverables, Orientation/ Introduction, Install/Uninstall Crew, Interiors

Dannhausen	Anna	Architecture	4	AutoCAD Accurender (AutoCAD 3D rendering program) Microsoft Office Suite Adobe Illustrator Adobe Photoshop Dreamweaver	Organized Personable (good with phone calls and dealing with people)	Business Plan, Scenario Plan, Prototype, Interiors
Fischer	Jordan	Design	Grad	Adobe Photoshop Adobe Illustrator Adobe InDesign Macromedia Flash Macromedia Dreamweaver Rhino (surface modeling) Maxwell (rendering software) Photography Videography Rough Prototyping Interviewing	Extracting Meaning from complex data Motivation Consensus Building Creative Direction Improvisation Framing problems to provide a new perspective Leading during the generation of ideas, and following during the implementation of ideas.	User Research (Leader), Orientation/ Introduction, Install/Uninstall Crew, Production
Henson	Jessica	Architecture	4	Autocad 3D Studio Max Microsoft Office Suite Adobe Illustrator Adobe Photoshop Mathcad SAP2000 Dreamweaver	Organized Leadership Outgoing Hard-working	Planning/ Deliverables (Leader), Feedback, Install/Uninstall Crew, Prototype, Collection of Materials and Supplies
Herrera	Stephanie	Architecture	4	Autocad 3D Modeling Animation Adobe Suite Microsoft Office Suite	Organized Enjoys working with hands Research	User Research, Orientation/ Introduction, Install/Uninstall Crew, Prototype, Construction

Jones	Sarah	Design	Grad	Adobe Photoshop Adobe Illustrator Adobe InDesign Macromedia Flash Macromedia Dreamweaver Rhino Solid Edge AutoCad Matlab Pbasic Page Layouts	Rendering Implementation Delegating	Planning/ Deliverables, Feedback, Install/Uninstall Crew Production (Leader)
Kestner	John	Design	Grad	Program in Java, Basic Stamp, etc Write HTML	Communicate effectively with words, illustrations, photos and models Design user-centered products and interfaces that look good and communicate what they're about	Business Plan (Leader), Feedback, Install/Uninstall Crew, Production
McLeish	TJ	Professor	Prof	n/a	n/a	Professor
Perry	Nicolas	Architecture	4	General Computer Skills (above average) Adobe Suite CS2 AutoCad Microsoft Office Suite Laser Cutter 3D Studio Max Sketchup Wood Shop Soldering electrical Circuits Knowledge of electronics concepts and components (beginner) Project scheduling and cost estimation	Organized Fast learner	Planning/ Deliverables, Orientation/ Introduction, Install/Uninstall Crew, Prototype, Synthesis (Leader), Construction
Pierce	James	Mathematics	4	Adobe Photoshop Adobe Illustrator Macromedia Dreamweaver Java Eclipse Machining Welding Fabrication Research, exploration, and analysis	Learning new skills (e.g. electrical/hardware)	User Research, Feedback, Install/Uninstall Crew, Prototype, Design Leader, Production

Popov	Nikolay	Mechanical Engineering	3	AutoCAD Microsoft Office Suite Basic C++ and Matlab Basic Electronics	Honest Caring	Business Plan, Feedback, Data Analysis, Install/Uninstall Crew, Prototype,
Puschkar	Jackie	Business	2	Microsoft Office Marketing Business strategies	Personable Organized	Business Plan, Scenario Plan, Interiors
Wong	Jacintha	Business	4	Adobe Photoshop AutoCad 3D Studio Max Microsoft Office Suite	Artistic	Business Plan, Scenario Plan, Deliverables

Designation of Roles

Role	Description	Assigned to
Master Schedule Maker	Responsibilities include planning a master schedule and keeping it current	Jessica Henson
Meeting Minutes Taker/ Organizer	Responsibilities include taking minutes of each meeting, recording the information on a standard form, and uploading minutes on to igroup site. (see grading criteria for specific details)	Jessica Cawvey
Meeting Agenda Maker/Timekeeper	Responsibilities include meeting with Master Schedule Maker and putting together a Meeting Agenda for each class. (see grading criteria for specific details)	Nicolas Perry
Weekly Status Reporter	Responsibilities include developing an individual Weekly Progress Report form, compiling a weekly status report that includes Meeting Minutes, Meeting Agendas, and Weekly Progress reports from each team member. (see grading criteria for specific details)	Jacintha Wong
Igroup Coordinator/ Communication Facilitator	Responsibilities include collecting all contact information and posting on igroups as well as keeping the igroups site and folders organized	Jacintha Wong
Webmaster	Responsibilities include setting up and design, and maintaining website for class	John Kestner
Treasurer	Responsibilities include maintaining the budget, collecting receipts and turning them into the Ipro office for reimbursement.	Jessica Henson

Head Researcher/ Historian	Responsibilities include applying to the internal review board for project testing and delegating necessary research as well as photographically documenting the progress of our project	Jordan Fischer
Presentation Coordinator	Responsibilities include delegating and managing all assignments that need to be done for final presentation on IPRO day and assuring all material is received on time.	Sarah Jones

6.0 Obstacles

Market Research:

The main obstacle met in the market research was obtaining the type of data needed rather than the data readily available. Most of the research that was initially found was in the way of statistics and number comparisons. While this information was not altogether invalid, a more useful data type was needed for our project in the way of marketing strategies for energy reducing products and how to best create and market an energy awareness product so that it would be successful on the marketplace despite the largely apathetic population. The business plan team decided to work with different specific business scenario options so that the research would be geared towards a specific type of business scenario and would be easier to access.

