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Influencing Energy Consumption Behavior in Residence Halls through Education and Outreach

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Abstract

Future energy security and availability are two dilemmas facing the United States today. While the focus has been dominated by the idea of switching to alternatives, there are less expensive measures to decrease our current energy consumption namely through energy efficiency and conservation programs. Despite billions of dollars invested in energy efficiency programs we know little about the investments and behavioral nudges that lead to the highest return on investment (Bailey, 2013).Therefore, this study contributes to the literature by using a program-evaluation approach to examine behavioral adjustments in an even lesser known setting- a university. Specifically, we examined energy consumption patterns within four undergraduate dormitories. This study evaluated behavioral modification programs through the use of an experimental design, assigning two dorms as the control group and two as the experimental group. We used a difference-in-differences analysis to determine effectiveness of the educational mechanism in reducing electricity consumption. Based on our findings, this study offers suggestions for future energy behavioral modification programs within a university setting where this type of research can be beneficial.

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The energy sector plays a key role in the economy due to its mutual interdependence with economic activity (Bhattacharyya, 2011). The resources used to provide energy underlie the global economy and provide a means for economic exchange worldwide. Dependence and availability of energy sources result from this active exchange and create a global issue of a depleting supply and increasing demand. Energy economics is a subfield of economics which focuses on the allocation of resources that include nonrenewable and depletable resources, such as coal, oil, and natural gas. Allocation of these resources is determined by supply and demand forecasting (Bhattacharyya, 2011).

Consumer impact on the availability of nonrenewable resources can be reduced by switching to renewable forms of energy or by reducing the demand for these resources. Consumers do not have a direct demand for oil, coal, or natural gas; instead they indirectly demand these resources for the services they provide, such as electricity. In other words, consumers have a derived demand for fossil fuels and other resources. Consumers' derived demand for energy stems from the current infrastructure of our economy, which relies heavily on fossil fuels as energy sources to fuel cars, heat homes, provide electricity, etc. This infrastructure was established centuries ago with little consideration toward the limited supply of fossil fuels. Our infrastructure and reliance on fossil fuels has since become a convenience to fuel our economy.

This paper examines the effects of an energy educational mechanism for reducing electricity consumption. Over the course of three months, residents of the Towers dormitories of West Virginia University were educated on ways to reduce their electricity consumption in order to benefit the university as well as the environment. Electricity consumption was monitored over the course of the study. Results of a differences-in-difference analysis showed that the dormitories whose residents received energy education had reduced consumption relative to dormitories that did not. This paper will discuss brief contributions to the literature, some background surrounding the issues of energy economics, and discuss the project in full detail followed by suggestions for future research.

This study contributes to the literature in two ways. First, this research focuses on human behavior and its impact on economics. Previous studies examine the effects of incentives and feedback on behavior changes, whereas this research examines the effects of education on human behavior. University settings offer one of the largest laboratories to test the effectiveness of education and can offer insights into which type of policies have an effect on energy consumption. Secondly, this research contributes to the literature by furthering investigations on experimental economics. Experimental economics is a branch of economics focused on individual behavior in a controlled laboratory or field setting, which helps to prove or disprove economic theories, while creating insights about behavior. Experimental economics utilizes the experimental approach to analyze economic questions.

Experimental economics aims to understand the effects of administrating a trial on a group while holding another group as a control in order to understand the effects of a treatment. This type of design aids in many policy discussions and furthers the development of economics as a science. This type of economic research requires an economist to interpret the effects of an intervention, or mechanism on some object while holding another object constant. In the case of this research the intervention was an educational mechanism, and the object was human behavior. Experimental economics also integrates the counterfactual which, determines the "what if otherwise" factor. In order to understand the effects of the treatment an economist must understand what the outcomes would be with and without treatment. Accounting for the counterfactual makes experimental economics a strong tool for policy decisions.

Background

The amount of energy consumed depends on the price. Since the costs associated with energy consumption are borne after the product or service is rendered, that is, consumers do not bear the cost of electricity use each day until they receive a collective bill at the end of the month. Therefore, energy conservation is not always a consumer driven behavior or use pattern. Further, consumers may not reduce their electricity consumption simply because they do not know where to start. Institutions as well as households contain multiple sinks (e.g., electrical appliances) that consume electricity daily. It can be difficult for consumers or institutions to pinpoint the source(s) that utilizes the most electricity and make investment decisions that will yield the greatest reduction in consumption. Such planning and decision making is often not practical for everyday life.

