Spring 4-2014

Exploring Data-Driven Electricity Feedback on Energy Conservation Behavior in the University of Dayton Student Neighborhood

Daniel R. Esposito
University of Dayton

Exploring Data-Driven Electricity Feedback on Energy Conservation Behavior in the University of Dayton Student Neighborhood

Honors Thesis

Daniel R. Esposito

Department: Physics

Advisor: Robert J. Brecha, Ph.D.

April 2014

Exploring Data-Driven Electricity Feedback on Energy Conservation Behavior in the University of Dayton Student Neighborhood

Honors Thesis

Daniel R. Esposito

Department: Physics

Advisor: Robert J. Brecha, Ph.D.

April 2014

Abstract

In general, homeowners do not have a concrete idea of how much energy their houses are using at any given moment. This energy "invisibility" is thought to be a barrier toward people adopting more sustainable behaviors. This study involves installing energy monitors in houses in the University of Dayton student neighborhood to analyze two important questions: whether the monitors teach students about the relationship between their activities and energy consumption, and whether the monitors influence students to adjust their household behaviors. Due to complications with and uncertainties in the data, quantitative conclusions could not be drawn. Fortunately, data collected from the distribution of questionnaires resulted in insightful conclusions regarding student attitudes and behaviors concerning the monitors. In essence, very few students consistently looked at their energy monitors, but those who did tended to learn from them and change their behaviors. It is recommended that future projects be conducted including further education and sufficient incentives to see whether more students respond to the monitors. Regardless, it can be concluded with confidence that students would be more inclined to save energy should they have to pay their own utility bills. At this time, installing energy monitors in every house would be inadvisable.

Dedication or Acknowledgements

This thesis is dedicated to my parents Rich and Lynn Esposito for their constant love and support. I would like to deeply thank my advisor Dr. Brecha for all the guidance, direction, and knowledge he has given me over the past few years. I am also greatly indebted to Kurt Hoffmann for all the help he has provided me; without him, this project would not have been possible. Finally, I would like to thank the University of Dayton Department of Facilities, Honors Department, and Physics Department for their support and funding for this project.

UNIVERSITY *of* DAYTON

Table of Contents

1. Introduction

The intent of this project was to explore the combined effects of continuous, direct feedback and intermittent, indirect feedback on students' consumption of electricity in the University of Dayton student neighborhood. Direct feedback was to be presented through energy meters with movable display units, whereas indirect feedback was to be delivered through monthly informational utility bills. An experiment was designed in which one group of houses would receive both types of feedback while the other group would receive neither—the energy behaviors of the houses could then be compared to determine whether receiving feedback led to a decrease in overall consumption over time. A questionnaire was also designed to be distributed following the experiment to determine the degree to which experimental-group students interacted with and learned from the energy monitors and utility bills.

In the "Background" section, we will explain the problem that inspired this study, define feedback and its various forms, note the role of incentives, outline what we hoped to learn from this project, and discuss some of the complications we had anticipated. In the "Process" section, we will explain in detail how the study and questionnaire were designed, how we intended to execute the experiment, and the methods we devised to analyze the data. We will also indicate where the study was forced to diverge from these original intentions, whether due to technical difficulties, problems with the data, or realizations made after the experiment had been put into motion. In the "Results" section, we will present and discuss the data from the experiment and the responses to the questionnaires. In the final section, we will draw conclusions where possible from these results. An appendix and bibliography are attached for further exploration and reading.

2. Background

2.1 Problem

The world's supply of fossil fuels is limited and the time will come when it takes more energy to retrieve the fuels than can be produced by the fuels themselves. Likewise, current renewable energy sources alone cannot satisfy the excessive levels of consumption of today's society. While vigorous scientific research is being conducted to increase the energy that can be extracted from renewable sources, technology alone likely will not be able to solve the energy crisis. As resource availability falls over time, their prices will increase accordingly; lacking any alternatives, these rising prices will force people to change their consumption habits. It is clear that as a whole, people will need to commit to more sustainable lifestyles in order to cope with the realities of a limited energy supply. We are looking to respond proactively by encouraging people to make behavioral changes naturally and of their own volition; the alternative is to wait to react to crisis—a tumultuous situation we would be wise to avoid.

Residential energy usage comprises a significant percentage of total usage in the USA, as shown in Figure 1 on the following page ("Electricity Overview | Center for Climate and Energy Solutions," 2011); thus, homeowners could make a considerable contribution toward reducing the nation's energy budget simply by adopting more conservative household habits. Further, it has been observed that the consumption from identical houses often varies by at least a factor of two due to the differences in the occupants' behavior, even when the houses in question are built to consume little energy by design (Darby, 2006).

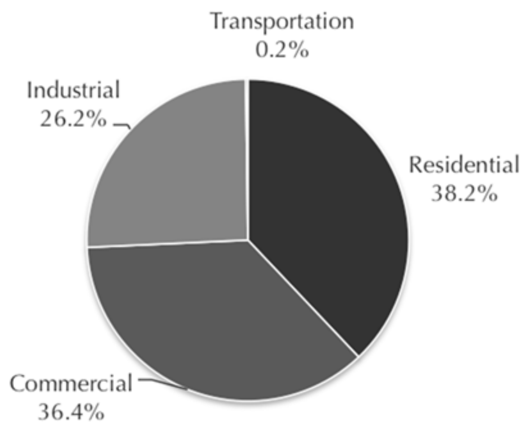


Figure 1. Electricity Usage by End Use Sector in 2011

One study has estimated that the national "reasonably achievable emissions reduction" in the residential sector can be about 20% within 10 years should the "most effective non-regulatory interventions" be used. As an example, the study indicates that an estimated 35% of the population would choose to adjust their thermostat in response to the appropriate interventions, saving 4.5 million metric tons of carbon per year. Such reductions in residential energy consumption through behavior change would cost far less than many suggested alternatives (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009).

One major roadblock to decreasing domestic consumption is that energy is "doubly invisible" to homeowners. First, energy is difficult to conceptualize, let alone quantify meaningfully. People likely do not know how much energy they are using on any given day. Second, people may struggle to associate energy-saving values with their daily activities since they are "performed in the context of everyday life" and thus are not the focus of much attention (Burgess & Nye, 2008). In order to break down these conceptual barriers, many studies have proposed introducing feedback to households through energy meters and more informative billing.

2.2 Feedback and Energy Meters

The US English Oxford dictionary defines feedback as "information about reactions to a product, a person's performance of a task, etc. used as a basis for improvement." In the discussed context, feedback refers to any information available to a household regarding its energy consumption with hopes of using such information to alter behaviors and decrease consumption. While there are many manifestations of feedback, we are primarily concerned with direct feedback through real-time energy monitors and indirect feedback through informative billing.

Energy meters with real-time displays allow homeowners to see how much energy they are using at any given moment. Thus, energy becomes explicit and concrete rather than a hidden, abstract concept. While the readings (typically measured in kilowatt hours) may not mean much at first, they serve as reference points which occupants can use to judge energy behaviors (Burgess & Nye, 2008). Whenever the monitor displays a reading above the recognized "natural baseline energy" for the house, occupants sometimes take notice and try to discover why the spike occurred. Occasionally, homeowners will take notice of "greedy appliances" and replace them with more efficient models (Hargreaves, Nye, & Burgess, 2010). In one study, an anonymously interviewed expert contends that "instant information on electricity use seems to have a wake up effect" on house occupants and that interaction with the monitor is necessary to "unfreeze habitual behaviors" (Martiskainen & Coburn, 2011). Thus, energy meters have the potential to connect energy costs to the daily activities responsible, making energy both visible and more relatable.

Energy bills, on the other hand, are a form of indirect feedback, arriving on an intermittent basis and presenting summaries of energy usage over long periods of time. The quality of the bill is characterized by its frequency, its medium, its presentation or specificity, and the presence and usefulness of a standard by which to compare it. In particular, a frequent, easy-to-interpret bill which compares that period's consumption to the same period in previous years is more useful than a bill lacking any of these attributes. Studies have shown that receiving more informative energy bills leads to reduced consumption in the home (Ling & Wilhite, 1995). Whereas direct feedback provides a reference point which helps homeowners discover wasteful practices and appliances, indirect feedback helps them notice changes over the long term (Darby, 2006).

A comprehensive review of the literature concerning energy feedback concludes that "clear feedback is a necessary element in learning how to control fuel use more effectively over a long period of time and that instantaneous direct feedback in combination with frequent, accurate billing […] is needed as a basis for sustained demand reduction." Savings from forms of direct feedback range from 5-15%; savings for indirect feedback range from 0-10%. In both cases, the savings depend on the manifestation and quality of the feedback and the context in which it is employed. All things considered however, a combination of both forms of feedback has the potential to result in quick, significant reductions in energy consumption at a relatively low cost. Further, feedback is intrinsically valuable as a way to inform homeowners about how their behaviors relate to energy usage. While it may affect people differently, feedback holds even more potential when combined with proper advising (Darby, 2006).

2.3 Incentives

The ultimate goal of installing energy monitors and sending households informative bills is for occupants to adopt more sustainable behaviors and therefore reduce domestic consumption. Behavior change must be motivated, however, and unless people have some incentive to make adjustments, their habits will remain the same. For some, financial reasons are sufficient for them to pay attention to the feedback and alter their behaviors. Households which are especially concerned with the environment will be able to motivate themselves to take action. In many cases however, interventions are necessary to keep homeowners from ignoring feedback entirely.

In some cases, not much is required to change behavior. For example, one study has shown that when guests checked in at a hotel, those who made a specific commitment to reuse towels and accept a symbolic pin were 25% more likely to follow through, hanging at least one towel during their stay (Baca-Motes, Brown, Gneezy, Keenan, & Nelson, 2013). Essentially, people can be motivated to alter their behavior if they commit to doing so, even if the commitment is not binding in any way. Another potential incentive could be competition among houses in a region. Seeing that other houses have been more successful in conserving energy could serve as a catalyst to changing one's own habits.

2.4 Motivation

It is well known that the savings achieved from introducing feedback will vary with context (Darby, 2006). Thus, while many studies have observed the effects of energy monitors and improved billing systems on homeowners who are employed and must pay their utility bills, this study attempts to see how feedback affects college students who live in university housing and are exempt from viewing or paying such bills. These students would have no financial incentive to save energy, so any reductions in consumption would be due to environmental motives or incentives capitalizing on psychological factors (i.e. commitments or competition). A study such as this could answer three questions of varying usefulness: first, would students check the energy monitors often and pay attention to bills sent for informative purposes; second, would students learn about the relationship between energy consumption and daily activities; and finally, would feedback alone lead to a measurable decrease in consumption? If either of the last two applies, it could be concluded that it is worthwhile for universities to invest in supplying monitors and informative bills. After all, students learning about energy and its connections to the household should be sufficient for universities to pursue installing a feedback infrastructure, as all universities aspire toward educating their students to be informed and constructive members of society.

2.5 Anticipated Difficulties

Unfortunately, there are many potential complications that can arise in a study such as this. For example, it is difficult to determine from metering data alone whether each house's inhabitants are living sustainable lifestyles. Differences in consumption between houses may be due to variations in time spent in the house, which would not necessarily correlate with sustainable behavior. In this study for instance, households that eat out often will consume much less gas and electricity than others who cook their own meals; all else being equal, this could lead us to falsely conclude that the former house is more sustainable. Regardless of how groups are defined in consumption studies (i.e. by income, building type, etc.), huge differences within groups (up to 700%) are often seen. Studies of this type also tend to introduce many sources of error by their nature (Jensen, 2008).

In some cases, people may be turned away from more extreme energy saving behaviors (i.e. hang-drying clothes) in order to avoid negative labels. We still live in a culture where comfort and convenience tend to hold higher value in society than sustainable behavior—thus, going further than the social norm to conserve energy may be met with accusations of being "weird" or "obsessed." Particularly in a college environment where social image is paramount, students may be immediately opposed to their energy monitors, failing to adopt new behaviors or even ignoring the feedback completely. When introducing the meters to the students, any advice to reduce consumption should stress that certain environmental practices are easy (more so than claiming they are good) (Jensen, 2008).

One study emphasizes the difficulty we may encounter in attempting to identify a trend of decreasing energy consumption over time. While forms of direct feedback have often been shown to be effective, eventually people will have made all the behavior changes they are willing to make and will not have the motivation to take steps to further reduce consumption. After some period of time, the monitors mostly lose their purpose and are consulted only to examine specific issues such as the introduction of a new appliance to the home (Hargreaves, Nye, & Burgess, 2013). The hope in this study is that this end point will not be reached prior to the conclusion of the experiment, since students tend to only live in a particular house for one academic year.

