A Study of Student Energy Use at Smith College

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ABSTRACT

An increasing number of institutions are concerned about climate change, and Smith College is among them in working to reduce its impact. Student energy use comprises a significant part of the 44% of purchased electricity used by the college. Our study aims to measure student energy use, compare student energy use based on location, size of houses, and class year, and identify major energy consuming appliances. Through conducting student surveys, analyzing data, and researching successful initiatives to change student energy use behavior, I gained a deeper understanding of the highest energy consuming items and highest energy consuming sections of campus. This information is crucial for the College to make plans to increase energy efficiency and conservation among students. Houses with 20 residents or less and houses with 41 o 60 residents use the least amount of energy, while houses with 30-50 residents and 90 residents and above use the most amount of energy. Students living in Lower and Upper Elm use significantly more energy than students living elsewhere on campus. Among class years, there is no statistically significant difference in energy use behavior between first-years and seniors. Gathering this information has allowed us to better understand student energy behavior and propose recommendations to the college to increase energy efficiency and conservation on campus, with the larger goal of achieving the Climate Action Plan to neutralize Smith College's greenhouse gas emissions.

INTRODUCTION

With global climate change gradually becoming a public concern, governments, businesses, and individuals alike are looking for ways to reduce their impacts on the environment.

The carbon footprint, a measurement of the amount of greenhouse gases released into the atmosphere as a result of one's actions, serves as a useful indicator of a party's impact on the environment (Minx and Wiedmann, 2007). Greenhouse, or heat-trapping, gases include water, carbon dioxide, methane, nitrogen oxide, nitrogen dioxide, and hydrofluorocarbons, among others. These gases are released in the atmosphere at low concentrations to maintain the Earth's climate and support life, but as human technologies become increasingly complex and used on a larger scale, the levels of greenhouse gases have increased as well. This has resulted in global temperatures rise, leading to severe climate changes worldwide. Carbon dioxide is among the weakest of the greenhouse gases, increasing temperatures only slightly relative to others, but is by far the most common. Carbon footprints are generally measured in carbon equivalents or simply in metric tons of carbon dioxide. When analyzed closely, a carbon footprint can provide useful information regarding our most wasteful behaviors and possible areas of improvement.

Having signed the American College and University Presidents Climate Commitment in 2007, Smith College has committed itself to neutralize its greenhouse gas emissions. Student groups in 2004 and 2007 calculated Smith's carbon footprint in metric tons equivalent to carbon dioxide ($MTeCO_2$), and according to the Climate Commitment, measurements must be updated every two years (Weisbord, 2008). The College's emissions were broken down into three categories: stationary sources, purchased electricity, and "everything else." Stationary sources include combustion of fuels from sources owned or controlled by the college, losses from refrigeration, and gases such as methane produced by farm animals; purchased electricity includes any emissions released during production of electricity used by the college; and the third scope includes emissions produced by commutes to and from the college, college-related air travel, waste disposal, and anything else not encompassed by the first two scopes. Smith

College's total footprint in 2007 measured up to 35,030 MTeCO2, 50% of which came from category 1, stationary sources, and 44% of which came from category 2, purchased electricity (Weisbord, 2008).

Some steps have already been made by the college to reduce emissions from category 1, such as the installation of a combustion turbine, so we plan to focus on category 2. Dano Weisbord is in the process of developing a climate action plan for the college to achieve carbon neutrality. His first proposed step is efficiency, followed by renewable power sources and fuels, and then followed by carbon offsets (Weisbord, 2008). In our project, we chose to focus on measurement because it provides the basis for institutional action. The specific objectives are to measure student energy use, make comparisons based on location, size of house, and class year, and identify major energy consuming appliances and propose a plan to increase energy efficiency on campus.

METHODOLOGY

Student Survey

Our project was an extension of engineering student Krysten Hall, who conducted surveys on student energy use in Ziskind House to determine if photovoltaic would be a viable option for that house. We consulted with Professor Denise McKay about this project, and used Krysten's survey questions as a reference point in designing our own survey. We also obtained some of the average wattage information for the various appliances from Krysten. A copy of the survey is in **Appendix 1**.