Price elasticity of demand is used to see how sensitive a change in quantity demanded is relative to a change in price. It is calculated by finding the percentage change in quantity over the percentage change in price. If price elasticity is greater than 1 then the demand is elastic meaning that the demand is sensitive to changes in price. Also according to the law of demand, as the price per kilowatt hour increases, the demand of energy for electricity should decrease and vice versa. Residents of the dormitories at West Virginia University pay a one-time price. Because of this one-time lump sum payment, it can be challenging to influence reductions in consumption by manipulating prices. Therefore, energy conservation programs and education will likely yield the largest impact on consumption.

According to Tietenberg and Lewis (2012), conservation has taken a front seat for most electrical utilities. With the possibility of new electricity-generating plants being built, there also comes a possibility of rate increases (Tietenberg & Lewis, 2012). These rate increases can be substantial, and one way to prevent construction of new plants is to reduce electrical demand through conservation.

Conservation of the natural resources we now use for energy production is crucial in determining their future availability. And one way to achieve energy conservation is through behavior modification. According to a study by Sutterlin, Brunner, & Siegrist (2011), researchers found that people who engage in more "energy-friendly" actions were more likely to feel their personal behaviors can create a change.

Human motivation for behavior is a mix of self-interest and social preferences (Rabin, 2006). The author states that the self-interest of humans should be the main focus of economists attempting to understand behavior in an economic sense. Because humans are dominated by their own self-interest it is difficult to induce a large group to collaborate on efforts in order to benefit the group as a whole. With problems surrounding economics policies including incorporation of taxes, the effectiveness of subsidies and their drain of public funds, the interest has increased in "non-price conservation programs"(Allcot, 2011).

If organized and produced effectively, psychological cues that modify behavior can have as much of an effect on consumer demand as change in prices (Allcot, 2011). Further, Lally, Wardle, & Gardner (2011) suggested that behavior change can result from habit formation because habitual behaviors are performed automatically and are more likely to be maintained. In their study done on habit development and behavior modification in people participating in a weight loss program, they were able to find that behaviors that were repeated were more likely to be maintained. Also, new behaviors that were linked with previous behaviors, such as work-day activities, created more stability and predictability in the participants (Lally et al., 2011). Therefore, this research focused on the effects of behavioral nudges from an educational mechanism in a large scale setting where funds are limited, and changes in price have little immediate effect on consumer choices. In order to set forth a group effort, this research first aimed at inducing individual habits through a focus on behavior modification.

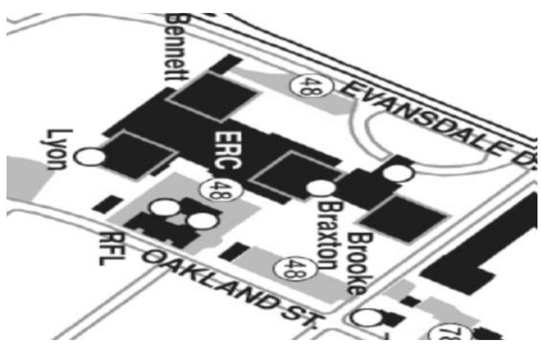
Project Description

Energy conservation and energy efficiency are often used interchangeably, even though they are two separate ideas. Energy efficiency focuses on directly influencing input requirements for an output, whereas energy conservation involves reducing the output (Croucher, 2011). For example, energy efficiency could be achieved through purchasing a smaller car that uses less gasoline, but energy conservation could be achieved by reducing the use of that car to once a day. This research focused on modifying energy consumption through conservation. Residents in college dormitories have little impact on what resources are used to power their living quarters, but they do have the ability to control how often they use the power supplied. Without directly changing the input for electricity, the effectiveness of the education on energy consumption behavior of the residents was evaluated on altering demand for the output.