Another concern is that while there is much people can do to reduce the energy they consume daily, many of these behavior changes will not be reflected in energy meter readings (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009). For instance, carpooling or driving less are behaviors that could be motivated by feedback in the household, yet these energy savings will not show up in our data. Further, students in university housing will have much fewer options when trying to improve the efficiency of their houses. They cannot upgrade their insulation, replace their water heaters with more efficient models, or make any other permanent adjustments to their houses. Since these actions tend to make the most noticeable changes to energy consumption over time, we may struggle to see the effects of minor behavior changes.

There are several potential roadblocks that could keep the students from learning from the feedback, which would in turn keep them from adjusting any of their behaviors. In one study, house occupants struggled to understand energy meter readings in units of kilowatt hours and pounds of carbon dioxide. They could, however, relate to outputs presented as monetary costs. The placement of the meters in the houses was also essential, as was the ease with which they could be read or understood and integrated into the "fabric of the household." In other words, should the displays be placed in or moved to a hidden location, require too much effort to comprehend, or fail to fit into the framework of the home, they will lose their ability to reliably transmit information (Hargreaves, Nye, & Burgess, 2010).

Some students may also be met with frustration on societal, communal, household, and personal levels. The previous study revealed that those who wish to replace certain appliances with more efficient models typically have a difficult time doing so, as many products have cryptic or absent descriptions of how much energy they consume. They also wanted to know how other households and industries were doing relative to them—they felt their energy savings would do little for the environment if others did not act similarly. In some cases, differences in opinion of how much energy a household should use resulted in family conflicts. Finally, while some occupants felt empowered by the monitors, others felt helpless, and some even simply expressed their desire to live comfortably and not worry so much about minor details (Hargreaves, Nye, & Burgess, 2010).

All things considered, while some assert that there are "lots of low hanging fruit" when regarding homeowners reducing energy consumption, others contend that "whatever you do, some customers won't care and other customers will" depending on their attitudes (Martiskainen & Coburn, 2011). While incentives can be helpful, we must be careful when introducing them as to not confound our experimental results. Despite the potential complications however, this study will still be useful in determining whether feedback should be introduced into the college setting and what effect it could have on the university's energy budget.

3. Process

3.1 Energy Monitors

Since the entire study depended on installing energy monitors in student houses, it was crucial that the appropriate model was selected. There were several parameters we decided upon before seeking out a model. First, the monitors needed to be relatively inexpensive—energy monitors are quite costly, and we needed cheaper models in order to afford a large sample size. Second, the monitors had to be simple. The University of Dayton Facilities Department agreed to install the monitors free of charge, but only under the demand that the installation be quick and straightforward. This ruled out complicated models that allow for homeowners to investigate particular appliances separately. It also kept us from buying models that required Ethernet cables to run through walls. Third, the monitors needed to be user-friendly, displaying "instantaneous usage, expenditure, and historic feedback as a minimum" (Darby, 2006). Finally, we wanted the monitors to have the capacity to store downloadable electricity data; while monthly reports are available from the university's energy provider, it would be interesting to explore more finely granulated data.

With these parameters in mind, we searched for the most suitable model, ultimately discovering Current Cost's EnviR monitor through an article in *Home Power* which compared several models side-by-side (Weliczko, 2012). These monitors were relatively cheap (discounted at $91/unit) and could be easily installed. They require only two current transformer (CT) clamps which are easily snapped in place around the two main power cables leading to the house's energy meter. The transmitter then wirelessly sends data to a mobile display which operates at a distance up to 100 feet. In addition, the displays store monthly data for the last seven years, weekly data for the last 14 weeks, daily data for the last 90 days, and data in two-hour intervals for the last 31 days. The data can be easily and quickly downloaded via a USB cable and downloadable Current Cost software and can be viewed in Microsoft Excel. The display itself shows the current rate of energy use of the house, the estimated cost (after setting a base rate), a graphical comparison of night, day, and evening usage, and usage over the last one, seven, or thirty days (Current Cost, n.d.). At the time, our only concern was the design of the display, which allows for mobility but does not leave the option for the display to be mounted. While it could be useful to move the display around the house, such a capacity runs the risk that the displays will be moved out of sight and forgotten—or even purposefully left in a drawer due to a lack of interest or fear that it may be damaged. A picture of the EnviR display has been attached in the Appendix; the specifications can be found in Current Cost's website in the Bibliography.

Ultimately, we were able to garner enough support to pay for 30 EnviR meters through the University of Dayton Honors Program ($1500) and the University of Dayton Facilities Department ($728), with the University of Dayton Physics Department covering the difference. The purchase was made early enough in order to give the Facilities Department ample time to install the monitors before students arrived for the Fall 2013 semester. In addition, we wrote a letter to be left in each house in which an energy monitor was installed. The letter informed the students that their house had been equipped with a meter and also briefly discussed its purpose, some steps they could take to reduce their consumption, and our hope that they would use the monitor to learn more about the complexities of energy use. We also notified them that we would enter at various points during the year to gather data, instructed them not to move or unplug the display, and warned them of the consequences of breaking or losing a display. We worded the message carefully in hopes that students would make internal commitments to save energy; while unlikely, it is possible that these commitments could act as incentives to change behavior as discussed earlier. Further, the letter was distributed by the Facilities Department with no mention that a study was taking place. This was done to avoid the Hawthorne effect to the best of our ability—we did not want students to be aware that their energy consumption was being monitored for a study. The letter has been attached in the Appendix.

3.2 Utility Bills

Students living in University of Dayton housing pay flat fees for their residences—these include utilities, and therefore the students do not receive utility bills. Fortunately, a program called the Greenhouse Effect was developed several years ago internally by the university which generates report cards for every university-owned house or apartment. The reports include measures of energy and natural gas use along with their costs and the total carbon footprint. They also weigh these measures against specifically designed models which factor in the distinct attributes and histories of the houses. Finally, the reports compare energy usage to the performance of other houses on the block and to the entire student neighborhood. Each report includes an attached graphical list of ways to reduce the consumption of electricity, gas, water, and goods in general. A previous analysis of the data taken during a five-month trial of the project in 2010-2011 suggested that nearly $21,000 was saved compared to model projections due to the reports, although this figure accounts for all of the hundreds of houses and apartments on the university's campus (UD Greenhouse Effect, n.d.). A sample report has been attached in the Appendix; the figures are real, but the addresses have been changed to preserve privacy.

The Greenhouse Effect reports essentially are the ideal "informative bill," since they include the prices students would be paying if they were not covered by the university while also providing information on the month's energy usage in comparison to the house's standard and other houses in the neighborhood. In addition, these comparisons with other houses may spark competition within the neighborhoods which has the potential to act as an incentive. It was our intention to keep sending these bills to the houses in our experimental group (which also have EnviR meters) while withholding them from the houses in our control group. It is worth mentioning now however that this unfortunately did not occur as planned. Unresolved issues with the university's natural gas provider kept the group in charge of the Greenhouse Effect from receiving aggregate gas data which is necessary to generate the reports. An alternative could not be developed in time for the study, and therefore none of the students received any form of informational utility bill. Thus, all conclusions drawn from this study must acknowledge that intermittent, indirect feedback was not available.

3.3 Selection of Houses

With the EnviR monitors ordered, the next step was to determine in which houses they would be installed. We ultimately wanted to measure the difference in energy consumption over time between houses in the experimental and control groups. In order to isolate the effects of feedback however, the houses had to be chosen in a careful and particular way. Using archival data from the university, we plotted energy versus time for several houses in the student neighborhood in an attempt to grasp the variability of electricity consumption on a house-to-house basis. Two of these plots are shown below, one which compares four houses of identical design and the other comparing four houses of differing size and occupancy:

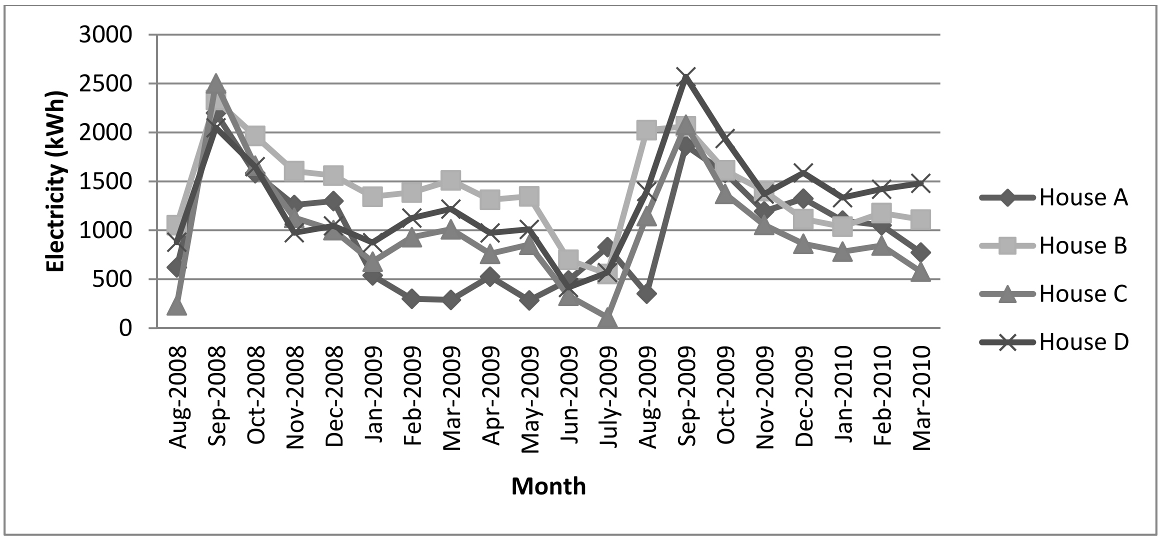


Figure 2. Monthly Electricity Usage of Four Identical Houses

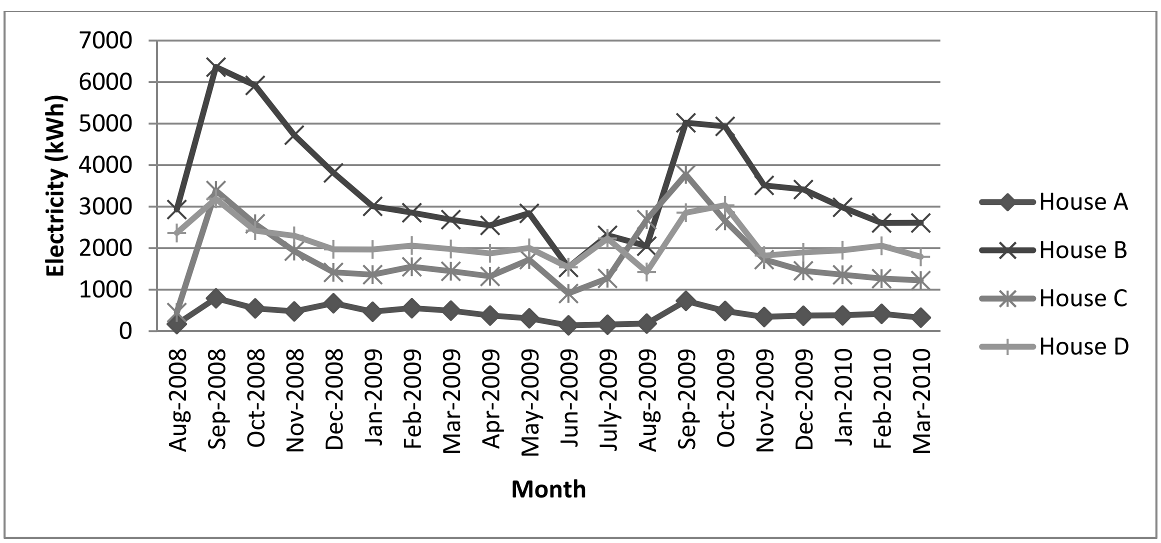


Figure 3. Monthly Electricity Usage of Four Houses of Varying Size & Occupancy

Notice the different scales in the two graphs—at a glance, it is easy to see that the variations are much greater among houses of varying size and occupancy than among houses of identical structure. Thus, comparing energy savings of houses of varying sizes may be difficult (impossible, even) since variations in consumption would likely be due to size and occupancy differences rather than differences in behavior. Instead, comparisons should be made between houses that are as similar as possible in order to isolate the effects of energy feedback.