Feedback/Testing:

Surveys were written and placed on an internet survey site and then filled out by volunteers. However, because the surveys stood alone without any context of a prototype to provide additional energy feedback to the volunteer, the feedback from the surveys we received back had little to no value for informing prototype design. The obstacle that this created was that the feedback we needed was reliant on in-house testing, which took much more time than just handing out surveys. It was also much more intrusive and intensive of a process for both the team and the volunteers. It is harder to find people who are willing to have the prototypes in their houses for an extended amount of time and who care enough to interact with the prototypes. The majority of the team's contacts ranged in age groups that do not own houses nor pay for their own energy bills. However, the team found three homes of volunteers that were willing to open their homes for the purpose of our prototype testing. Time was something that we were fighting with this project because each test took time to design, produce, and prepare the prototypes to test. Then about half of a week would be spent testing and then the test would be uninstalled and the data would be analyzed. The team worked hard to get as many tests completed within homes as possible in order to best inform the final design solution.

A large obstacle that the team faced has is that one of our RF1 receivers ceased to collect data after about twelve hours of testing for an unknown reason at the first in-home test. When trying to collect data on a three day in-home test, it was inconvenient to end up with only twelve hours of usable data. After the first test we contacted the manufacturer and they helped to conduct a debugging experiment to uncover the problem and get it fixed so we could continue with the prototype testing. The second in-home test was installed but the same experience happened and the data collected was cut short of what was expected. Changes were made to the interface and computer being used to attempt to fix the problem. After running it at one of our team member's house for about half a week without any problems we were ready to install the prototypes in a third home test. Unfortunately, the third test had same result. Thus, all of the data collected from our prototypes in home tests was for a very short amount of time. This problem would have to be fixed with the design interface and inner-workings of the prototype devices. However, by the time the third test was completed, there was no time left to fix the problem and perform an additional test. We hope that the IPRO gets continued next semester so as to have the time to fix this problem and in turn be able to attain more concrete data to design with.

7.0 Results

User Profile:

The user profile has been identified as having three main attributes. Our ideal user would be someone who pays their own bills, is an early adapter (first wave consumer) and some who is forward looking (excited/concerned about the future).

Product Research:

There is a variety of products, both commercial and conceptual, whose aim is to make energy visible to the homeowner. We've identified three general product categories for energy-awareness products.

Diagnostic Tools:
Pros: detailed information about specific appliances
Cons: difficult to use, cannot easily see total energy consumption
Examples: Kill-A-Watt, current clamps (used by electrical technicians)

These are small, handheld tools that measure the energy consumption of individual appliances. These products require the user to plug in the appliances they want measure, hence they require a significant amount of effort from the user. These products also have several advanced data collecting features.

In-Home Energy Meters:
Pros: easily see real-time total energy consumption
Cons: difficult to track consumption of individual appliances
Examples: Power-Cost Meter, Centameter, The Energy Detective, Wattson, Building Dashboards

There are two sub-categories of in-home energy meters:

1. Portable energy display units

These products essentially take the confusing, analog power meter outside your house and map it to a portable digital display inside the house. The homeowner can take the energy meter anywhere in the house and see, in real-time, the amount of energy they are consuming. They also have the option of viewing energy consumption in terms of Watts or dollars. These products also typically display other useful information such as the time and date.

2. PC-based energy displays

These are very similar to the portable energy display units, except they use a PC to display and manipulate energy data. These products also tend to have additional advanced feature capabilities. For example, Building Dashboard displays a wealth of information about resource consumption to the homeowner via charts, graphs and animations. This info can be viewed on a home PC, electronic kiosk, or other web-enabled computer devices.

Artistic / Para-Functional:

Pros: fun, aesthetic, thought-provoking

Cons: lack practical information and use-qualities

Examples: Wattson, projects by the Static! Group at the Interactive Institute (including the Power Aware Cord, Erratic Radio and Flower Lamp)

There are a wide range of products ideas whose aim is to cause the user to reflect on their relationship with technology and energy rather than to give practical feedback. There are three approaches typically used that may be considered more artistic than utilitarian.

1. Ambient Information:

The Power Aware Cord attempts to make energy usage visible by literally having a cord that lights up to reflect the amount of energy being used. The Wattson, which primarily functions as an in-home energy meter, also conveys the numerical energy information with colored lights that accomplish functional as well as aesthetic ends.

2. Subversive Technology:
These are products that turn-off or behave erratically when consuming too much energy. For example, the Erratic Radio "untunes" when excessive power is being consumed.

3. Equating Low Consumption with Aesthetics:
An example is the Flower Lamp, which "blooms" to become more beautiful when less energy is used.

Insights from Product Research
The insights from our product category research are summarized in a list of qualities we consider keeping, losing and adding to our design.

Keep
+ feedback on individual appliances
+ feedback on total household consumption
+ real-time feedback
+ dollar and wattage metrics
+ fun and engaging interaction
+ aesthetic appeal

Lose
+ required interaction from the user
+ complex setup

Add
+ prescriptive feedback or coaching
+ long-term goal evaluation
+ rewards and incentives

Metric and Feedback Brainstorming:

We began by brainstorming different metrics to communicate feedback to the users on their consumption habits. Four basic categories were formed to represent the metrics that were generated:

1. Products/Rewards:

- Coupons, Wish list of prizes, Rebates, Money Back on energy bill payments, Food/Drinks, Shoes

2. Numeric:

- Money, Kilowatt hours, watts

3. Ecological Impact:

- Ecological footprints (individual property, town), How many _______ (power plants, earths, landfills, oceans, forests, etc.) represent the amount of energy the household uses in a ___________ (year/month/day)?

4. Sensory:

- Color, symbolic color, smell, vibration, lights (dim, brighten, dancing, flashing, etc.), sound (ambient noise, music, machinery, etc.)

We also brainstormed how best to display the feedback and can up with these ideas.

- Graphs, Charts, Mapping behavior and how it affects someone else

From this list of options, we began to integrate certain ones into the prototype system to test on subjects. We would then make conclusions about which ones were most effective.

Market Research:

The market research conducted to this point focused on three different alternatives. The first was where the product should be located. Based on the research, the largest energy consuming devices in the home are located in the kitchen. These include refrigerators, dishwashers, freezer, and electric range and oven. Other major energy consuming devices include air-conditioning, space heating, lighting, and water heating.