Originally, my teammate and I had planned to send a campus-wide survey through an online website, but found that to be an unfeasible plan. We consulted with Professor David Smith, who recommended us to sample a percentage of student population, rather than attempt to sample the whole campus. In order to fulfill our second objective of comparing student energy use between house size and location on campus, Britni and I chose to sample houses based on those criterion. For house size, we researched the different capacities of each house, and divided houses into categories of small, medium, and large (Living at Smith, 2009). A small house was defined as a capacity of 18-40 residents, a medium house was defined as a capacity of 41-60 residents, and a large house was defined as a capacity of 61-105 residents. We chose to sample two houses from each size category. The small houses included Hopkins (18 residents) and Duckett (37 residents), the medium houses included Chase (57 residents) and Hubbard (53 residents), and the large houses included Cutter (80 residents) and Wilson (102 residents).

In our sample size for house location on campus, we separated the houses in five categories as defined by the college: Quad, Lower Elm, Upper Elm, Green Street, and Center Campus. For each housing location, we chose one house as the representative sample for that location. Morrow represented the Quad, Baldwin represented Lower Elm, Talbot represented Upper Elm, Morris represented Green Street, and Cutter represented Center Campus. The house capacities for all five houses were large houses in the range of 68-84 residents.

After deciding which houses we would sample, we contacted the house leader (House President, Head Resident, or House Community Advisor) of each house and distributed surveys to each resident by posting it on their door. We gave students a week and a half to complete the survey and return it to a box by their house leader’s door. To encourage students to complete the survey, we included a raffle of two $25 gift certificates. To protect the anonymity of survey participants, students were able to write their name at the bottom of the survey, and tear the ends off to be entered into the survey.

We collected all the completed surveys and entered the responses into an Excel spreadsheet. In our spreadsheet, we noted the survey respondent's house, size, location of house on campus, class year, and the type and number of appliances they own, and the hours they use it. We also took note if the appliance was energy efficient, or if a computer was on sleep mode or energy save mode. To determine the average wattage for each appliance, we either consulted facilities management or researched the average wattage on websites, and if there was a range in wattage, we chose the higher value (Saving Electricity, 2009). After finding the average wattage of each appliance, I calculated the weekly kWh of each appliance by multiplying the [(# of X appliance) (# of hours used) (average wattage of X appliance) (7 days)]/ 1,000 watts to find the weekly kWh. For example, to calculate the weekly kWh for a desk lamp, I performed the following calculation: [(1 desk lamp) (3 hours) (60 watts) (7 days)]/1,000 watts = 1.26 kWh/week. We calculated the weekly kWh for all the appliances used by each student.

There were several assumptions we needed to make as we were reading and recording our survey responses. In some survey responses, we encountered ranges in hours of use for our listed items. For example, a computer may be listed as in use for 10-12 hours. In cases with a range, we chose the higher value, and in this case, it would be 12 hours. While reading the responses, we had to make assumptions about if the appliance was plugged in or in use. For the desktop and laptop, we assumed it was on, unless stated otherwise. For example, one survey response noted her laptop was turned on for 24 hours, but on sleep mode for 10 hours. Therefore we calculated the laptop to be turned on for 14 hours and on sleep mode for 10 hours.

For cell phones, if the value was 16 hours or less, we assumed the phone and charger were plugged in, and if the value was 16 hours or more, we assumed only the charger was plugged in, unless stated otherwise. For the washing machine, we chose a kWh value for hot water, assuming hot water is used for every load, since our assumptions include taking the higher value. For the laundry washers and dryer, we assumed it was in use for 40 minutes and 60 minutes, respectively, and these values go into our calculation of amount of energy consumed. For the printer, if the value was 2 hours or less, we assumed the printer was in use, and if the value was 2 hours or more, we assumed the printer to be on standby, unless stated otherwise. For all the other appliances, we assumed they were turned on and in use as listed.

Appendix 2 provides the wattage information of the electrical appliances used by students. Using this information, we used Excel to calculate the total consumption (kWh/week) by each student, the total energy consumption by each appliance, the average per capita consumption by each appliance, and the percentage of total sample consumption used by each appliance.

Statistical Analysis

We used Minitab 15 to test our second objective of student energy use between house size, location on campus, and class year. We set our first null hypothesis to be per capita consumption does not differ with house capacity and our alternative hypothesis to be per capita consumption does differ with house capacity. The significance level was set at $p \leq 0.05$, to ensure a 95% confidence in our results. The independent variable would be house capacity and the dependent variable would be per capita energy consumption. For the house capacity, I used the regression and f-test functions of Minitab to see if there is a relationship between per capita energy consumption and house capacity. We tested linear, quadratic, and cubic regressions.