In the graph comparing identical houses, notice how the electricity usage of the least efficient house can be as much as two to four times that of the most energy efficient house. Since the buildings themselves are identical in structure, the energy usage depends solely on the behavior of the occupants. Thus, Figure 3 gives us reason to believe that enough variability exists to detect statistically significant differences in energy usage. Fortunately, the University of Dayton owns several duplexes and pairs of identical houses. It is from this pool that we selected which houses to use in the study. In particular, 13 duplexes and 11 pairs of identical houses were selected. The other duplexes on campus were excluded because both houses shared an internal energy meter and thus the consumption data could not be separated between the two. Since we exhausted the list of pairs of identical houses, we ended up using only 24 of our meters—the additional six were kept as replacements should they be necessary. For each duplex or pair of houses, one was selected to be in the experimental group (thus receiving an EnviR meter) and the other was defaulted to the control group. Except for a few special cases, the house with the lower address number was chosen for the experimental group. It should also be noted that one pair of identical houses had to be dropped from the study;

the wrong addresses were given to the Facilities Department, and hence that pair's meter was never installed.

3.4 Methods of Data Selection

One of the difficulties in designing a study of this nature was deciding which measure to use to quantify energy savings. Even with sets of identical houses, the challenge still remained to find a measure which best communicates energy savings over a period of time. Before beginning the experiment, we decided upon three separate measures. The first measure compares energy usage for each house on a month-to-month basis using previously designed models to control for temperature (developed by the University of Dayton Building Energy Center). We would expect to see an inverse relationship between time and energy usage, since the behaviors resulting in the largest energy savings would likely be discovered first, followed by habits that save less and less energy. The primary anticipated problem with this measure was that no baseline energy usage would have been established for the group of occupants. Thus, if the largest energy savings resulted in the first month, it would go unnoticed in the absence of data to compare it against. A potential solution would be to use an average of the past several years of occupants' energy usage as a baseline, although we recognized this might not be reliable. If the current occupants had retained their house from the previous year, we could perhaps use last year's average energy consumption as the baseline, however.

The second measure compares energy usage for a particular house with the data recorded from previous occupants who lived in the same house. The energy usage of each month of the current year could be compared against a baseline established from the usage during that month over the last five or more years. For houses in the control group, we would expect the usage of the current year to be similar to that of the house's history for that month (possibly controlling for temperature and number of occupants if necessary). For houses in the experimental group however, we would expect there to be a difference in the usage of the current year and the historical average for that month. Additionally, we believed we might see the difference grow larger as the months go on, or as the occupants develop more and more energy-saving behaviors. An anticipated problem however was that one or more of the previous groups of tenants may be more environmentally conscious than the current group. If this was the case, it was possible that the concern of these previous groups would lead them to conserve more energy than the current group which might not have a deeply rooted desire to conserve. We designed the questionnaire (to be discussed later) to account for this, however, with the goal of identifying which houses had no environmental conscience or made no attempt to conserve.

The final measure takes advantage of having selected duplexes and identical pairs of houses. Essentially, the control group (the houses without monitors) would serve as the baseline from which judgments could be made about the experimental group (the houses with monitors). Calculating the difference in energy usage between the two houses gives a measure from which we could potentially use to determine energy savings. In theory, the control group would have no motivation to change its conservation habits while the experimental group would be influenced by the feedback. Therefore, we could conclude that feedback had some degree of effectiveness if the experimental houses used less and less energy when compared to the control houses over time.

In order to analyze the data, we planned to use Energy Explorer C, a program designed by Kelly Kissock of the University of Dayton. The software "derives statistical models between energy use, weather, and other variables, drives these models with typical weather and variables, and uses the resulting models and coefficients to analyze the energy performance of facilities over time and in comparison to other buildings" (Kissock, 2006). This program would allow us to compare houses side by side after having factored in the weather and typical meteorological data for each time interval.

3.5 Data Collection

The data collection process was supposed to occur in four steps: ensuring the meters were properly installed before students arrived, and then downloading data during fall break (10-9/10-13), winter break (12-13-13/1-12-14), and spring break (3-5/3-9). All except one visit were conducted with the help of the university's Environmental Sustainability Manager Kurt Hoffmann. I maintained the disguise of being a student worker for the Facilities Department in order to lead students to not suspect this was a research project. Unfortunately, several difficulties arose during the process which had negative implications for the data we obtained. These will be discussed chronologically in this section with the data and relevant issues presented more clearly in the "Results" section.

With students scheduled to arrive roughly from Thursday August 15 to Sunday August 18, we arrived on campus early (Wednesday August 14) in order to check the houses in the experimental group. We wanted to ensure the EnviR meters were properly installed and their displays were in an easily noticeable location. We also wanted to leave a copy of the informational letter with the meters since the technicians had not done so. After searching the first four houses, we could not find any of the displays. We later discovered that they were left in the basements, despite instructions to move them to the common areas of each house. This was problematic because all basements in student housing are locked, so students were unable to access the monitors during this time. This issue was eventually resolved, but most of the houses did not receive their displays and letters until August 27, 28, or 29—when they had already lived in their house for over a week. The dates in which each house received their meters were recorded and taken into account when analyzing the data.

On September 18, we received an email from one of our houses reporting that their display was not functioning properly. We checked the monitor ourselves on September 25 and found that the meter itself was never properly installed in the utility room. On September 26, we emailed a similarly designed house, and the occupants responded saying their meter was dysfunctional as well. We submitted work orders for both houses, and the issues were resolved; unfortunately however, the data we later obtained only extends back until the dates when the meters were properly installed.

On October 21 2013, we made our first attempt to gather data from the meters. At our first stop however, our attempts to download the data took over an hour, and we still were unable to establish a proper connection. Our computer was missing some drivers which we installed on site, but the program necessary to facilitate the download had to be sent to us from Current Cost through email. We sent the request for the email and agreed to reconvene at our earliest opportunity.

On October 28 2013, we made our second attempt at downloading the data. The program worked by reading the data from the displays and presenting it in four tables—bihourly, daily, weekly, and monthly—which could then be downloaded as Microsoft Excel files. Following the download of the data, we then had to delete the data from the program (although not from the displays) before the next meter could be accessed. The whole process only took a few minutes per monitor, except in some situations when the data randomly failed to download correctly on the first one or more attempts. We ended up visiting 20 of the 24 houses due to time restraints; in five of the houses, we were unable to download the data. The problems encountered at each house were recorded and are listed in the Appendix. We sent in work orders for each house in which we encountered complications and planned to meet again when the requests had been fulfilled. It should also be noted here that during this trip, we discovered that financial readings were not properly configured in the displays—monetary information, when available, was presented in British pounds.

On November 21 2013, we returned to the problematic houses and visited the remaining four houses we failed to visit on our prior trip. This time, we obtained data from all but two of the meters, one of which could not be found. Again, these problems are listed in the Appendix. Finally, on December 12 2014, we revisited every house, successfully downloading data from all but one house. Due to time restrictions and a reordering of priorities following a fundamental problem with the data (discussed in the "Results" section), we never collected data for the third cycle (planned for March 5-9).

During this process, we made several observations that suggested the monitors were not being put to good use. Some were left in the corners of rooms, buried under clothes or behind furniture. Occasionally occupants would admit that they never so much as glanced at the displays. All instances of negligence were recorded so that caution could be taken before drawing conclusions from the data.

3.6 Questionnaire Design and Distribution

Even before collecting data, we knew it remained very possible that we might see no changes at all between the experimental and control houses. As discussed in the "Anticipated Difficulties" section, there are many complications and complexities in a study of this nature. In the chance that we would be unable to draw conclusions from our data, we designed a questionnaire to learn qualitatively how the feedback affected the students. Using the results from the questionnaire, we could perhaps at least answer the first two questions of the study—namely whether students paid attention to the meters and whether they learned about the connections between behavior and electricity usage. We could also potentially answer whether students made an effort to change their behaviors, even if the data could not serve as quantitative support. The questionnaire would mark the end of the experiment however, since it would then make the students explicitly aware that they were being studied. In addition, we designed a separate questionnaire for the control group inquiring about these students' environmental consciences. The results could be matched with houses in the experimental group to determine if instances arose where one house in a duplex was initially much more sustainability-oriented than the other.

In designing the questionnaires, we utilized the services of Survey Monkey—a professional survey distribution and analysis website. Using the free version involves accepting several restrictions, such as the inability to import raw data in Excel. Additionally, we were restricted to ten questions per survey; this turned out to have a positive effect however, because it removed the temptation of designing long questionnaires which may be ignored by students. Thus, our goal was to gather as much information in ten questions as possible, while still making the questionnaire as simple and quick to complete as possible.

Following an introductory question asking in which house the questionnaire participant lived, our questions were divided into two sections—one concerning the energy monitors, and the other concerning one's consciousness toward environmental issues. The control group questionnaire consisted only of the introductory question and the latter of the two sections. The former section asked some basic fundamental questions, including whether students were aware that they had a monitor and how often they looked at it. The next few questions were more informative, inquiring about whether students learned from the monitors, with whom they discussed energy readings, and about details of their relationship with the monitors. The questionnaires themselves as well as their results will be presented in the "Results" section; the emails sent to the experimental and control groups have been included in the Appendix.

To give ourselves enough time to examine the data while still allowing a reasonable period to collect as many responses as possible, we waited until February 18 and 19 to distribute questionnaires to the experimental and control groups respectively. We sent reminders on February 28 to both groups. We then began analyzing the responses on March 6.

4. Results

4.1 Electricity Data and Complications

A great deal of data was collected during this experiment, including bihourly, daily, weekly, and monthly data from the energy monitors in the experimental group (roughly from August to December), as well as monthly data from Dayton Power and Light for all houses (for several years up through February 2014). Unfortunately, when we began analyzing the daily data from the energy monitors, we were given reason to believe the data was somehow translated incorrectly. We have two files for every house—one from taking measurements in late October, and another for taking measurements in the middle of December. The first file extends back to the installation dates of the monitors, which occurred in late July. The second file extends back about three months to the middle of September. In order to combine the files, we tried to match the dates, expecting the data to overlap accordingly. In doing so, we noticed that the data did not overlap correctly in seven of the houses. For example, on the first file, a reading for October 17 was 51.5 kWh, yet the number was different for October 17 on the later file. Further, that reading (51.5 kWh) was listed on October 24 on the latter file. In these two particular files, all of the data was shifted by seven days. The magnitude of this shift differed for the other six houses experiencing this issue.

Regardless of how this dilemma was approached, we could not find a way to reconcile the shift in data between the two files. Trusting the first file and shifting the second file backward (as necessary to match the data) leaves data vacancies for a good portion of December; doing so doesn't make sense, since we would have to assume (among other things) that the monitor stopped operating correctly during the last few days of its operation. Trusting the second file and shifting the first forward implies that the first file somehow managed to collect data for several days following the date of collection for that file. As neither instance makes sense, these shifts rendered the data for these houses as essentially unusable.

Two modes of thought contributed toward abandoning the energy monitor data entirely. The first was an uncertainty that the data was even accurate for the other houses. Improper translations occurring in a third of all houses raised the question as to how much we could actually trust the data—something could be inherently wrong with the program. Further, we could not check the monthly monitor data with the data we receive from Dayton Power & Light, since the latter bills the houses in the middle of the month whereas the monitor gives reports at the first of every month. The second consideration for abandoning the data resulted after an examination of the files with no shifts as well as some preliminary responses from the questionnaires. We used the Energy Explorer C program to view the temperature-controlled data for several houses, but no trends were visible, let alone progressions suggesting the houses were using less energy as time elapsed. In addition, initial questionnaire responses as well as information gained from casually talking to participants while gathering data in their houses suggested that students were not paying attention to their monitors. It would be a wasted effort to try to determine significance in the data if students confessed they never looked at the displays, especially if the data was suspected of being faulty. Instead, our attention turned to the data received from Dayton Power & Light in order to compare the experimental and control group directly, although with the same qualification that any determined significance would be questionable at best.