Also researched was the initial cost of the product versus the long term benefits. An example that was found regarding this was the use of compact fluorescent light bulbs rather than incandescent light bulbs. The companies that sell these light bulbs found that they needed to have a low enough price to sell them, because people are concerned with initial cost. This is especially true for landlords who do not want to pay the higher initial cost for something they are not paying for on a daily basis.

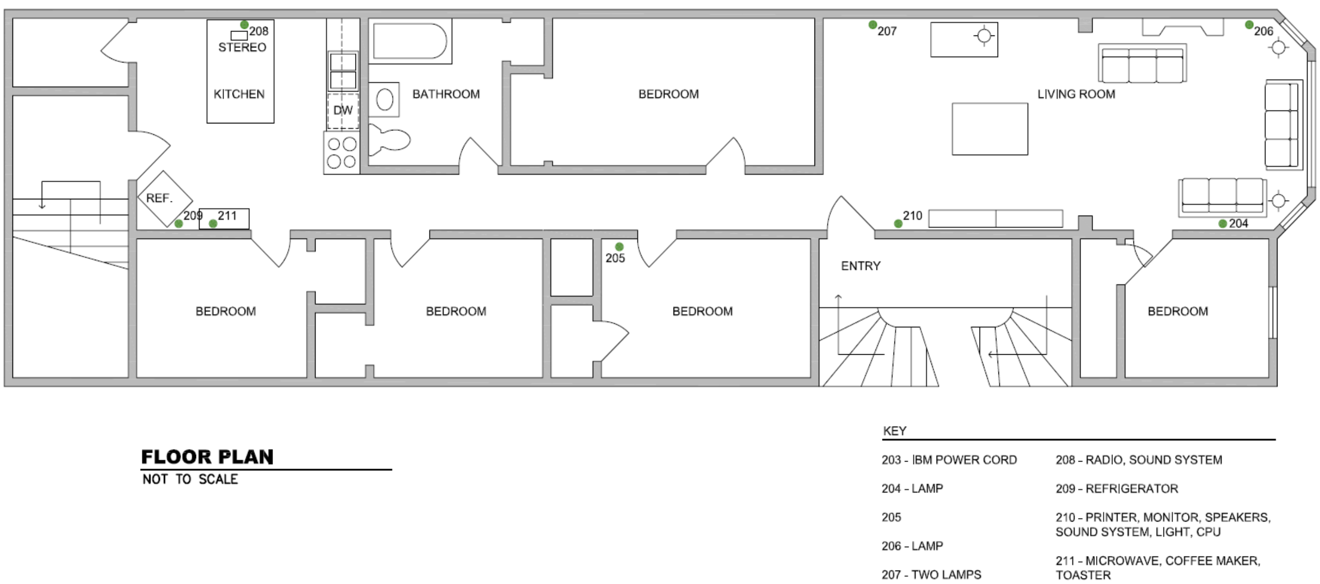
The final research shows the benefit of aligning our product with an already successful program. An example of a program that would be beneficial to associate with is Energy Star. Their popularity and stature would give our product high regard right from the beginning.

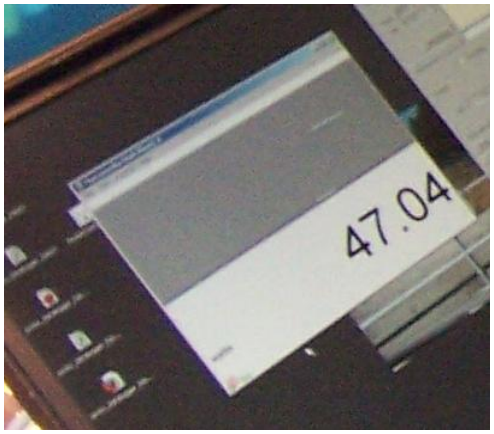
Test Phase 1

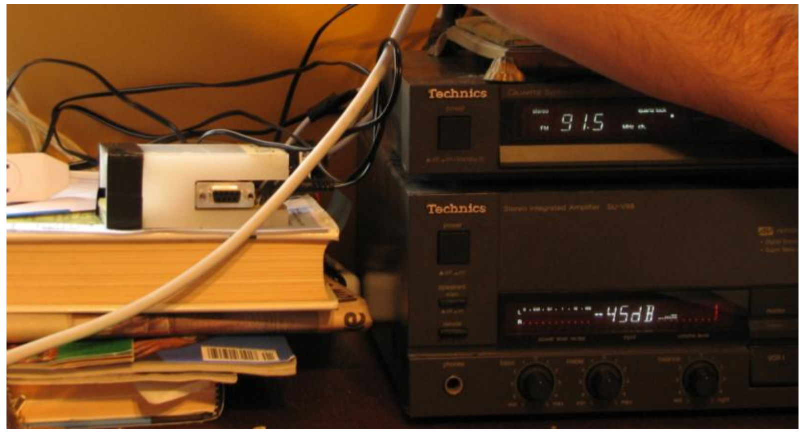
Prototype #1 Description:

The first prototype consisted of a computer screen and connecting wireless modules. The modules were connected to electric devices throughout the apartment of the test subjects. These modules sample the amount of current passing through an extension cord, and when it detects a change in the amount of current, it sends that sampled reading to a laptop. The computer screen displays a summation of kilowatts and a bar of color. The color ranges from green to red based on the amount of energy being used (red is near maximum, and green is all devices off).

Testing Procedure:
The first testing period lasted 3 days. It took place in an apartment with 6 residents. For this test, the screen was placed in the living room. This location was chosen because of its central location, and as an area where many of the users spent time. As seen in the floor plan, 8 wireless modules were placed throughout the apartment and connected to the listed devices.