The goal of this project was to analyze if simple behavior modifications could cause a decrease in energy consumption resulting in net economic and environmental benefits for the institution and community-at-large. The core objective of this research study was to reduce power consumption by inducing residents to power off computers, electronic gadgets, lights, and power strips when not in use. Residents were educated on the concept of phantom power, in which appliances continue to use electricity if not fully powered off or placed in a dormant state. A similar study done in New Zealand found a 16.2% difference in electricity consumption nightly and 10.7% difference in electricity consumption daily as a result of incorporating visual feedback, prompts and incentives to reduce electricity use (Bekker et al., 2010). Due to budget constraints this research only utilized visual prompts to induce behavior modification.

The proposed research study, an Occupant Engagement Initiative (OEI), was conducted at the Evansdale Residential Complex (ERC), also known as the Towers located at West Virginia University. This area was studied because of geographical location, similarities in dimensions of the buildings, and the high student population within each building.

Figure 1. Layout of the Towers Residential Complex



Bennett and Lyon Towers served as the OEI control group (no education or outreach activities were conducted) while residents of Braxton and Brooke served as the OEI research group. Residents in the OEI research group were exposed to the educational mechanisms that promoted sustainable energy conservation practices. Over the course of the study, the conservation practices adopted by the students were measured by how much electricity was consumed in each building, and we measured by the amount of electricity consumed in each building.

Importance of Project/Statement of the Problem

College and university campuses are like small autonomous cities. As a result of the size and activities on college campuses, they have become a major energy consumer with significant economic and environmental implications. Energy efficiency and energy conservation are systematic issues that many campuses across the United States have not yet addressed. If the derived demand for energy decreases, not only is the impact on energy availability reduced, but efficiency is increased. Reducing consumers' derived demand for resources can create significant savings for a university as well as increase the non-renewable energy resources available for the future. The intermediate goal was to educate students on their individual impact on university-wide electricity consumption to induce a decrease in demand. Therefore it was hypothesized that effective education and outreach activities of occupants in campus residence halls would result in behavior changes that reduce energy consumption.

Methods

This study examined electricity consumption from September 2012 through the end of November 2012 at the Towers dormitories of West Virginia University. The direct energy consumption studied is related to electricity for lighting, energy used for laundry facilities, and phantom load. Electricity used for air conditioning is included in the electricity consumption measured for this study, but was not incorporated into the educational mechanism. The energy used for heating was excluded from this study because it is provided by steam, which does not allow residents to choose a set-point temperature for their individual rooms during the cooler months. The goal of this study was to determine if an energy educational mechanism could modify residential behavior to be more sustainable and conserve electricity within their dorms.

Location and Setting

The Evansdale Residential Complex (ERC), Towers complex was chosen because of the similarities between all four buildings. Each tower has nine floors assigned to housing residents and each holds between 450-525 residents at maximum occupancy. Brooke tower is the only tower with an additional floor assigned for residential housing. Each floor has the same number of rooms, same layout, and same square footage. The floors consist of one single-occupant room, twenty four double-occupant rooms, and one triple-occupant room. It was assumed that all rooms were filled to maximum occupancy. Each room consisted of one room light, a closet light for each occupant of the room, a lamp with various light bulbs for each occupant's desk, and an average of four outlets per occupant. The Towers are all located within a one block radius of one another. They are designed to house undergraduate students and residential assistants.

Participants

Participants of this study included undergraduate incoming freshman and their residential assistants of the Towers complex. The population consists of a diversity of different races, gender, and educational interests. The population was split into two groups based on living arrangements which determined meter connection. The towers had previously been split up into two groups and assigned to a meter prior to this study. Each group consisted of 900-1050 participants. Residents living in Brooke and Braxton tower are connected to one meter, while residents of Lyon and Bennett tower are connected to another meter. Although dormitories were randomly assigned either control or experimental, the only stipulation for their assignment was that Brooke and Braxton had to be grouped together, and Lyon and Bennett had to be grouped together due to previous meter connection.

Education and Outreach

The educational mechanism consisted of small and large scale posters, energy conservation brochures, three class seminars on energy education, and a monthly educational booth set up outside of the dining hall. One large poster measuring twenty four inches by thirty six inches contained five tips to reduce energy consumption, and one small poster measuring eleven by seventeen inches explained the amount of electricity one sixty watt light bulb uses in an hour. The posters were placed on every residential housing floor of Brooke and Braxton Tower.