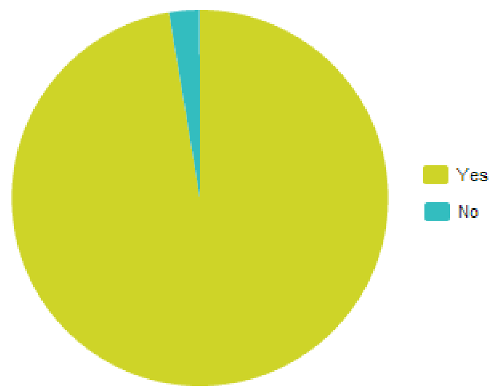
The data from Dayton Power & Light is presented in a table in the Appendix, along with other useful categorical information about each pair of houses. In our analysis of the data, we made quick comparisons between the experimental and control groups by subtracting the electricity usage of the former by that of the latter for each month; positive numbers represented instances in which the experimental group used less energy than the control group. Of course, the importance lied in the trends over time. With too few data points to run any rigorous statistical analysis, we identified eight instances in which there may be a trend toward the monitors leading houses to conserve energy, yet also five instances in which there may be an opposite trend. There were also eight pairs of houses in which no guess could be made in either direction about a trend. For each pair in which a positive trend was thought to possibly exist, we looked to see if any members of the experimental group for the house answered the questionnaire; if they did, we looked to see whether the energy monitor led them to change their behavior. This occurred in only one case, and only one of the four respondents for that house claimed the energy monitor was responsible for a change in behavior. Thus, it seems very unlikely that we would be able to make any significant conclusions regarding whether energy monitors were responsible for reductions in energy consumption. As a result, we switched our priorities to the questionnaire, where we would at least have sufficient data to make useful conclusions.

4.2 Questionnaire Results and Discussion

Although our quantitative exploration turned out to be fruitless, there was still much to be learned from the questionnaire responses of the students. We will first discuss the data gathered from the section on energy monitors (distributed to the experimental group only). We will follow this with a comparison of the environmental attitudes of the experimental and control groups. Additional information has been included in the Appendix. The results of the first question for both groups, which asks respondents to report which house they live in, have been incorporated into the table in the Appendix reporting on Dayton Power & Light data.

Question 2: Did you realize you had an energy monitor in your house?

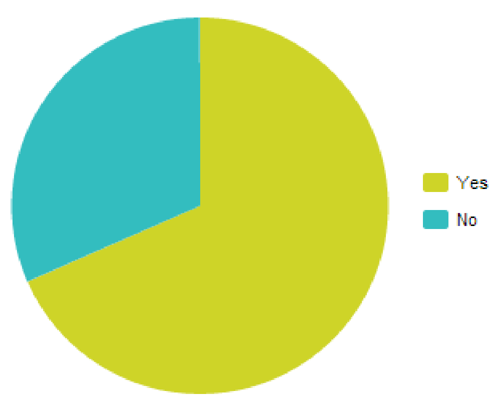
Choice	Rel. Frequency	Frequency
Yes	97.37%	37
No	2.63%	1
Total		38/39



Fortunately, it appears just about every student who responded to the questionnaire was at least aware that they had a monitor.

Question 3: Did you read the notice from the Facilities Department that was placed with the monitor at the beginning of the academic year?

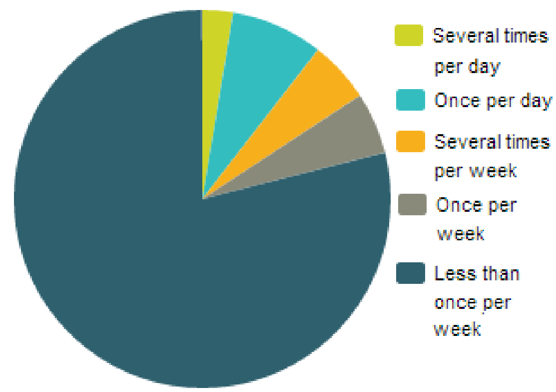
Choice	Rel. Frequency	Frequency
Yes	68.42%	26
No	31.58%	12
Total		38/39



Question 2 suggests that about two thirds of all students read the notice from the Facilities Department (attached in the Appendix); this is lower than desired.

<u>Question 4:</u> How often did you look at your energy monitor?

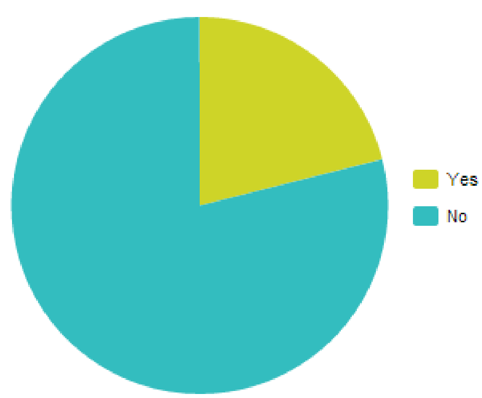
Choice	Rel. Frequency	Frequency
Several times per day	2.63%	1
Once per day	7.89%	3
Several times per week	5.26%	2
Once per week	5.26%	2
Less than once per week	78.95%	30
Total		38/39



This question represents our first true cause for concern. If roughly 80% of students looked at the monitor less than once per week, it is unlikely they were able to make a connection between the readings and their energy consumption habits.

<u>Question 5:</u> Did your energy monitor help you learn about the connection between energy use and the daily activities taking place in your house? If yes, please explain.

Choice	Rel. Frequency	Frequency
Yes	21.05%	8
No	78.95%	30
Total		38/39



This distribution is unsurprising following the responses received for question 4. After isolating the respondents who chose "yes" for question 5, we went back and looked at their selections for question 4. As we might expect, six of the eight students who claimed to have learned something from the monitors had looked at them at least once a week. In addition, as we will see later, five of them claimed the readings led them to change their behaviors around the house. Thus, although these results may not be definitively visible in the quantitative data, there were some students in the sample who paid attention to the monitors, learned from them, and changed their behavior as a result.

Question 5 also allowed students to submit comments. Students who responded "yes" had the following to say:

> **Participant 1:** "I changed my attitudes towards energy saving activities, because I saw the projected cost per month or per day to run our household. We kept it near our door so it was easy to look at on the way out."
>
> **Participant 2:** "Helped me realize how much energy we use by leaving lights, appliances, etc. on."
>
> **Participant 3:** "I could tell the difference if we left the lights on at night or during certain days."
>
> **Participant 4:** "The incredible consumption of energy due to heating and cooling cost ignorance is alarming."
>
> **Participant 5:** "It cost more money to use the microwave etc."
>
> **Participant 6:** "For example, during the day or on especially cold days, the energy usage would be higher, while during the night, it was less."
>
> **Participant 7:** "TV."

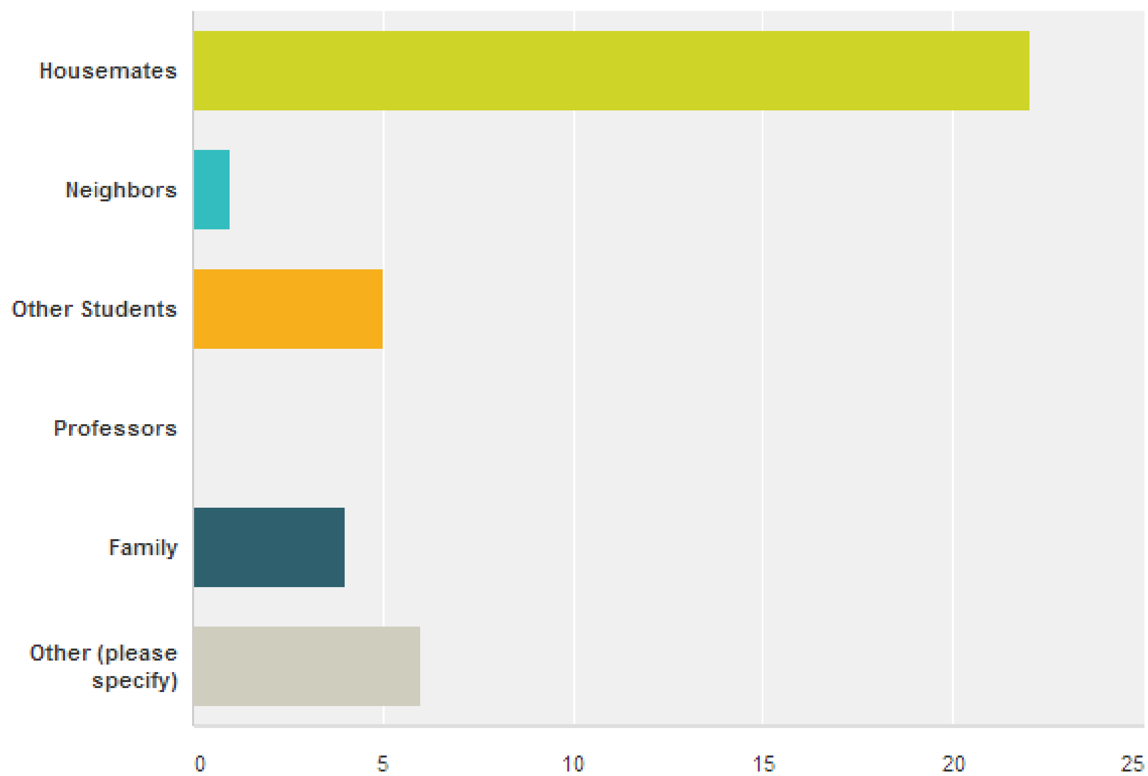
Thus, it appears these students made some useful observations about the relationship between certain activities and the resulting energy or monetary costs. A few other students also weighed in, stating the following:

> **Participant 8:** "I could care less. In a [University of Dayton] house I'm already paying a lot so the school can front the bill for us leaving all the lights on all day long."
>
> **Participant 9:** "We do not really look at it. We just keep it plugged in and let it go."
>
> **Participant 10:** "I forgot about it."
>
> **Participant 11:** "We forgot about it most of the time and unplugged it when we needed the outlet."

Participant 8's response is most concerning—it seems to suggest some students may use even more energy due to not having to pay the bill. Likewise, they may feel free to use as much as they desire since they are paying for it indirectly through housing costs. This attitude, if widespread, could be responsible for a great deal of overconsumption.

Question 6: With whom did you discuss the energy monitor readings?

Choice	Frequency
Housemates	22
Neighbors	1
Other Students	5
Professors	0
Family	4
Other	5
Total Number of Respondents	29

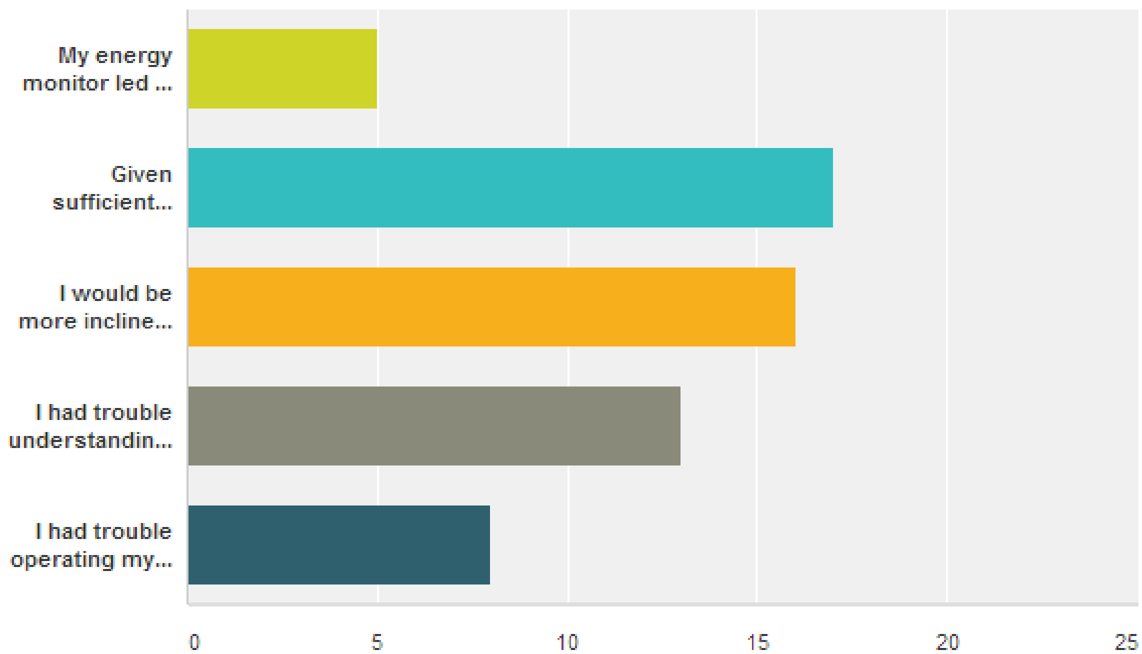


For this question, multiple answer choices could be selected simultaneously. We can assume that those who skipped the question did not discuss the readings with anyone. In addition, four of the six respondents who selected “Other” clarified that they did not talk to anyone about the readings. The other two respondents who selected this choice claimed they discussed the readings with the Facilities Department. We talked to students in the two respective houses during our data-gathering visits however, so they were likely talking about us. The responses in general suggest that people tended to talk amongst housemates, if anyone; only a few discussed the readings with others.