Feedback Screen

Wireless module, attached to radio (208)

Testing Results:

During the test phase, users were encouraged to jot down thoughts about their experiences. We also interviewed the subjects after the test. We were also able to use the logged data to create a graph showing the usage history collected from each module. Through these experiences we learned a few key insights;

- seeing the feedback in an area close to the consumption point is important
- there are multiple modes of use including: immediate, peripheral, passive engagement, focused, active engagement
- active engagement decays over time as the "novelty" experience wears off
- the metric of kilowatts gave little meaning

Design Criteria Changes:

We then moved to improve the prototype for a second test period. To give users feedback in close proximity, we added a scale in the form of several lights which corresponded with each wireless module. This would allow users to see the reaction of a device on the entire system without moving to the room with the computer screen. We also changed the information displayed on the computer screen. A large block of color corresponding with the wireless modules was displayed. A projected dollar value was also displayed based on the current energy usage. We hoped that a dollar value would give more meaning to the user than the kilowatt value.

Test Phase 2

Prototype #2 Description:

Prototype 2 still uses a centrally located display on a laptop screen, however the interface has changed. The screen now shows more than one numerical metric. The display now provides information in kilowatt-hours and dollars rather than just in watts. Each of these two values are averaged over the last 24 hour period and projected forward for a month. The display tells the user, "if you continue consuming at this current rate, you will spend $X in a month and use X kwh of energy in the same month." The display allows the user to toggle between the two numerical metrics, only showing one at a time. The screen also shows a colored square which changes from green, to yellow, to orange, to red to give a real-time representation of the home's total consumption where green represents low consumption and red represents high consumption. In addition to the centrally located display, prototype 2 features remote displays. Each device/appliance is connected to a remote LED light display. It has four LEDs of the same four colors used in the square on the main display and the color shown on the laptop screen is mimicked on the remote LED displays. These displays were installed near each of the devices being monitored to allow the user to see a real-time representation of the house's consumption without having to walk over to the main display. (See attached pictures of display interface and remote displays)

Testing Procedure:

The team developed a more organized testing procedure for the second installation. Four roles were designated according to different tasks that needed to be done during the installation and takedown.

Installation Procedure

People Needed

- *Narrator/Documenter* – Explains procedure to owner and answers all necessary questions. Documents all activities, including location of all devices and client responses.
- *Installer* – Decides where all devices will be located based on the response of the client as to which appliances are used most frequently.
- *Measurer* – Measures and records layout of living space and devices.
- *Draftsmen* – Drafts layout of the living space and device locations.

Time Line *(estimated)*

- Measuring and Layout – 45 minutes
- Installing and documenting devices – 1 hour
- Testing devices – 10 minutes
- Introduction and exit – 15 minutes
- **Total time of Installation – 2 hours and 10 minutes**

Order of Operations

Installation

- Arrive at client's house and as a group, introduce yourselves and thank them for their participation.
- Narrator asks for a showing of the most frequently used appliances in the house on a daily bases.
- Installer evaluates devices and determines which appliances to install the devices on based on the accessibility of the appliance.
- Draftsmen and Measurer split off to document the space.
- After Narrator explains and answers all questions Narrator joins Installers to document.
- Installers test installation of the devices and make sure everything is in proper order.
- Narrator gives final explanation of the journal entries and any final questions (include FAQ)

Take-Down

- Narrator reviews journal entries to make sure everything is clear then asks exit interview questions.
- Installer takes down all devices and returns everything to its proper manner.

Narrator's Script

Installation

(Upon entering the house)

Hi, my name is _______ and I am the team leader and contact for this project, thank you for all of you participation. (*Introduce everyone and what they will be doing throughout the visit)* Why don't you start by showing us the house and which appliances you feel you use the most on a daily bases.

(Walk through of the house, Installer should be recording locations on appliances and accessibility of outlets, Measurer may break off and begin laying out the house.)

(After walk-through)

We would like to ask your permission to install devices on… *(list chosen appliances).*

(After client approves)

This is the device that we are installing *(show device)* this piece clips over the power cord and measures the amount of energy being used by the appliance. The device records the amount of energy used and sends the data to the computer screen and it shows up on a monitor. I'll show you more about the feedback when the devices are hooked up.

(Narrator joins the Installer to document the devices, this should take about a an hour)

(Show and explain the feedback to the client and make sure they fully understand the operation of the project)

The project will be installed for three days and you are asked to keep a journal. Make sure you date and time the entries and write what ever you feel about the product at that time.

Based on the information I have given you what are you expecting from this project?

(upon exiting)

Thanks again for your participation, again my name is _____ and here is my contact information in case you have any questions later on. We will be back on _____ at _____ to un-install the devices.

Take-Down

(Upon entering)

How did everything go?