In the second study, we tried to test if consumption patterns differ by housing location. We set the null hypothesis to be per capita consumption does not differ by location and the alternative hypothesis to be per capita consumption does differ by location. We conducted one sided, two-sample t-tests, with the following groups as independent variables: Center Campus, the Quad, Green Street, Lower Elm, Upper Elm, and the dependent variable being per capita energy consumption. Through Minitab 15, we compared all of the different areas on campus with each other.

In the third study, we tested if energy consumption depends on class year. We set the null hypothesis to be per capita energy consumption does not vary with class year, and the alternative hypothesis to be per capita energy consumption does vary with class year. The independent variable was class year and the dependent variable was per capita energy consumption. Again, we tested linear, quadratic, and cubic regressions.

In our fourth study, we conducted a visual comparison of energy consumption and confirmed our conclusions by testing some of the comparisons using the one sided, two-sample t-tests. We set the null hypothesis to be appliances do not differ from one another in per capita consumption, and the alternative hypothesis to be appliances do differ from one another in per capita consumption.

RESULTS

Student Surveys

We distributed 657 surveys to ten houses and received 210 surveys, with an overall response rate of 32%. **Appendix 3** shows the breakdown of survey response for each house.

Consumption by House Capacity

Student energy use varies significantly with house capacity (Appendix 4, Figure 1). The p-value of the cubic regression is 0.033, f-value is 29.92, and n-value is 108. Therefore we reject the null hypothesis that consumption does not differ with capacity.

Consumption by House Location

Our first null hypothesis is that Lower Elm uses the same amount of energy as Center Campus, Green Street, and the Quad. Our alternative hypothesis is that Lower Elm uses more energy than Center Campus, Green Street, and the Quad. The p-values for this test were between 0.004 and 0.006, rejecting the null hypothesis that Lower Elm uses the same amount of energy as Center Campus, Green Street, and the Quad.

Our second null hypothesis is that Upper Elm uses the same amount of energy as Center Campus, Green Street, and the Quad. Our alternative hypothesis is that Upper Elm uses more energy than Center Campus, Green Street, and the Quad. The p-values for this test were less than 0.001, rejecting the null hypothesis that Upper Elm uses the same amount of energy as Center Campus, Green Street, and the Quad.

Since both Lower Elm and Upper Elm use more energy than Center Campus, Green Street, and the Quad, our third null hypothesis is that Lower Elm and Upper Elm use the same amount of energy, and the alternative hypothesis is that Lower Elm and Upper Elm use different amount of energy. The p-value for this test was 0.555, indicating that we must fail to reject the null hypothesis.

The fourth null hypothesis is that Center Campus, Green Street, and the Quad all use the same amount of energy, and the alternative hypothesis is that Center Campus, Green Street, and the Quad use different amounts of energy. The p-values were between 0.167 and 0.814, indicating that we fail to reject the null hypothesis.   The n-value is 133. (Appendix 4, Figure 2 and Figure 3) provides a graphical comparison of energy consumption by house locations.

Consumption by Class Year

Using the regression and f-tests, the results are not statistically significant and we fail to reject the null hypothesis that per capita energy consumption does not differ by class year. The p-value is 0.172, f-value is 4.36, and the n-value is 197, (Appendix 4, Figure 4).

Consumption by Appliances

There are 4 tiers of energy consumption. The highest consumers are washing machines and fridges. The second highest are coffee makers, hair dryers, laptops, and drying machines. The third tier includes desk lamps, floor lamps, mounted lights, TVs, fans, alarm clocks, and stereos. The last tier (the lowest consumers) includes desktops, cell phones, DVD players, electric kettles, humidifiers, and printers. (Appendix 4, Figure 5) shows the total consumption by each appliance (kWh/week). The highest energy consuming appliances include laundry washer using 1,172 kWh/week, fridge using 1,070 kWh/week, and coffee maker using 893 kWh/week. (Appendix 4, Figure 6) shows the per capita energy consumption by each appliance, with washers using 5.58 kWh/week, fridges using 5.13 kWh/week, and coffee makers using 4.29kWh/week. (Appendix 4, Table 1) charts the most commonly used appliances. Laundry washing machines comprise 18.24% of total energy consumed, fridges comprise 16.81% of total energy consumed, and coffee makers comprise 13.89% of energy consumed.

DISCUSSION

Size of House

Below about 35 residents and above about 75 residents, consumption is proportional to house capacity. Between 35 and 75, consumption is inversely proportional to house size. Optimal house capacities for low consumption are below 20 or between 60 and 80 residents. House capacities with high consumption are between 30 and 50 residents and above 90 residents, (Appendix 4, Figure 1). Therefore it is true that there is a relationship between energy consumption and house capacity.