The seventh question was designed to fit several yes/no questions into one question (to supersede the limitations of Survey Monkey). Thus, each “answer” has important implications in its own right.

<u>Question 7:</u> Please check each selection to which you would reply "yes."

Choice	Frequency
My energy monitor led me to change my habits around the house.	5
Given sufficient incentives, I would look at my energy monitor more often and/or try to conserve more energy.	17
I would be more inclined to look at my energy monitor if it were mounted somewhere clearly visible.	16
I had trouble understanding my energy monitor.	13
I had trouble operating my energy monitor.	8
Total Number of Respondents	31



Those who skipped the question either did not agree with any statements or were not interested in reading through all of the responses. Now, as we discussed earlier, only five students claimed that the monitor was responsible for some change in their habits around the house; these same students earlier mentioned that the energy monitor helped them learn the relationship between their actions and the associated energy costs. While this is an important result, the fact that only an eighth of all respondents (let alone all students in the study) were impacted in this way is discouraging.

On the other hand, the remaining four questions suggest that policy and technological changes could lead to the energy monitors having a greater effect on the other students. Nearly half of all respondents noted that they would be more likely to check the monitors if they had enough of an incentive to do so; half of these same students also said they would check their monitor more often if it were mounted somewhere clearly visible. Many other students (almost half of all respondents in total) also claimed that mounting the display would be helpful, confirming our original fear that the mobility of the display could cause problems. Finally, about a third of the respondents mentioned they had difficulty understanding the monitor, while a fifth had trouble operating the monitor entirely. Thus, a major problem may have lied with the monitor itself. While there is no guarantee that students would respond more favorably to a more user-friendly model, the apparent complexities and malfunctions of the EnviR model should not be overlooked.

Students also had a chance to make general comments on question 7. Some of the responses included the following:

Participant 1: "We didn't know it was for us, we figured you were just trying to do a study on energy consumption in the [University of Dayton student neighborhood]. Pretty much just ignored the whole thing."

Participant 2: "To be honest, and I'm being very frank, I doubt student are even slightly concerned about the energy they consume because they pay so much for university housing that they feel like they deserve to use more energy than the average person would consume living in a house they are paying for with their hard earned cash."

Participant 3: "There should be more emphasis and education was provided to these folks who are having their first experience of responsibility for a house's energy consumption and impact on our ecosystem."

Participant 4: "If it was mounted near our thermostat and we won a prize for being in the top ten least energy using houses we would've tried harder."

Participant 5: "I didn't really know what the numbers meant."

Participant 6: "It never worked and was pretty much useless."

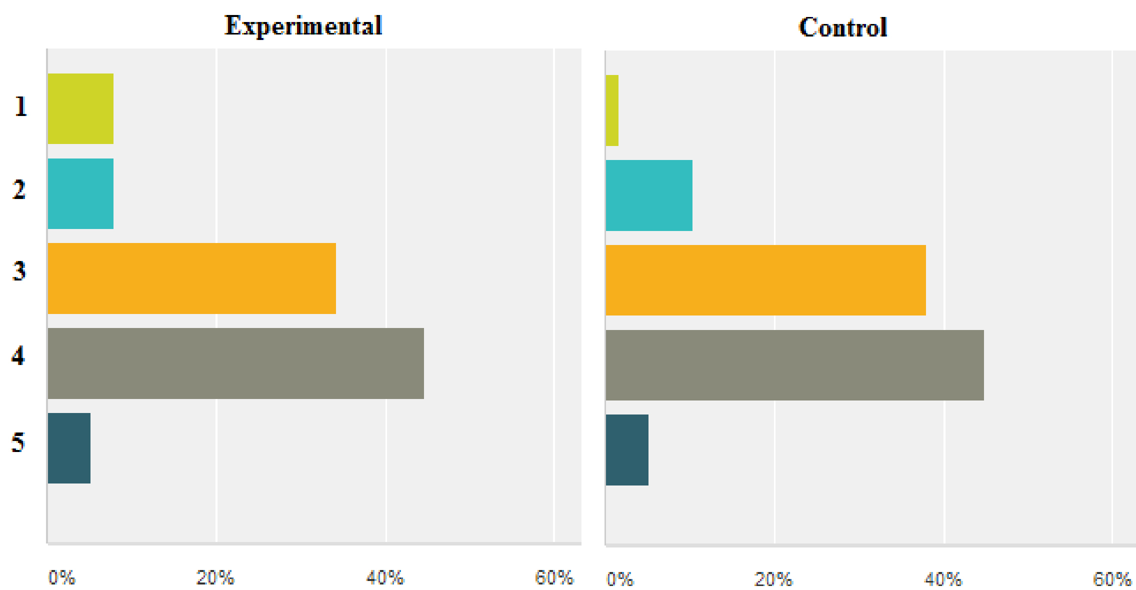
Note that the labeling of the participants has no relation to the labeling used earlier for question 5. Participant 2 seems to confirm one of our biggest fears—that students will use energy freely since they "deserve" to do so as compensation for paying tuition. Without monetary incentives, this seems like it would be a difficult barrier to break down—awareness of the problem will not affect this group of people. Participant 4 expands on this by suggesting that a prize would have been enough of a motivation, although it is debatable what the magnitude of the prize would have to be in order to influence people. Participant 3 provides some enlightening insight, claiming that a lack of education and insistence on our part contributed to less interaction with the monitor. Of course, for the purposes of this study, we tried to isolate the effects of the monitor without providing further influence (aside from the letter left with the monitor); in practice, energy monitors should certainly take this advice and further educate the students. This does not solve the problem highlighted by participant 2, however. The other responses simply furthered the notion that the monitor was too complicated and unreliable.

We will now compare the responses of the Environmental Consciousness portion of the questionnaire between the experimental and control groups. For the control group, these questions consisted of the entire questionnaire.

<u>Question E8/C2:</u> How concerned are you about global climate change and other environmental issues?

Scale: 1 – Not concerned at all; 5 – Extremely concerned.

Weight	Experimental Group Frequency		Control Group Frequency	
	Relative Frequency	Frequency	Relative Frequency	Frequency
1	7.89%	3	1.72%	1
2	7.89%	3	10.34%	6
3	34.21%	13	37.93%	22
4	44.74%	17	44.83%	26
5	5.26%	2	5.17%	3
Total		38		58

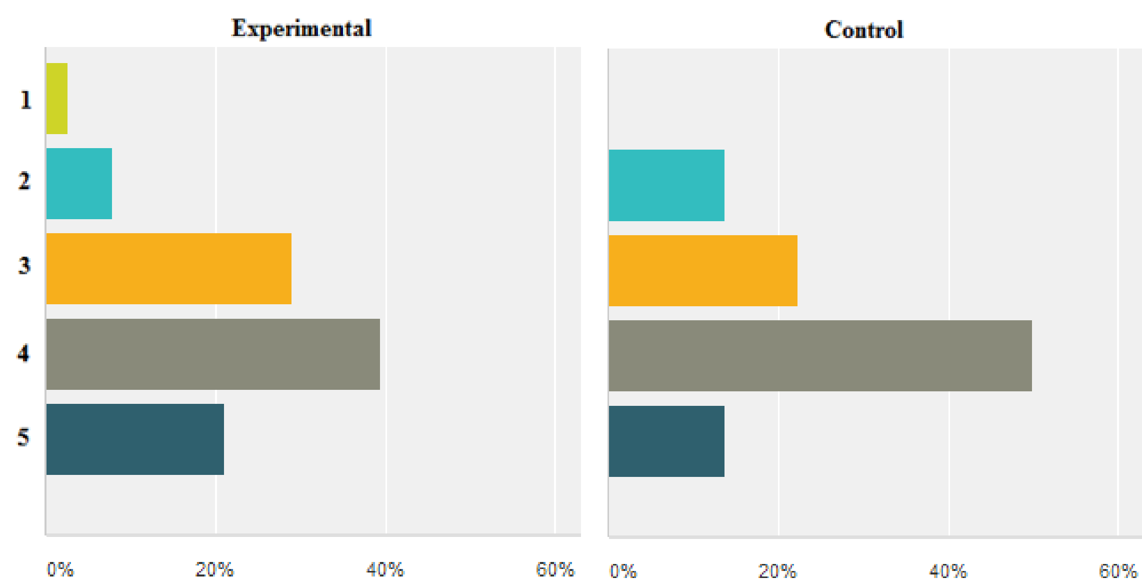


The responses for the two groups are nearly identical, so the only meaningful differences are likely those between houses of the same duplex. This can be difficult to determine for houses in which only one student responded. Regardless, it is encouraging to see such a large number of students claim they have genuine concern for environmental issues.

<u>Question E9/C3:</u> How important do you believe individual actions (i.e. practicing energy-saving behaviors in one's house) are in reducing greenhouse gas emissions and conserving energy?

Scale: 1 – Completely unimportant; 5 – Extremely important.

Weight	Experimental Group Frequency		Control Group Frequency	
	Relative Frequency	Frequency	Relative Frequency	Frequency
1	2.63%	1	0	0
2	7.89%	3	13.79%	8
3	28.95%	11	22.41%	13
4	39.47%	15	50%	29
5	21.05%	8	13.79%	8
Total		38		58

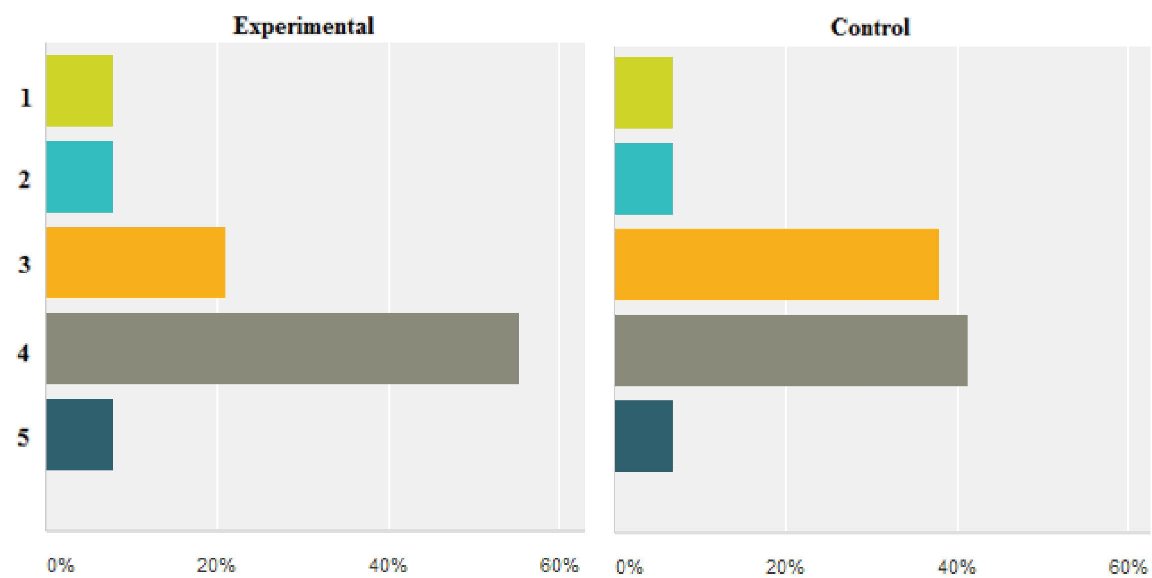


Again, the distribution for the experimental and control groups are quite similar. After isolating the eight respondents in the experimental group who believed household behaviors were "extremely important," we saw that three of them made a connection between household actions and the energy monitor readings, and only two of them claimed that the monitor led them to change their behaviors.

<u>Question E10/C4:</u> To what degree do you practice energy-saving behaviors (i.e. turning off lights when leaving a room, adjusting the thermostat to avoid wastefulness, etc.) in your house? Please explain.

Scale: 1 – I make no attempt to save energy; 5 – I make every attempt to save energy.

Weight	Experimental Group Frequency		Control Group Frequency	
	Relative Frequency	Frequency	Relative Frequency	Frequency
1	7.89%	3	6.90%	4
2	7.89%	3	6.90%	4
3	21.05%	8	37.93%	22
4	55.26%	21	41.38%	24
5	7.89%	3	6.90%	4
Total		38		58



This time, while the distributions are largely similar, the experimental group claims to put forth a little more effort in saving energy around the house. Of the three students in the experimental group who claimed to "make every attempt to save energy," only one's household habits changed in response to having an energy monitor—in fact, one of the three admitted to be unaware of having a monitor at all. Of course, this sample size is too small to make any significant conclusions. Three of the 21 of the students in the next highest category claimed their behaviors changed, but the majority noted they would have paid more attention if the monitor was somewhere clearly mounted.