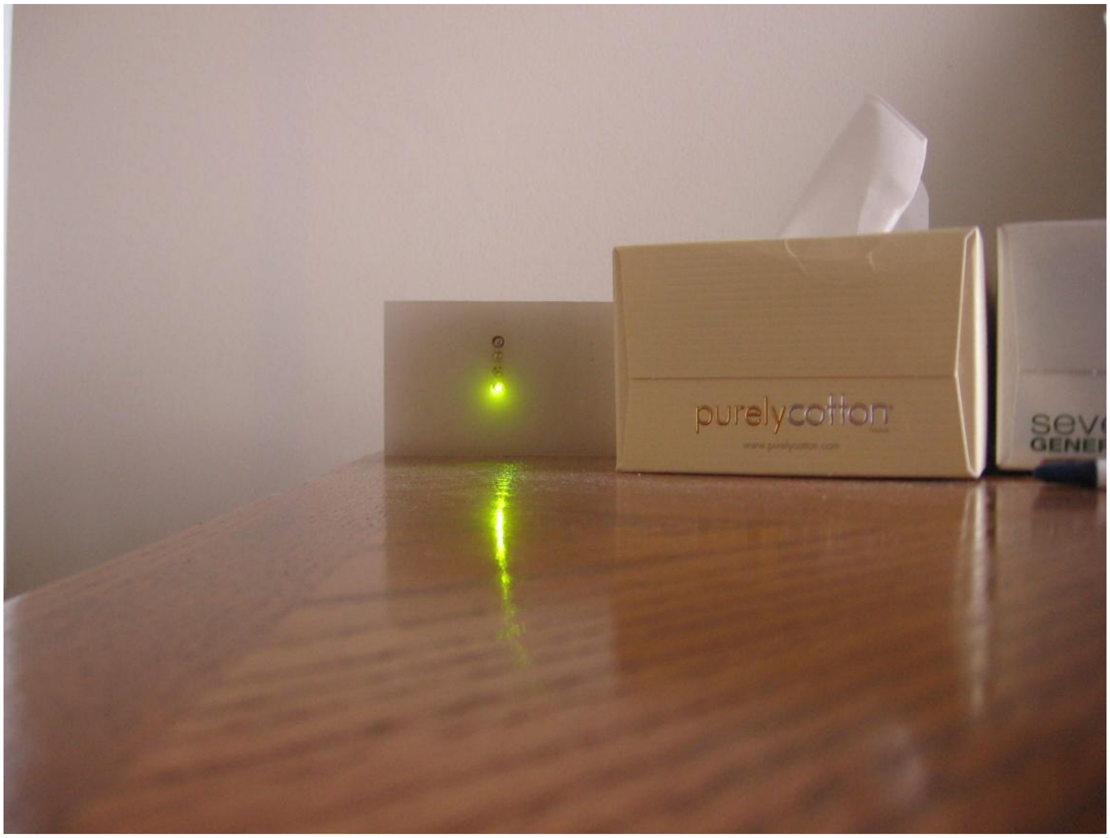
(Insert closing interview questions here, Narrator records answers. Install takes devices and returns everything to its normal state.)

Testing Results:

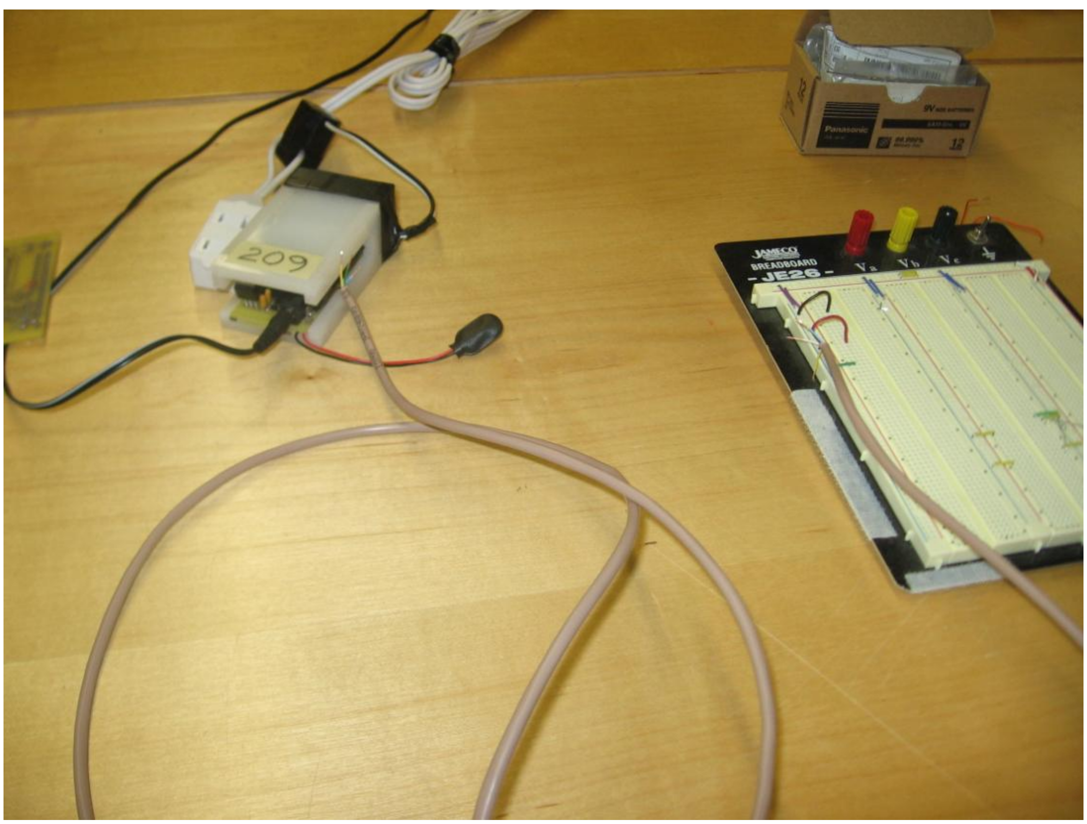
Unfortunately, the software had a bug and shut down after 10 hours of use, however this setback did not affect the value of information we gathered from the test. We generated a graph exactly like the last test's graph, but it only showed the first 10 hours of use. We were also adamant on taking pictures and using digital recording of the installation process. We have many pictures of the testing site and our prototype installed. The most valuable piece of data gathered was a video-recorded interview with the user after the test. The user was unaware that the system shut down after the first day of testing, but did notice that it was not working very well. She was intimidated by the display because of the fact that it was a laptop and she was afraid of fiddling with someone else's computer. She was also confused by the directions she was given on how to interact with the display. The combination of the two made her apprehensive to interact with the display at all. However, she did mention that the location of the display was very effective because she could see it from most of the rooms in her house. She was interested in learning about the consumption of the individual devices and she had difficulty learning this from the prototype because the numerical metrics gave a projected estimation for a month's worth of usage rather than a record of immediate consumption. In regards to the colored method of feedback, she enjoyed seeing the colored LED displays from a distance and they were very effective for giving a real-time representation of the home's consumption. The only drawback was confusion for what exactly constitutes a color to change. It was difficult to understand what types of consumption behaviors would cause the color to change.