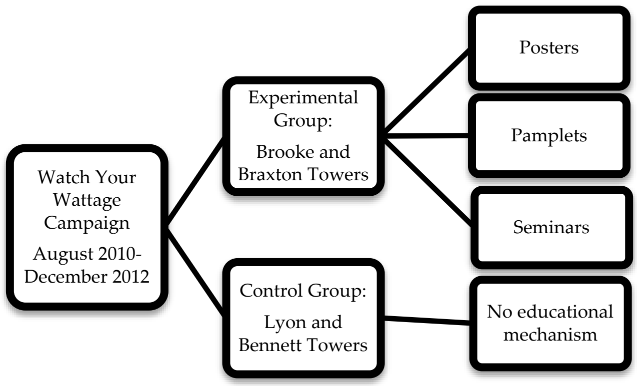
The educational seminars were held during the month of October. A total of three seminars were held at the Braxton Residential Faculty Leader's home located behind the dormitories. The residents were informed of the seminars at least one week in advance via email and signage throughout Brooke and Braxton Halls. The seminars included pizza and a movie related to energy. Attendance to all educational seminars was completely voluntary. At the end of each dinner the residents remained at the house for a short education presentation conducted by the author. The presentation included facts about energy savings and other sustainable initiatives going on around campus.

A booth was set up outside of the Towers dining hall to allow Brooke and Braxton residents to obtain information pamphlets on energy conservation once a month from August to November. The pamphlets were double sided and focused on electronics, lighting, and laundry energy conservation.

Two-group Experimental Design

A post-test only, two-group experimental design was used to determine if energy education had an effect on electricity consumption reduction. Traditionally an experimental design consists of a control group and an experimental or treatment group. The treatment group, the experimental group receives treatment (X), while the control group does not receive the treatment (Tochim, 2006). In this particular study, the treatment (X) was an energy educational mechanism. A diagram explaining the experimental design is listed below.

Figure 2. Two-Group Experimental Design



With a two-group experimental design, a pre-test is not necessary due to the random assignment factor. Using this design helps to determine if the two groups are different after the treatment has occurred. This type of design does not use repeated measurement, and is a good decision for an experiment of this caliber because it requires random assignment and is more likely to utilize persons who would be aware of which group they fit into (Tochim, 2006). This type of approach is excellent for interpreting cause-effect relationships, such as determining if an energy educational mechanism has an effect on behavior modification resulting in a decrease in consumption.

Data Analysis

Data sources for this research were the meter readings which were used to analyze the differences in consumption. Lyon and Bennett Tower were compared with Brooke and Braxton to determine the difference between how many kilowatts per hour of electricity were consumed each month. Monthly electricity consumption for the Towers was recorded and inserted into an excel spreadsheet. The electricity consumption was reported in total kilowatt hours used per month. September was the earliest month within the study that the team was able to access. The chart below explains this data configuration.

Table 1. Electricity Consumption Measured in kilowatt hours for the Fall Semester of 2012

Date	Usage (kWh) Brooke/Braxton	Month to Month	Monthly Consumption (kWh)
9/5/2012	12,154,811	9/5/2012-10/4/2012	150,133
10/4/2012	12,304,944	10/4/2012-11/1/2012	153,695
11/1/2012	12,458,639	11/1/2012-12/1/2012	166,801
12/1/2012	12,625,440		
Date	**Usage (kWh) Lyon/Bennett**	**Month to Month**	**Monthly Consumption (kWh)**
9/5/2012	11,931,435	9/5/2012-10/4/2012	205,785
10/4/2012	12,137,220	10/4/2012-11/1/2012	191,721
11/1/2012	12,328,941	11/1/2012-12/1/2012	171,980

12/1/2012	12,500,921		

Due to the limitations within our data collection, we were only able to collect data from September through the end of November. Once the data were broken down into monthly usage, the data listed below was used to calculate differences in consumption between the control and experimental dormitories in order to determine if the educational mechanism created a decrease in total kilowatt hours (kWh) consumed. The differences in usage for the two groups were found by subtracting the experimental groups' usage from the control groups' usage. The difference-in-differences were found by subtracting the differences in consumption from one month to the next on the control group from the differences in consumption from one month to the next of the experimental group. The following equation demonstrates the difference-in-difference measurement.