Students also had a chance to leave comments regarding this question. We will first examine those in the experimental group. Seven of the nine students who left comments explicitly mentioned turning off the lights when the room was not being used. Four students talked about adjusting the thermostat, usually by lowering it before going to bed. Other students made the following remarks:

> **Participant 1:** "I don't think my efforts will make a difference unless a bunch of other folks do the same. I turn off lights, thermostat is always at a comfortable level."
>
> **Participant 2:** "My commitment to save energy is strong. Even shutting off the shower while soaping or shampooing can save gallons of water!"
>
> **Participant 3:** "Since [the University of Dayton] pays for everything we waste more than when we're at our parent's homes."

Participant 1 reflects a common attitude that one cannot have an effect unless others follow suit. Thus, it may be important to share consumption data between houses for motivation or to induce competition. Participant 2's set of responses revealed that he or she found the energy monitor helpful, used it to change his or her habits, and answered at the highest level in the other two environmental consciousness questions. Even so, this student reported that sufficient incentives would have led to even more conservative behaviors. The comment by participant 2 shows that some students may have saved resources in other domains (such as water), which would not have shown up in our electricity data. Thus, the monitor may have had effects like this on other students in ways we did not measure. Finally, participant 3 reflects the attitude of the students who take advantage of not having to pay utility bills—although this is a different student than the earlier students who echoed this attitude in questions 5 and 7.

We will now examine the comments made by those in the control group. Of the 58 respondents, 33 left comments, some of which are very revealing. We attached the entire set of comments in the Appendix, but we will reference a few important ones here. In general, about two thirds reported turning off lights when not in use, one fourth mentioned adjusting the thermostat, one third discussed saving water, and one fifth talked more loosely about turning off or unplugging appliances. We will now briefly discuss nine other interesting points, referencing the participants by numbers assigned to them in the transcript in the Appendix.

Participant 26 claimed "I do all that I can [to save energy], but the guys I live with don't really care about [saving energy] at all." He even reported that "one might even say they're against it." As a result, he feels he is "fighting a losing battle." Certainly it would be difficult to save energy in an apathetic—even antagonistic—environment. Participant 30 notes that his or her roommates also seem to be unconcerned about wasting energy, yet he or she feels "it would be intrusive to go [into their rooms and turn their lights off while they are not there] or preach my ideals to them." As mentioned in the "Background" section, passionate sustainable behavior is not valued by everyone; thus, asking roommates to turn lights off could come across as "preaching ideals," which may be too confrontational or ineffective for some people. In total, eight participants reported that while they try to save energy, their roommates make no effort.

Participant 2 stated bluntly, "I don't practice energy saving because I don't have to pay my own utility bills." Further, he or she claimed that "last year, while living in a land lord house, I was much more aware of my own and my roommates' energy consumption." Two other participants reported similar views. This simply stresses how environmental motivations may not be enough for some people to conserve energy—financial incentives could be much more influential (even for the environmentally concerned). On a more vengeful note, participant 32 stated "[University of Dayton] housing costs are so inflated that spending energy is my way of getting back." This may be a destructive form of retaliation, but it is important to note that such negative attitudes toward perceptions of overpricing may arise.

Participant 6 left a lengthy quotation from a website summarizing a scientific view that claims we have no effect on climate change. This participant also reported having no concern over environmental issues, and he or she makes no effort to conserve energy. Thus, this viewpoint can be very detrimental. If this student were presented with convincing evidence in favor of the other viewpoint, perhaps his or her actions would change accordingly. Otherwise, we can assume that only monetary incentives would drive behavior change. No other participant explicitly expressed this view.

Participant 21 expressed a desire for a timed thermostat, since the main issue preventing energy conservation for his or her household lies in forgetting to adjust the thermostat every night before going to bed. Similarly, participant 23 said "I tend to take energy for granted and I don't always think about it." Further, this participant tries to be more conservative "when it crosses [his or her] mind." Forgetfulness seems to be the theme here; the latter participant perhaps would have benefitted greatly from having a mounted energy monitor.

Participant 12 stated "I do what I can to conserve energy, but our house structure pretty much negates any efforts." He or she claims that the household keeps the heat at a high level since they "lose so much heat through the doors and windows." One other student reported keeping the heat on high in order to counteract poor insulation. Hence, drafty houses may discourage people from saving energy; since they cannot improve the insulation, the resolution lies with the university upgrading the houses' infrastructure.

Participant 8 stressed the importance of receiving informational billing. Last year, this student lived in a landlord house and received a monthly bill. Aside from financial incentives, the student claims the bill "had much more of an impact" than not receiving any reminder of how much energy was being consumed. Solving this problem may simply be a case of reinstituting the Greenhouse Effect informational bills which unfortunately were not available during the time of this study.

Participant 10 reported that his or her household is "more likely to leave a light on or two in order to prevent coming home to a dark house." This student elaborated that doing so is based on "more of a concern for safety/being scared than anything else." The university reflects this view, as it has wired all campus houses to leave their front porch lights on during all dark hours. Thus, this habit is understandable; this behavior is unlikely to change without students feeling fundamentally more secure in their particular neighborhood.

Finally, participant 22 showed the greatest initiative, going as far as to “use lamps versus overhead lights in the house or opening windows to use the natural lighting.” Further, this participant claimed carpooling to be important to his or her lifestyle. This example is included to contrast with some of the more negative responses we have received, such as participant 32’s remark about exacting revenge on the university for high housing costs. In other words, there are students on campus who go to great lengths to conserve energy despite all of the issues brought up by the other participants.

For the most part, all three distributions for the environmental consciousness section are similar between experimental and control group responses. Thus, they may be representative of the campus’s attitude in general (or, more precisely, of those willing to respond to such questionnaires). Again, since most houses only had one or two people respond to the questionnaires, it is difficult to make confident conclusions as to whether such attitudes made a difference. Of the pairs of houses in which these responses were examined, it appeared that most houses tend to have people of varying attitudes, with some more concerned than others. The efforts of one student making every effort to conserve may be overshadowed by the wastefulness of others. This is a difficult metric to quantify with the data available. Even so, as we will see in the next section, we can make some meaningful conclusions, offering some policy advice as well as suggesting improvements for future research efforts.

5. Conclusions

While this study was designed with an emphasis on exploring quantitative data and hoping to see trends over time (as outlined in section 3.4), various factors contributed to us having to abandon such pursuits. The shifts in energy monitor data made us question the validity of the data entirely; in addition, the monthly data from Dayton Power & Light did not provide enough sample points to run any conclusive statistical analyses. Our other potential measures—comparing monthly usage with historical data of each respective house, and comparing duplexes and identically structured houses with each other—were ineffective either because no trends existed or the trends were lost in the great deal of noise inseparable from a study of this nature. Regardless of these difficulties, questionnaire results suggested that even if trends existed and were identifiable, we could hardly state that the energy monitors were responsible. In fact, quantitative efforts may not be useful in studies of this type until the researcher can be confident that students are at least paying attention to the energy monitors on a regular basis.

Fortunately, the questionnaire provided useful insight from the participants of the study which could guide the direction of university policy and future research efforts. For instance, although about 80% of students rarely looked at their monitors, those who reported looking at least once a week almost always made a useful connection between their behaviors and the associated energy costs. These same students also reported changing their behaviors as a result. While we cannot conclude that looking at the monitors directly led to the changes in behavior, we can say that the monitors helped these students learn more about household energy consumption, and that this group in particular cared enough to translate this knowledge into action. Further, these students had varying opinions on the environmental consciousness survey, so their environmental attitudes did not necessarily lead them to make such changes.

In order for it to make financial sense to install energy monitors in all student houses however, the issues representing the other 80% of students must be addressed. Two factors appear to be particularly important. First is that many students feel no need to conserve energy since they are not paying the utility bills—or they feel the high cost of living frees them from any guilt of overconsumption. Many of these same students report that incentives could lead them to change their behaviors. The second factor concerns the monitors themselves—namely that future models should be mounted by the thermostat, be easier to understand, and be more reliable. In addition, we learned that the apathy of roommates, a disbelief in human involvement in climate change, forgetfulness, poor insulation, a lack of informative billing and education in general, and concerns about safety all serve as barriers toward the formation of conservative habits. On the other hand, students seem to care about environmental issues, believe that household actions have at least a fairly significant impact on climate change, and tend to put some (oftentimes great) effort into saving energy. Thus, there is hope for widespread behavior change on the University of Dayton's campus should certain issues be addressed.

Future experiments in this domain could take a few forms, each of which would provide additional useful information. First, a general study examining the environmental attitudes of all of campus could be useful, including questions corresponding to energy monitors and what would have an effect on the students' behaviors. Second, should a study like this be conducted again, emphasis should be placed on finding more suitable monitors. In addition, education should be pushed on the experimental group, incentives should be offered, and informational billing should be included. All of these factors could result in a greater percentage of students reporting that their behaviors changed in response to the monitors. Even with these changes however, it is probably a wasted effort at this point to depend heavily on quantitative results—future studies should stress examinations of students' attitudes toward the monitors, their actions, and the environment.

Even without further research, it is fairly clear that a change in policy toward students paying for their own utilities should result in students conserving more energy. The logistics of this may be very complicated, but if it can be achieved, it would likely result in marked savings. Another possibility would be to incorporate a certain baseline energy use—if students spend below the baseline, they would be reimbursed accordingly. We acknowledge that this may take away from guaranteed funds for the university; it would be up to the university to decide whether this approach is feasible and in line with its priorities. If nothing else, perhaps prizes could be awarded to the top few houses on each street which manage to conserve the most energy. Without some form of monetary incentive, it may not make sense at this time to install energy monitors in every house. We are hopeful that with sufficient further research and inventive, daring new policies, energy monitors may soon be useful tools in educating students on the relationship between energy use and household behaviors and even saving significant amounts of energy on campus.

6. Appendices

6.1 EnviR Monitor Display

6.2 Greenhouse Effect Report Card

UNIVERSITY of DAYTON

Learn. Lead. conServe.

Greenhouse Effect Report Card

MARCH , 2013

1234 EXAMPLE AVE

Grade: B+

***Total Cost: $222.83**

Detailed Info

	*Cost	Usage	Typical Usage	Difference	
Electricity	$18.20	317 kWh	521 kWh	Saved	39.1%
Natural Gas	$124.68	146 ccf	155 ccf	Saved	5.9%
Cable & Internet	$79.95***				
Total	$222.83				

How Do We Measure Up?

	Your House		Your Street		All UD Houses	
Electricity	Saved	39.1%	Wasted	-2.4%	Saved	5.6%
Natural Gas	Saved	5.9%	Saved	18.0%	Saved	4.1%

Grade: B+

***Total Cost: $222.83**

Carbon Footprint: 2,426 lbs CO_2

Report Type: House

Your Rank: 62 of 308

Best this Month: 4321 ENERGY WAY

*These costs are provided for your educational benefit.
*These are NOT payments that you are required to make.
**Actual Cost differs slightly from Avoidable Energy Cost because of the meter service charge.
***The cable and internet costs provided above are estimates intended to show what you might pay for these services as a consumer. UDit provides additional service and support beyond standard consumer cable and internet service. This figure is not connected to the actual cost of the service or how it is budgeted for in the comprehensive housing fee.


UD PRESENTS
THE GREENHOUSE EFFECT
INITIATIVE TO INCREASE THE UNIVERSITY'S SUSTAINABILITY
SAVE GAS
Wash your clothes in cold water.
Be aware of the amount of hot water you are using, especially in the shower.
Keep your windows closed when it gets cold.
GREEN THERMOSTAT SETTINGS
WINTER
68°F when indoors
60°F outdoors/sleeping
SUMMER
75°F when indoors
80°F outdoors/sleeping
SAVE ELECTRICITY
Turn off your computers and printers, especially overnight. Screen savers do not save energy.
Study outside in the sunny weather and use as much natural light as possible.
Plug electronics into power strips and turn them off when not in use.
Turn off all lights when not in use.
When you leave for a weekend, unplug all of your electronics.
CONSERVE WATER
Avoid leaving your water running
Turn water off while brushing your teeth.
Do not flush trash down the toilet.
Take shorter showers.
THE GOAL
is to reduce student energy use by 5% campus wide and change student understanding of sustainability and its importance.
TIPS TO REDUCE YOUR ENERGY
Eager to get green and significantly reduce residential energy use, UD will send out monthly Energy Report Cards to all neighborhood houses.
IMPROVE YOUR GRADE
green.udayton.edu
RECYCLE
Follow UD's set regulations on which items are recyclable.
green.udayton.edu/recyclelist.htm
Recycle everything you can.
CUT BACK ON WASTE
Use reusable mugs and cups throughout the day instead of wasting plastic cups daily.
Purchase used or recyclable items and borrow items from friends when possible.
Reuse the plastic bags you already own for things like lining your trash can.
Use a hand towel instead of paper towels as much as possible.
Purchase a reusable bag for your shopping needs.
RESIST OVERCONSUMPTION
Think of what you are buying and what you really need.