The only house in our survey that is below 20 residents is Hopkins House. As a resident of Hopkins House, I can share information about the nature of the house and hypothesize why this house is a low energy consuming house. Hopkins is a co-op house, with a full, shared kitchen and a predominantly environmentally conscious population. Only one or two residents out of the eighteen residents have a personal fridge, since there is a communal and personal fridge in the kitchen for everyone to use. There is also a communal coffee maker in the kitchen. Additionally, the house has several drying racks for students to hang their washed clothes, which is often in use. A possible hypothesis that students in the future can test is if a smaller house community makes residents more accountable to each other. This may be the case for Hopkins House. For example, during the Million Monitor Drive, a campaign to put student computers on energy save mode, Hopkins House placed among the top three houses with the highest participation rate. Many of the residents are involved in environment-related organizations, such as Smith College Community Garden, Green Team, and the Bike Kitchen, and get their vegetables from a Community Shared Agriculture in the fall. Overall, the residents have a stronger tie to the environment than most other residents in other houses on campus.

Our study does not explain energy consumption behavior, so I cannot explain why houses in our sample (Chase and Cutter) with 60-80 residents are low energy consumers, and houses with 30-50 residents and 90 residents and above are high energy consumers. We recommend that future EVS 300 students conduct surveys on student energy consciousness, student involvement in environmental student organizations, and the role of recycling representatives in each house.

Location of House

Students living in Upper and Lower Elm use more energy per capita than those living in Center Campus, Green Street, and The Quad, (Appendix 4, Figure 2). The houses with the highest per capita energy consumption are Baldwin (134.65 kWh/week), Wilson (120.44 kWh/week), and Talbot (108.30 kWh/week). The houses with the lowest per capita energy consumption are Hopkins (23.50 kWh/week), Cutter (28.55 kWh/week), and Chase (29.99 kWh/week), (Appendix 4, Figure 3).

Energy consumption patterns differ among different parts of campus because the residents may be lacking in environmental awareness and education in comparison with other houses. In the Quad, our representative house was Morrow, one of the most environmentally active houses on campus. Morrow House has a sustainability group to encourage their fellow residents to turn off lights, turn down the heat, recycle, and raise environmental awareness. Morrow House Council decided to use their house funds to change their shower heads to lower flow models. Additionally, among the houses with low energy consumption (Center Campus-Hopkins, Green Street-Morris, and the Quad-Morrow), all of these houses have a kitchen or dining hall. However, among the houses with high energy consumption (Upper Elm-Talbot, Lower Elm-Baldwin), both houses do not have kitchens or dining halls. This lack of communal kitchen area may explain why our sample houses on Upper and Lower Elm have higher energy consumption patterns than our sample houses in Center Campus, Green Street, and the Quad.

Class Year

Consumption does not vary with class year. While the line on the graph looks like there is a relationship between consumption and class year, the line should be flat, indicating no relationship between consumption and class year. We know this to be true because the p-value is 0.172, which is too high to show a relationship between consumption and class year.

Energy consumption between different class years is not statistically significant. This signifies that student's environmental behavior does not change very much during their time at Smith. However, if we had a larger sample size, the results may have been statistically significant. Additionally, since our p-value is 0.172, we still have a fairly high certainty rate, though it is not statistically significant.

Major Energy Consuming Appliances

While only 17 out of 210 students have coffee makers, coffee makers still rank high in its per capita energy consumption because of its high wattage. Laptops also rank high among the top energy consuming appliances, not because it necessarily has a high wattage, but because most students have a laptop and use it frequently. **Appendix 4, Figure 7** shows the Percentage of Total Sample Consumption Used by Each Appliance

The top energy consuming appliances are laundry washers, fridges, and coffee makers because their wattage and/or frequency of use are high. However, the laundry washer wattage may be overestimated because the number we obtained from a website assumes one is using hot water for every load, which may not be the case. Dano Weisbord, the Smith College Sustainability Coordinator, suggested a more reasonable assumption that 33% of loads are run at "hot", 33% at "warm", and 33% at "cold." However, when researching the wattage information of various appliances, we chose values at the top end of the range, and tried to maintain consistency among our measurements.