Design Criteria Changes:

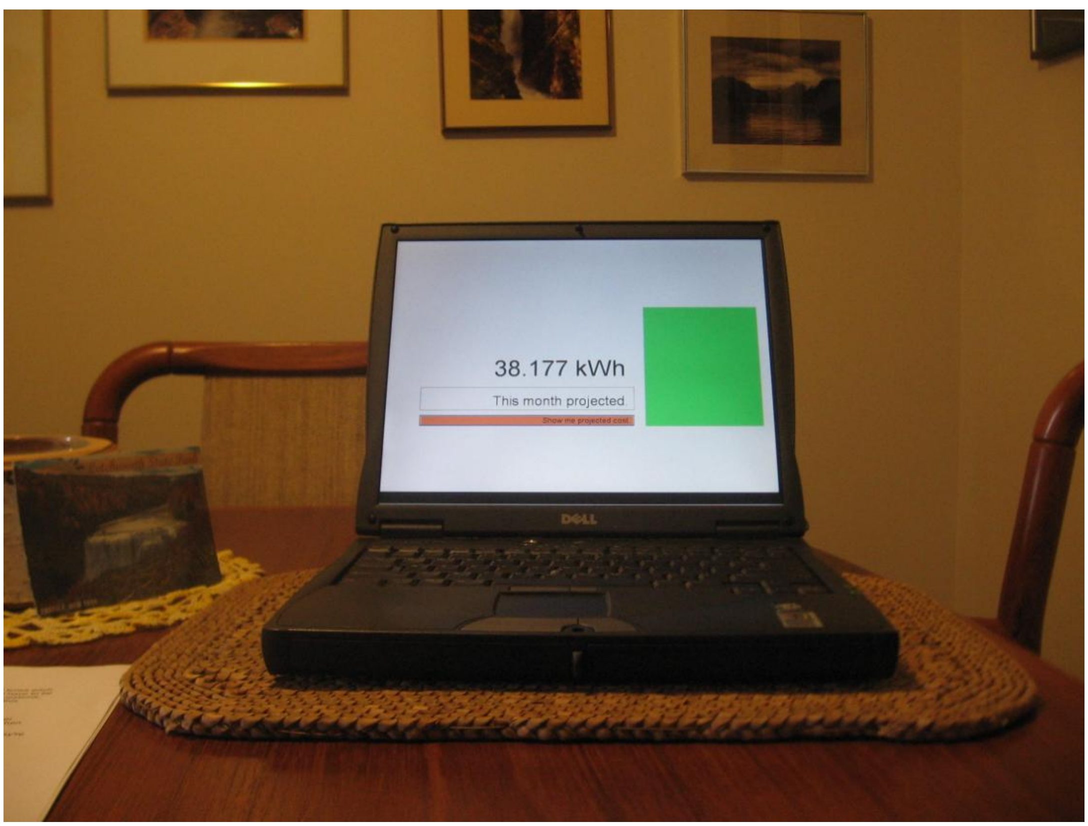
Firstly, the laptop needs to be disguised to make it less intimidating for the user. It can be done in such a way to just leave the screen and one button exposed for simplicity of use. Another thing to adjust for the next test is to give a clear explanation of how to interact with the interface including an activity that the user(s) can see how the system works while the installers are present. This will give them an opportunity to ask questions and clear up confusion. Lastly, the interface should be re-worked to include both the metrics used in the first test and those used in the second. The display should show real-time consumption in watts as well as projected consumption in kilowatt hours and dollars and cents. This would give the user an opportunity to understand just how turning on a specific device in their home will affect the overall consumption of the house as well as what constitutes a color change. We can also give ourselves some constructive criticism on the overall testing procedure. It needs to be more precise and more structured. After running two tests, we have learned what kind of things can go wrong and we can prepare for them ahead of time. Each role should be followed strictly so the users are not confused by four different people giving instructions. Although we have done a great job of this so far, we should continue to be considerate of the people we are testing and their property we are testing on.



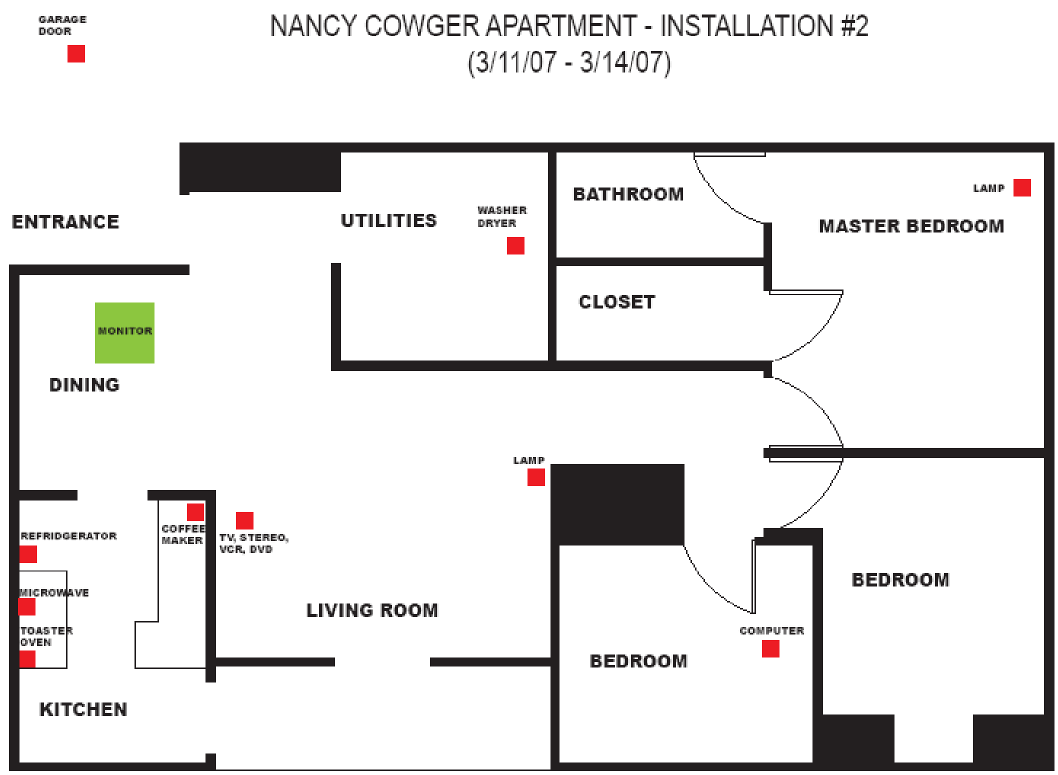
LED Module (above) Typical Module (below)