$$(E_2 - E_1) - (C_2 - C_1), \quad (1)$$

where E_2 denotes the consumption (kWh) of the experimental group in time period two, E_1 is the consumption in kWh of the experimental group in time period one, C_2 is the consumption in kWh of the control group in time period two, and C_1 is the consumption in kWh for the control group in time period one. This calculation will be discussed in greater detail in Table 2 located in the Results section.

Results

Results from the difference-in-differences analysis revealed a difference in consumption between the experimental dormitories and the control dormitories. Although the differences were not analogous from month to month, the data analysis reveals that the differences do still exist. The differences in consumption between the experimental and control dormitories are fairly substantial at first, but then decline as the semester progresses. Potential reasons behind the decreasing differences between the experimental and control dormitories will be further discussed in the Discussion section. The results are listed below in Table 2.

Table 2. Monthly Electricity Consumption Comparison between the Control and Experimental Dormitories: Differences in Differences

Date	Brooke and Braxton Tower Usage (kWh)	Lyon and Bennett Tower Usage (kWh)	Differences in Usage (kWh)	Differences in Differences
9/5/12-10/4/12	150,133	205,785	55,652	17,626
10/4/12-11/1/12	153,695	191,721	38,026	32,847
11/1/12-12/1/12	166,801	171,980	5,179	

Once the differences in total kilowatt hours consumed between the control and experimental dormitories were calculated, we examined the percentage difference in consumption. The values were calculated by subtracting the consumption of the control group from that of the experimental group, then dividing that value by the control groups' consumption. That was then multiplied by 100 to determine percentage difference. This metric is calculated as follows.

$$\frac{Experimental - Control}{Control} \times 100 \tag{2}$$

The results from the percentage differences analysis are listed below in Table 3.

Table 3. Percentage Differences in Consumption

Date	Brooke and Braxton Towers Usage (kWh): Experimental Group	Lyon and Bennett Tower Usage (kWh): Control Group	% Differences in Consumption
9/5/2012-10/4/2012	150,133	205,785	-27.04
10/4/2012-11/1/2012	153,695	191,721	-19.83
11/1/2012-12/1/2012	166,801	171,980	-3.01

Discussion

Difference-in-differences analysis is a type of data analysis used to compare the effects of a treatment by comparing the differences between the outcomes of an experimental group with a control group. In order to complete this type of analysis it is assumed that the control and experimental groups will be the same excluding the treatment variable. Although results of this type of analysis are justifiable, the design of the experiment is often very difficult because it is hard to determine if the results of a difference-in-differences analysis are a result of the treatment or some other omitted variable. Although the control and experimental groups may not be one hundred percent comparable, the differences-in-differences analysis is used to determine that the observed differences are a result of the treatment. Or in other words, in absence of the treatment the observed differences would not exist.

The majority of difference-in-differences analyses compares the differences between the control and experimental group pre-treatment, and then does a comparison of the differences post-treatment. However using a post-test only analysis is also an option. That type of estimate assumes the differences observed are only a result of the treatment. The percentage difference in consumption analysis was also used for this research as a way to compare the two groups' usage.

This research included a large group of participants, which made it difficult to convince individual consumers to disregard their own self-interest and modify their own energy consumption behavior in order to benefit their residence hall. Participants were analyzed by which dorm they lived in and targeted as a group. This research also required residents of Brooke and Braxton Tower to modify their behavior in order to be more energy efficient. The behaviors the participants were expected to perform included turning off light fixtures, unplugging electronics, turning off computers and printers when not in use, and using low or not heat settings for washers and driers, etc.

As this research attempted to modify behavior it was limited on the ability to target individual resident behavior and to link behavior to already existing tasks. The majority of the participants were incoming freshman at West Virginia University, although some included second and third year residents because residential assistants were also participants of this study. The residents were targeted from the beginning of September to the end of November, when they were also being exposed to new surroundings, and a new location. For this reason there were extremely limited ways to connect their new behavior with previous behavior associated with the university. This research's limited ability to target individual resident behavior made it difficult to create behavior modification. Due to solicitation policies within the dorms the research team was not permitted to enter the residential floors of the halls. Residents could only be exposed to education at their own interest.