6.3 Student Energy Meter Notice

Dear resident,

Your house has been equipped with a real-time energy meter. These meters measure how much energy your house uses and sends that information to a display in the common area of your house. This allows you to see how much energy your house is using at any given time, and take steps to reduce that energy use if you desire.

Some steps you can take to reduce your energy usage include the following:

- Adjusting your thermostat a few degrees higher during hot weather and a few degrees lower during cold weather.
- Turning things off (i.e. laptop, printer, television, stereo, fan, gaming systems) when not using them, as opposed to leaving them idle.
- Hand washing dishes rather than relying on a dish washer.
- Cold-washing your laundry (if applicable).
- Turning off lights when leaving a room or the house.

Making a commitment to any of the above can go a long way toward significantly lowering the energy usage of our community. We hope you will take advantage of your energy meter in an attempt to learn more about the complexities of energy use.

From time to time, these meters may require maintenance. You will be given at least 24 hours' notice via email before a technician is sent to perform this maintenance. We will make every attempt to schedule maintenance during breaks.

Please do not disconnect, unplug, or remove the display. The fine for broken or missing displays will be $150. If you are having trouble with your display, please email Kurt Hoffmann, Environmental Sustainability Manager, at khoffmann1@udayton.edu or call at 937-313-1092.

Thank you for your participation in UD's sustainability initiatives!

Kurt Hoffmann

6.4 Data Collection Log

The following log was kept during the collection of the first set of data (occurring over two days: October 28 and November 21). Loosely, the location and status of the energy monitor was recorded along with any other observations made by either Environmental Sustainability Manager Kurt Hoffmann or myself. [o] indicates we were able to collect data; [X] indicates we were unable to collect data. The house codes correspond to the codes used in the table in Appendix 6.5.

First Date of Collection (October 28, 2013):

[o] A1 – monitor plugged in on floor of kitchen.
[o] B1 – monitor unplugged on table in common room.
[X] C1 – monitor plugged in on mini-fridge, but not connected to meter (no Wi-Fi).
[o] D1 – monitor plugged in on mantle in common room, tucked away in back.
[o] M1 – monitor plugged in by window by front door.
[X] N1 – monitor plugged in on kitchen counter; it is properly paired with the meter, but it is not reading the energy for some reason.
[o] O1 – monitor plugged in in basement (which we unlocked); we moved it upstairs and placed it on top of the kitchen fridge.
[o] E1 – monitor plugged in by front door.
[o] J1 – monitor unplugged by window sill in common room.
[o] V1 – monitor plugged in in Laundry room.
[o] U1 – monitor plugged in on kitchen countertop.
[X] G1 – monitor unplugged on floor of common room; it also was not connected to the meter (no Wi-Fi).
[o] F1 – monitor plugged in on kitchen window sill by sink.
[o] R1 – monitor plugged in on kitchen window sill by sink.
[o] H1 – transmitter is outside of electrical panel; it was disconnected when we got here. The display was connected and was somehow reading data. We reconnected the transmitter.
[o] I1 – transmitter is not completely connected; it was also outside of the electrical panel. The display was connected and was somehow reading data. We reconnected the transmitter.
[X] Q1 – could not find the monitor.
[X] L1 – monitor plugged in on mini-fridge in common room; it was not connected to the meter (no Wi-Fi).
[o] K1 – monitor plugged in on window sill by front door.
[o] W1 – monitor plugged in on table by front door.

Second Date of Collection (November 21):

[o] G1 – monitor plugged in on floor of common room; only managed to retrieve data from November.
[o] P1 – monitor plugged in by window on coffee table to the right when you enter; only managed to retrieve data from November.
[o] Q1 – monitor plugged in upstairs under a desk in the rightmost bedroom; the student who led us to the monitor admitted this was the "first time I've ever looked at it."
[o] T1 – monitor plugged in upstairs on windowsill.
[X] S1 – could not find the monitor.
[o] L1 – monitor plugged in on mini-fridge in common room.
[o] J1 – house was being renovated; this will affect the data!
[o] C1 – monitor plugged in by fridge in kitchen.
[X] N1 – monitor was paired properly but still not reading energy.

6.5 Data Table

House	Number of Questionnaire Responses	Notes	Monthly Electricity Usage (kWh)					
			Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014
DUPLEXES								
A1	2		608	324	265	267	233	373
A2	4		584	585	554	651	407	638
∆		+trend?	-24	261	289	384	174	265
B1	2	[shift]	2056	1374	955	853	547	959
B2	2		1829	1127	991	1240	440	1021
∆			-227	-247	36	387	-107	62
C1	0	[shift]	1167	848	765	707	464	1157
C2	0		914	736	829	826	627	781
∆		+trend?	-253	-112	64	119	163	-376
D1	3	[shift]	1314	843	735	582	356	616
D2	2		463	338	424	425	340	594
∆		+trend?	-851	-505	-311	-157	-16	-22
E1	0	[shift]	1797	1184	657	658	469	997
E2	2		1083	764	501	493	412	623
∆		+trend?	-714	-420	-156	-165	-57	-374
F1	1	[shift]	813	582	488	406	360	543
F2	0		661	662	454	499	358	573
∆			-152	80	-34	93	-2	30
G1	0		1111	1017	741	730	375	769
G2	2		847	536	354	453	380	621
∆			-264	-481	-387	-277	5	-148

House	# of Questionnaire Responses	Notes	Monthly Electricity Usage (kWh)					
			Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014
H1	3		1767	1315	1270	1276	626	1225
H2	4		3058	2761	2463	1850	1781	1625
Δ			1291	1446	1193	574	1155	400
I1	2		1935	1399	1016	1057	648	1258
I2	1		2378	1483	1057	870	678	1280
Δ		-trend?	443	84	41	-187	30	22
J1	4 (1Y)		1858	1117	660	642	470	993
J2	4		1351	737	771	524	543	807
Δ			-507	-380	111	-118	73	-186
K1	1 (1Y)	[shift]	1612	1180	789	858	773	1139
K2	2		1836	1172	946	948	799	1164
Δ		-trend?	224	-8	157	90	26	25
L1	5		1509	954	625	728	573	902
L2	1		1956	1378	1465	1162	877	1428
Δ			447	424	840	434	304	526
M1	1		912	662	357	386	352	510
M2	2		771	562	492	476	275	512
Δ			-141	-100	135	90	-77	2
SIMILAR PAIRS OF HOUSES								
N1	1	[no data]	1612	1082	844	690	274	807
N2	1		667	593	655	550	269	607
Δ		+trend?	-945	-489	-189	-140	-5	-200
O1	1		1676	898	905	1161	848	1087
O2	1		1509	690	448	467	395	591
Δ		-trend?	-167	-208	-457	-694	-453	-496

House	# of Questionnaire Responses	Notes	Monthly Electricity Usage (kWh)					
			Sep 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014
P1	2	[shift]	774	439	359	435	319	486
P2	3		1721	1268	577	589	468	862
Δ		-trend?	947	829	218	154	149	376
Q1	1		1192	679	468	594	377	633
Q2	1		614	429	310	402	468	1073
Δ		+trend?	-578	-250	-158	-192	91	440
R1	4 (1Y)		972	634	561	586	478	669
R2	2		533	516	593	603	446	1139
Δ		+trend?	-439	-118	32	17	-32	470
S1	2		836	553	524	521	367	645
S2	1		1464	1130	910	691	398	764
Δ		-trend?	628	577	386	170	31	119
T1	0		1074	755	774	598	719	1010
T2	4		1105	865	953	861	626	895
Δ			31	110	179	263	-93	-115
U1	0		1767	1567	1166	953	576	853
U2	3		1355	1153	855	762	639	894
Δ		+trend?	-412	-414	-311	-191	63	41
V1	1 (1Y)		1827	1427	1407	1128	676	1171
V2	4		1598	1188	988	796	428	911
Δ			-229	-239	-419	-332	-248	-260
W1	2 (1Y)		1449	1051	654	597	590	859
W2	4		1619	1144	825	761	532	939
Δ			170	93	171	164	-58	80

Note: Data is from Dayton Power & Light; Houses labeled with a "1" are in the experimental group.

Legend:

- [shift] indicates houses in which a data shift occurred between the two electricity files downloaded from the energy monitors
- [no data] indicates we could not download the data from the monitor.
- (1Y) indicates that one questionnaire respondent claimed his or her household habits were changed due to the monitor.
- Δ marks the row in the pair indicating the energy saved by the experimental house relative to the control house.
    - +trend? indicates a trend may exist in which the experimental house decreased energy consumption relative to the control house.
    - –trend? indicates a trend may exist in which the experimental house increased energy consumption relative to the control house.
    - (Note: trends were estimated by examining the change in D values from September to February 2014.)

6.6 Questionnaire Emails

The following emails were sent to students in the experimental group and control group on February 18 and 19 respectively, which included links to their respective questionnaires. They were sent through the University of Dayton Facilities Department by Kurt Hoffmann in order to retain an air of authority.

Title: "Survey regarding your energy meter"

Body: "Since the beginning of the 2013-14 academic year, we have been conducting a study in an attempt to determine the effects of energy monitors on energy awareness and conservation. Your house was one of the few selected to have an energy monitor installed. Below you will find a link to a very short questionnaire concerning your energy monitor. It is imperative that we hear from you in order to form conclusions for our study. Please lend us a few moments of your time to complete the survey.

[Link to Experimental Group Questionnaire]

Thank you!"

Follow-Up (February 28): "If you have not done so already, please respond to our questionnaire about energy use. It is very short--on average, students who have filled it out already have spent merely two minutes! In addition, it is important for everyone in your house to fill out the survey, not just one representative.

Thank you--we appreciate your time."

Title: "Please respond regarding energy use in the student neighborhood"

Body: "Dear student,

Since the beginning of the 2013-14 academic year, we have been conducting a study concerning the consumption of energy in houses in the UD student neighborhood. Your house was one of the few selected to be monitored over the course of this year. Below you will find a link to a very short (4-question) survey concerning your views on the environment and sustainability. It is imperative that we hear from you in order to form conclusions for our study. Please lend us a few moments of your time to complete the survey.

[Link to Control Group Questionnaire]

Thank you."

Follow-up (February 28): "If you have not done so already, please respond to our questionnaire about energy use. It is very short--on average, students who have filled it out already have spent under a minute! In addition, it is important for everyone in your house to fill out the survey, not just one representative.

Thank you--we appreciate your time."

6.7 Control Group Responses to Question C4

Question C4: To what degree do you practice energy-saving behaviors (i.e. turning off lights when leaving a room, adjusting the thermostat to avoid wastefulness, etc.) in your house? Please explain.

1 “Living with other people hinders the ability to really make an impact on the house’s environmental impact overall. That said, I still try my best to turn off lights, save water, and turn off the heater when possible.”

2 “I don't practice energy saving because I don't have to pay my own utility bills. Last year while living in a land lord house, I was much more aware of my own and my roommates' energy consumption.”

3 “It’s a product of my upbringing to turn off the lights when you leave a room or the faucet or the television. It’s not as much an environmental concern as it is a money concern.”

4 “We make sure the lights are off if no one is in the room.”

5 “When I am the last one to bed, I try to turn off all the lights. Once I start the shower, I get in instead of taking my time to get in. I open windows instead of using the thermostat.”