Display with Projected Cost (above)   Display with Kilowatt-hours (below)



Installation of a Module (microwave)



<u>Test Phase 3</u>

Prototype #3 Description:

Prototype 3 again had wireless modules connected to a centrally located display on a laptop screen; however a picture frame box was made to lay the laptop down in. Thus the only thing that the test subjects saw was the laptop screen and one button to toggle between two displays. This made the display less intimidating by disguising the fact that it was still a computer. The interface was also changed to combine the two types of feedback that we had previously tested with. On one screen a reading of current watts being used plus the kilowatt-hours averaged over the last 24 hours and projected for a month plus the color corresponding to the LED lights on the wireless modules. On the other screen, a reading of current dollars being spent plus the averaged dollar amount spent over the past 24 hours projected for a month plus the same corresponding circle of color. This gave the user an opportunity to understand what constitutes a color change and just how turning on a specific device in their home affected the overall consumption of the house in real-time feedback as well as projected amounts. Each of the wireless modules consisted of a good amount of wires, extension cords, plugs, and the LED display itself. In addition to making a wooden box for the laptop, we also made little wooden boxes to enclose all of the electronics of the individual displays so that the only thing the user would see is the LED display and the wooden box. This also made the system seem less intimidating and more credible.

Testing Procedure:

The installation procedure did not change as much in documentation from the second test as it did in the actual execution. There was only one person assigned to talk with the testing subjects in order to perform a preliminary interview, explain what the test was going to do, how to work the system, and what to expect. This allowed the volunteer to learn about the system, feel comfortable to ask any questions, and see the system in action through one single person without becoming overwhelmed. *(see* **Installation Procedure** above)

Testing Results:

Unfortunately, the software again shut down after 12 hours of use even though we thought the system had been de-bugged. This setback was discouraging as it was the last test our team had time to perform, however we did receive some valuable data in the way of subject interviews and many pictures of the test. We generated a graph exactly like the last test's graph, but, like the previous test, it only showed the first 12 hours of use. The test was conducted in a one bedroom apartment in which two married college students resided. The volunteers had some insightful feedback. They noted that they surprisingly did not mind having the modules dispersed around the house and that they did help them to think more about their day-to-day energy usage. Even though the lights were not hooked up to our system, they were much more conscious of when lights were unnecessarily turned on within their apartment. The volunteers noted multiple times that the LED lights on the individual modules were not only too bright but too general in the way of feedback. They did not find themselves looking to the modules for energy readings but solely to the large central display. They also noted that the projected monthly total cost was especially informative feedback that the system provided; however, they did not really get a correlation between the colors being displayed and the actual numerical/monetary power usage data. The volunteers left us with this, "Efficient power consumption became a tangible part of our life, something that wasn't just an abstract idea but day to day choices with visible results."

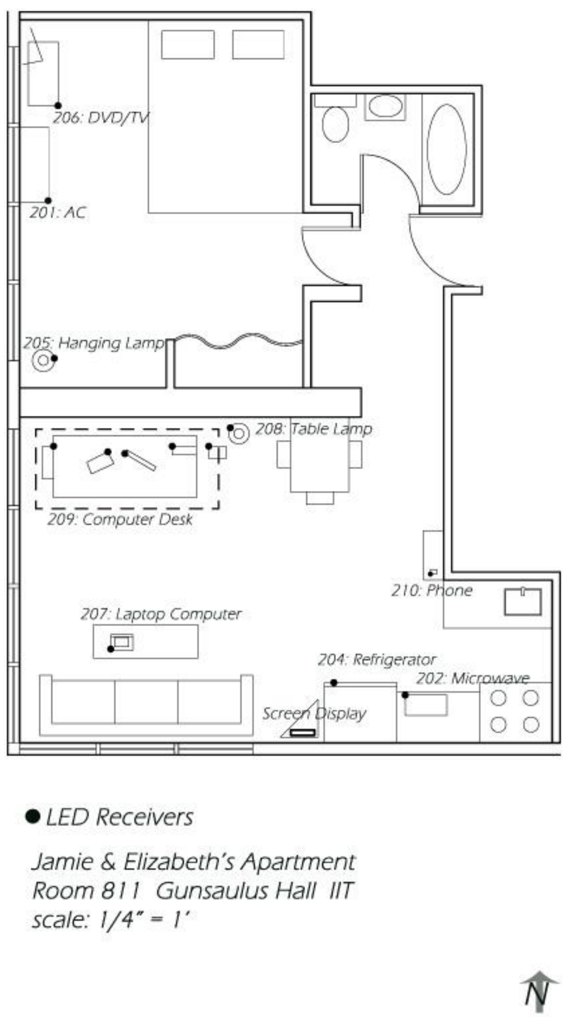
Design Criteria Changes:

Although prototype #3 was the last test that we had time to run, there are many opportunities to still improve the design of our prototypes. What we would like to have continued had there been time was more in-home testing of effective feedback and better integration of the system into home testing prototypes. Specific changes that could have been made to the prototype from the last test would include a graphical reading of trends and percentages of energy usage along side the monetary and wattage readings on the central display. We would like to make the central display into solely an interactive display that was non-dependant of a computer so as to present the system as an easy to use product for all generations. Also we would like to have explored the design of the small modules more thoroughly in order to perhaps include more quantitative data for each component that is hooked up to the system. A power usage reading of each individual component that was hooked up to the system would be helpful in knowing the exact amount of energy being used and the distribution of that energy between each individual component. Many people would find it convenient to know what component the majority of the electricity bill is coming from. A visual reading through

LEDs could still be integrated into the individual modules but perhaps with a timed button so that the light only reads for three seconds or so when needed. This would address the brightness of the constant light.