Other assumptions for the decline in differences in consumption as the month progressed throughout the semester were based on changes in climate, a lack of motivation for student involvement in educational activities, and the price elasticity of demand. As the climate became cooler, air conditioning in the buildings were switched off and replaced with the heating system. Heating for the dormitories is provided by steam and uniformly set throughout each dorm. Residents do not have the option to set their room temperatures to their preferred temperature in the winter, but do have to option to do so in the summer by utilizing their room air conditioners. Education involving the use of air conditioners was excluded from our educational program because the majority of the air conditioners within the dormitories were not properly functioning previous to this study.

Residents' motivation during the length of study might have also contributed to the decline in differences in consumption. Residents of the experimental group had little desire to become "better and better" at conservation because they were not shown the goal they were working towards. That is, no visual feedback was put in place in order to keep student motivated. Their greater differences in consumption at the beginning of the study could have been due to the fact that the posters were new and stimulated interest. However, as the semester progressed and the posters become just another object hanging in the halls and their motivation to conserve could have possibly declined.

Another assumption for the decline in differences in consumption between the control and experimental dorm could have been the response of residents based on price elasticity of demand. Residents of the dormitories at West Virginia University pay a one-time price. They pay room and board in a lump sum fee before they are permitted to move in. This does not allow for changes in quantity to be associated with changes in price. In other words, the residents are never exposed to any electricity bills while living in the dorms, so they have no monetary incentive to save. They would only be saving the university money, and the effects of the savings would not take place until they have vacated the dorms for second-year housing.

The only residential behavior that could be affected by changes in price as a result of changes in demand are residents who choose to live in the dormitories during multiple years at the university. Although the one year residents would not modify their quantity consumed as a result of changes in price, the educational mechanism provided within this research study could have an effect on electricity consumed in apartment setting where utilities are not included. To further this research, an analysis of electricity consumption within an apartment complex could be conducted to see if education has an effect on energy conservation when price acts as a factor.

Conclusion

The use of a two-group experimental design can pose many challenges when trying to explain applications to economic theory, but if it designed and outlined correctly it can offer insights underlying economic decisions. It allows economists to understand consumers the way chemists understand elements. The only difference is a chemist can sometimes have more control over its variables used in an experiment. An experiment could be perfectly arranged, but there are still some variables that can never be controlled or adequately predicted.

By attempting to engage an entire dormitory in energy education, this experimental design faced many challenges but also tackled many hurdles. This research utilized one of the largest laboratories on campus and created a vision through future research. Based on the findings from Bekker (2010), this research will continue by incorporating visual feed-back and incentives paired with visual prompts. It is believed, based on their research, this will result in the highest reductions in consumption over a short period of time.

In conclusion to our findings, this team will further the development of this project by also creating a campus-wide initiative for sustainability. Consistent with the paradigm of the Office of Sustainability we will spread the idea if sustainability through our environmental stewards program and through various other programs around campus. Sustainability can be seen as a domino effect which incorporates economics, the environment, and various social aspects. As research is further developed it will incorporate the three tiers of sustainability to create the most effective program on campus.

Limitations and Recommendations

Limitations of this study included limited participant interest, time constraints, data collection constraints, and budget constraints**.** This research was conducted during the fall semester (September through November), and this time period proved to be one of the strongest limitations to this study. Because this research was only conducted from the beginning of September to the end of November, the analysis of the findings proved to be difficult due to a minimized number of data points. Although the posters and pamphlets were useful for this study, budget constraints created issues for furthering the development of the educational mechanism.

Recommendations for this research include incorporation of visual feedback and incentives in order to encourage participation, increase in the time of study to one full academic year rather than a semester, and more precise intervals of data collection in order to run a regression analysis to statistically understand the findings. This research has the ability to provide a stepping stone for further development of sustainability at West Virginia University within the

Office of Sustainability. As this research continues, development of a mechanism that incorporates visual feedback, prompts, and incentives is being discussed.

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