6 “’’Global warming’ refers to the global-average temperature increase that has been observed over the last one hundred years or more. But to many politicians and the public, the term carries the implication that mankind is responsible for that warming. This website describes evidence from my group’s government-funded research that suggests global warming is mostly natural, and that the climate system is quite insensitive to humanity’s greenhouse gas emissions and aerosol pollution. Believe it or not, very little research has ever been funded to search for natural mechanisms of warming…it has simply been assumed that global warming is manmade. This assumption is rather easy for scientists since we do not have enough accurate global data for a long enough period of time to see whether there are natural warming mechanisms at work. The United Nation's Intergovernmental Panel on Climate Change (IPCC) claims that the only way they can get their computerized climate models to produce the observed warming is with anthropogenic (human-caused) pollution. But they're not going to find something if they don't search for it. More than one scientist has asked me, "What else COULD it be?" Well, the answer to that takes a little digging… and as I show, one doesn't have to dig very far. But first let's examine the basics of why so many scientists think global warming is manmade. Earth's atmosphere contains natural greenhouse gases (mostly water vapor, carbon dioxide, and methane) which act to keep the lower layers of the atmosphere warmer than they otherwise would be without those gases. Greenhouse gases trap infrared radiation — the radiant heat energy that the Earth naturally emits to outer space in response to solar heating. Mankind's burning of fossil fuels (mostly coal, petroleum, and natural gas) releases carbon dioxide into the atmosphere and this is believed to be enhancing the Earth's natural greenhouse effect. As of 2008, the concentration of carbon dioxide in the atmosphere was about 40% to 45% higher than it was before the start of the industrial revolution in the 1800′s. It is interesting to note that, even though carbon dioxide is necessary for life on Earth to exist, there is precious little of it in Earth's atmosphere. As of 2008, only 39 out of every

100,000 molecules of air were CO2, and it will take mankind's CO2 emissions 5 more years to increase that number by 1, to 40. The 'Holy Grail': Climate Sensitivity Figuring out how much past warming is due to mankind, and how much more we can expect in the future, depends upon something called "climate sensitivity". This is the temperature response of the Earth to a given amount of 'radiative forcing', of which there are two kinds: a change in either the amount of sunlight absorbed by the Earth, or in the infrared energy the Earth emits to outer space. The 'consensus' of opinion is that the Earth's climate sensitivity is quite high, and so warming of about 0.25 deg. C to 0.5 deg. C (about 0.5 deg. F to 0.9 deg. F) every 10 years can be expected for as long as mankind continues to use fossil fuels as our primary source of energy. NASA's James Hansen claims that climate sensitivity is very high, and that we have already put too much extra CO2 in the atmosphere. Presumably this is why he and Al Gore are campaigning for a moratorium on the construction of any more coal-fired power plants in the U.S. You would think that we'd know the Earth's 'climate sensitivity' by now, but it has been surprisingly difficult to determine. How atmospheric processes like clouds and precipitation systems respond to warming is critical, as they are either amplifying the warming, or reducing it. This website currently concentrates on the response of clouds to warming, an issue which I am now convinced the scientific community has totally misinterpreted when they have measured natural, year-to-year fluctuations in the climate system. As a result of that confusion, they have the mistaken belief that climate sensitivity is high, when in fact the satellite evidence suggests climate sensitivity is low. The case for natural climate change I also present an analysis of the Pacific Decadal Oscillation which shows that most climate change might well be the result of….the climate system itself! Because small, chaotic fluctuations in atmospheric and oceanic circulation systems can cause small changes in global average cloudiness, this is all that is necessary to cause climate change. You don't need the sun, or any other 'external' influence (although these are also possible…but for now I'll let others work on that). It is simply what the climate system does. This is actually quite easy for meteorologists to believe, since we understand how complex weather processes are. Your local TV meteorologist is probably a closet 'skeptic' regarding mankind's influence on climate. Climate change — it happens, with or without our help.' - Roy Spencer Ph.D Former NASA Scientist."

7 "I always turn off lights out of habit."

8 "Laziness would be the main factor in our inability to practice energy-saving behaviors. When we lived in a landlord house and received a bill every month basically showing us how well we were conserving energy had much more of an impact than not having no reminder whatsoever as we do with living in UD housing."

9 "We are all pretty good about turning our lights off when we aren't in a room. We also always lower the thermostat when we leave for a break."

10 "Since my roommates and I have different schedules and live on a busier street I am more likely to leave a light on or two in order to prevent coming home to a dark house. It's more of a concern for safety/being scared than anything else."

11 “I always am turning lights off especially when I wake up and all of my roommates have left for student teaching for the day. I also work to conserve water between washing dishes and my showers last ten minutes tops. One of my roommates constantly leaves on lights and the television.”

12 “I do what I can to conserve energy, but our house structure pretty much negates any efforts. We have to keep the heat higher because we lose so much heat through the doors and windows, and have to leave the sink dripping to avoid freezing pipes (when it was cold).”

13 “I pay a flat rate for housing and my energy usage does not affect me financially, so I have little incentive to turn lights off, etc.”

14 “I always turn off the lights when leaving a room and at night. I change the thermostat to avoid waste.”

15 “We were more careful about conserving energy and water when we were in a landlord house and we had to pay for our utilities. I don't think we are wasteful now, but we aren't necessarily concerned about keeping the heat low or taking short showers.”

16 “I prefer to save energy and water as I lived in a sustainability house last year, but I have some roommates that do not find it as important as I.”

17 “Keeping thermostat low. Reducing Water Usage.”

18 “I try to turn off the lights and water when it's not being used.”

19 “I am always turning off lights to make sure that the energy is not wasted. For my roommates that's a different story. It is hard to keep the house warm so the thermostat is always on high.”

20 “We keep our lights off, thermostat at reasonable temperatures, fans off when we aren't in rooms, always fill the dishwasher and washer/dryer full before running them.”

21 “I would really like to have a timed thermostat so our house would be able to easily drop the setting at night and warm back up as we wake up. Many times we just forget to change it every night.”

22 “My roommate has a terrible tendency to leave the bathroom light on when she goes to practice in the morning. I always end up shutting it off. I also like to use lamps versus the overhead lights in the house or opening windows to use the natural lighting. I also carpool to save on gas.”

23 “In my day to day routine, I tend to take energy for granted and I don’t always think about it. However, when it crosses my mind I try to be conscious and turn off lights, use less water and etc.”

24 “We all turn off our lights and water when not in use but I wouldn't say it is a main priority.”

25 “Ensure lights and television sets are turned off when leaving the house for long periods of time.”

26 “I mean, I do all that I can (turn of lights, TVs, unplug chargers, etc.), but the guys I live with don't really care about those kinds of things at all. One might even say they're against it. So sometimes I feel like I'm fighting a losing battle. But I try to save energy whenever I can.”

27 “I make somewhat of an attempt.”

28 “It’s hard trying to get three other people to do simple things like recycle and keep the thermostat at reasonable levels especially this winter. I gave up the thermostat war but I do flip off useless lights and the tvs and things like that when I see them.”

29 “Turn off lights and electronics when not in use.”

30 “I go around turning lights off all the time, sometimes my roommates leave lights on all night or on in their rooms while they are somewhere else. I feel it would be intrusive to go and turn them off or preach my ideals to them.”

31 “I turn off lights when rooms are left unattended and I also used as little water as possible by not leaving the faucet running unless the dishes are being done.”

32 “UD housing costs are so inflated that spending energy is my way of getting back.”

33 “As a house we try to turn off all of the lights when we leave, not run the shower prior to getting in it, only using the heat when the house is cold. When it is nice out, we will open the windows rather than using a lot of air conditioning.”

7. Bibliography and Further Reading

Note: The following sources were referenced in the thesis.

Baca-Motes, K., Brown, A., Gneezy, A., Keenan, E. A., & Nelson, L. D. (2013). Commitment and Behavior Change: Evidence from the Field. *Journal of Consumer Research*, *39*(5), 1070–1084. doi:10.1086/667226

Burgess, J., & Nye, M. (2008). Re-materialising energy use through transparent monitoring systems. *Energy Policy*, *36*(12), 4454–4459. doi:10.1016/j.enpol.2008.09.039

Current Cost. (n.d.). EnviR - Specifications. Retrieved from http://www.currentcost.com/product-envir-specifications.html

Darby, S. (2006). The effectiveness of feedback on energy consumption. *Environmental Change Institute – University of Oxford.*

Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenbergh, M. P. (2009). Household Actions Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(44), 18452–18456.

Electricity Overview | Center for Climate and Energy Solutions. (n.d.). Retrieved December 14, 2013, from http://www.c2es.org/technology/overview/electricity

Hargreaves, T., Nye, M., & Burgess, J. (2010). Making energy visible: A qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy*, *38*, 6111–6119. doi:10.1016/j.enpol.2010.05.068

Hargreaves, T., Nye, M., & Burgess, J. (2013). Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. *Energy Policy*, *52*, 126–134. doi:10.1016/j.enpol.2012.03.027

Jensen, J. O. (2008). Measuring consumption in households: Interpretations and strategies. *Ecological Economics*, *68*(1/2), 353–361. doi:10.1016/j.ecolecon.2008.03.016

Kissock, K. Energy Simulation Software. (n.d.). Retrieved from http://academic.udayton.edu/kissock/http/RESEARCH/EnergySoftware.htm

Ling, R., & Wilhite, H. (1995). Measured energy savings from a more informative energy bill. *Energy & Buildings*, *22*(2), 145.

Martiskainen, M., & Coburn, J. (2011). The role of information and communication technologies (ICTs) in household energy consumption-prospects for the UK. *Energy Efficiency (1570646X)*, *4*(2), 209.

UD GreenHouse Effect. (n.d.). Retrieved from https://stars.aashe.org/institutions/university-of-dayton-oh/report/2011-09-07/ER/co-curricular-education/ER-2/

Weliczko, E. (2012, December 16). Tracking Your Energy Use | Home Power Magazine. Retrieved January 2, 2014, from http://www.homepower.com/articles/home-efficiency/electricity/tracking-your-energy-use?v=print

Note: The following sources were helpful but did not explicitly make it into the thesis.

Attari, S. Z. (n.d.). Global climate change and human behavior: Decreasing energy consumption.

Attari, S. Z., DeKay, M. L., Davidson, C. I., & Bruin, W. B. de. (2010). Public perceptions of energy consumption and savings. *Proceedings of the National Academy of Sciences*, *107*(37), 16054–16059. doi:10.1073/pnas.1001509107

Attari, S. Z., DeKay, M. L., Davidson, C. I., & de Bruin, W. B. (2011). Changing Household Behaviors to Curb Climate Change: How Hard Can it Be? *Sustainability: The Journal of Record*, *4*(1), 9–11. doi:10.1089/SUS.2010.9724

Christian Oltra, Alex Boso, Josep Espluga, & Ana Prades. (2013). Communication: A qualitative study of users' engagement with real-time feedback from in-house energy consumption displays. *Energy Policy*, *61*, 788–792. doi:10.1016/j.enpol.2013.06.127

Darby, S. (2010). Smart metering: what potential for householder engagement? *Building Research & Information*, *38*(5), 442–457. doi:10.1080/09613218.2010.492660

Gram-Hanssen, K. (2013). Efficient technologies or user behaviour, which is the more important when reducing households' energy consumption? *Energy Efficiency (1570646X)*, *6*(3), 447–457. doi:10.1007/s12053-012-9184-4

Groothuis, Peter A, & Mohr, Tanga McDaniel. (n.d.). Do consumers want smart meters? Incentives or Inertia: Evidence from North Carolina and Lessons for Policy. *2006*.

Gwendolyn Brandon, & Alan Lewis. (n.d.). Regular Article: Reducing Household Energy Consumption: A Qualitative and Quantitative Field Study. *Journal of Environmental Psychology*, *19*, 75–85. doi:10.1006/jevp.1998.0105

Hargreaves, T. (2011). Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. *Journal of Consumer Culture*, *11*(1), 79–99. doi:10.1177/1469540510390500

Huebner, G. M., Cooper, J., & Jones, K. (2013). Domestic energy consumption—What role do comfort, habit, and knowledge about the heating system play? *Energy & Buildings*, *66*, 626–636. doi:10.1016/j.enbuild.2013.07.043

R.J. Brecha, A. Mitchell, K. Hallinan, & K. Kissock. (n.d.). Prioritizing investment in residential energy efficiency and renewable energy—A case study for the U.S. Midwest. *Energy Policy*, *39*, 2982–2992. doi:10.1016/j.enpol.2011.03.011

Shwom, R., & Lorenzen, J. A. (2012). Changing household consumption to address climate change: social scientific insights and challenges. *WIREs: Climate Change*, *3*(5), 379–395. doi:10.1002/wcc.182

Van Dam, S. S., Bakker, C. A., & van Hal, J. D. M. (2010). Home energy monitors: impact over the medium-term. *Building Research & Information*, *38*(5), 458–469. doi:10.1080/09613218.2010.494832

Wokje Abrahamse, Linda Steg, Charles Vlek, & Talib Rothengatter. (n.d.). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, *25*, 273–291. doi:10.1016/j.jenvp.2005.08.002

Wood, G., & Newborough, M. (2003). Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. *Energy & Buildings*, *35*(8), 821. doi:10.1016/S0378-7788(02)00241-4