Homeowners and Test Users

Prof. McLeish explaining the display



8.0 Recommendations

One of the primary recommendations is to find the cause of the system error in the prototype. This would allow extended tests to be completed, which would give the team more feedback from users that interacted with the device for long periods of time.

One of the largest areas of research that needs to be continued is based on the point of decision making in the home. More information, research, and testing is needed to learn how consumers make energy decisions in their home and how they can be aware of the energy they are using. It is recommended that future work also consider additional types of feedback and their impact on consumers or potentially even ambient changes to communicate energy usage.

It is also recommended that the shape and design of the prototypes be considered as well as the type of display that is used. Perhaps a laptop is not even needed for the system.

The work of IPRO 334 has been rewarding for the team members and it is hoped that the new team members next spring will feel as strongly about this type of awareness and the potential that energy consumption awareness in the home can make a difference in how people consume this resource.

9.0 References

Abbound, Leila. "Philips Pushes Energy-Saving Bulbs:Why This Bright Idea Is a Hard Sell." The Wall Street Journal Online. 5 December 2006. 19 April 2007 <http://online.wsj.com/public/article/SB116528077211340649-oyZ5_Fo_MsGnrz_DaU4vnBDFp8Q_20070104.html?mod=tff_article>.

"Awareness." Wikipedia, the Free Encyclopedia. 14 April 2007. 19 April 2007 <http://en.wikipedia.org/wiki/awareness>.

Debatty, Regine. “Design for Increase Energy Awareness.” World Changing: Change your Thinking. 2 March 2005. 19 April 2007 <http://www.worldchanging.com/archives/002253.html>.

“Edward Tufte: ‘Presenting Data and Information.’” 19 April 2007 <http://www.mousetrap.net/~mouse/uta/PhD/tufte.html>.

“Energy Basics 101.” Energy Information Administration. October 2006. 19 April 2007 <http://www.eia.doe.gov/basics/energybasics101.html>.

“Energy Facts.” Solar Energy International. 19 April 2007 <http://www.solarenergy.org/resources/energyfacts.html>.

“ENERGY SAVINGS OFTEN BRING IMPROVEMENTS IN PRODUCTIVITY AND PRODUCT QUALITY.” Cool Companies. 19 April 2007 <http://www.cool-companies.org/profits/>.

“Frequently Asked Questions – Electricity.” Energy Information Administration. 19 April 2007 <http://tonto.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home>.

“Green building: From the basement to the roof.” HGTV. 19 April 2007 <http://www.hgtvpro.com/hpro/green_building/?ref=ribbon&affiliate=blocker&omnisource=GGL%7CCAMP024HGTVPro+Green+Remodeling%7CADGP014Do+It+Yourself%7CKWRD018home+energy+saving>.

“Green economics.” Wikipedia, the Free Encyclopedia. 4 April 2007. 19 April 2007 <http://en.wikipedia.org/wiki/Green_economics>.

“Green Products and Services Gain Support as Issues of Global Warming and Environmental Contamination Escalate.” Clean Energy Stocks. 24 January 2007. 19 April 2007 <http://cleanenergynews.blogspot.com/2007/01/green-products-and-services-gain.html>.

“Home Energy Saving Tips.” Permafrost. 19 April 2007 <http://www.permafrostonline.com/resources/home-energy-saving-tips.php>.

“How effective are market-based retail programs that incorporate ENERGY STAR?” Energy Star. 19 April 2007 <http://www.energystar.gov/ia/partners/reps/pt_reps_res_retail/files/retail_effectiveness.pdf>.

“Internet, New Economy Foster Widespread Energy Savings.” Cool companies. 19 April 2007 <http://www.cool-companies.org/energy/>.

Küppers, Klaus “RE-think + RE-cycle.” Designboom. 19 April 2007 <http://www.designboom.com/contest/view.php?contest_pk=6&item_pk=1956&p=1>.

“National Energy Policy/Overview.” Energy Research and Development. 10 January 2000. 19 April 2007 <http://energytrends.pnl.gov/italy/it004.htm>.

Orloff, Jeffrey. “Saving Energy.” About. 9 April 2007. 19 April 2007 <http://saveenergy.about.com/>.

“Regional Energy Profiles: U.S. Household Electricity Report FIGURES.” Energy Information Administration. 14 July 2005. 19 April 2007 <http://www.eia.doe.gov/emeu/reps/enduse/er01_us_figs.html#1>.

“Residential.” National Electrical Manufacturers Association. 19 April 2007 <http://www.nema.org/gov/energy/efficiency/residential/>.

Rosenwald, Michael S. “Showcasing the Growth of the Green Economy.” The Washington Post. 16 October 2007. 19 April 2007 <http://www.washingtonpost.com/wp-dyn/content/article/2006/10/15/AR2006101500685.html>.

“Static! Increasing energy awareness.” Interactive Institute. 19 April 2007 <http://www.tii.se/static/appearing.htm>.

“Usability.” Wikipedia, the Free Encyclopedia. 19 April 2007 <http://en.wikipedia.org/wiki/usability>.

“Viridian Principles 1.0.” Virdian. 19 April 2007 <http://www.viridiandesign.org/principles.html>.

Woody, Tood. “Verdiem: Energy-Saving Software Sales Boom as Corporate America Goes Green.” Green Wombat: environment + Technology. 19 December 2006. 19 April 2007 <http://blogs.business2.com/greenwombat/2006/12/green_wombat_sp.html> .

“You're ready for the Home Energy Checkup!” 19 April 2007 <http://www.ase.org/uploaded_files/homeenergycheckup/home.html#climate>.

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