According to a study conducted at Tulane University, the top three energy users in a college dorm room are: lights, computer, and refrigerator (Smith College Green Team, 2009). This is assuming there are no Energy Star appliances used. It is unclear how the students measured the top three energy users. On Amherst College's Green Amherst webpage, the top three energy users in a college dorm room are listed as refrigerator, computer, and light (Green Amherst, 2009). One of the top dorm room appliances in our survey included the coffee maker, which isn't in these the Tulane University and Amherst College findings because the wattage value we chose may have been too high, or their studies may not have included coffee maker as an appliance commonly found in a dorm room. Regardless of the specific rankings of these appliances, it is important to focus our energy on reducing consumption of all appliances, especially the top three energy consuming appliances where students can take pro-active steps to offset greenhouse gas emissions.

RECOMMENDATIONS

Steps the College Administration Can Take

The College and environmental groups on campus should vigorously promote Energy Star appliances during Central Check In by emphasizing the economic and environmental benefits of these products. According to a study conducted by Tulane University, a dorm room that only uses Energy Star appliances as compared to a dorm room that uses average appliances and lighting will experience a 50% greenhouse pollution reduction and a 50% reduction in utility bill (Energy Smart Shopping, 2009). The Energy Star Campaign has promoted a vigorous campaign to encourage consumers to change incandescent lights to compact fluorescent lights, put computers to sleep when it is idle, and purchasing Energy Star model refrigerators (assuming you must have a fridge, or you are not sharing a fridge with someone else). According to the Smith College Green Team “Getting Your Green On” pamphlet, if all 2,600 students made these changes, we could save $160,000 and offset 1,200 tons of greenhouse gas emissions a year.

To encourage students to purchase Energy Star products, the College should use a special marketing program to offer a small rebate to students who purchase Energy Star fridges. The College should also look into renting Energy Star refrigerators out to students, since most students will only use these small refrigerators during their college years, and then have it tossed out. At Central Check In and at the Campus Store, Energy Star appliances should replace less efficient ones. In the houses, the College should replace fridges that are not energy efficient to Energy Star refrigerators.

In terms of energy conservation, the College should provide the Green Team and Facilities Management with money to install smart meters to save the College electricity and money. Smart meters can track energy use daily, hourly, monthly, and even instantaneously.

The advanced meters can analyze each building's usage and the company of these meters even offer tips on how to cut back. The meters also allow houses to compare their energy usage with other houses on campus. Smart meters have changed the way consumers look at energy use, and the product website teaches people how to save power (Shogran, 2009). Homes with smart meters installed used about 15 percent less energy than they did before the meters were installed (Manwarren, 2009).

Education

The Earth Representatives in the houses should start a campaign to spread awareness of the amount of wattage various appliances consume, and easy steps each of us can take to reduce our electrical load. Earth representatives can do this through posters and educational house teas. Another important educational tool is to develop a pre-orientation program focusing on sustainability at Smith. Erlij (2007) has developed an excellent framework for how a sustainability pre-orientation program at Smith should look like. She states the principle goals of a sustainability pre-orientation program should be education, traceability, transparency, and social action. This pre-orientation program would educate students on various sustainability issues, including energy efficiency and conservation, and give them the opportunity to interact with staff members from Facilities Managements and Dining Services to get involved in sustainability at Smith.

Student Involvement and House Competitions

Currently, the Million Monitor Drive, a campaign to reduce energy consumption by turning personal computers onto sleep mode when not in use, and Earth Hour are the only two major house competitions to reduce energy consumption. I propose that the House Presidents Association Chair institute several new competitions to reduce energy use. One possible competition is to encourage each house to reduce its energy consumption as much as possible relative to the same month the previous year. The winner will be the one with the greatest reduction in energy use and will gain a prize. This type of competition can be replicated to include different academic buildings. Another idea that Oberlin College has adopted is holding an Ecolympics, a month of energy and waste reduction, and environmental education contest held among houses (2009 Ecolympics, 2009). With a strong sense of house community and student activism, Smith students are uniquely positioned to change their energy consumption behavior.

Appendix 1: Survey

What class year are you? ________________________

	How many do you have?	How many hours is it on per day on average?	Other Information Examples: energy efficient lightbulbs, computer on energy save mode, size of fridge, etc.
Desk Lamp			
Floor Lamp			
Wall/Ceiling, Mounted Light			
Desktop			
Laptop			
Phone Charger			
Television			
Hair Dryer			
Fridge			

How many loads of laundry do you wash each week? ___________
How many loads of laundry do you dry each week? ___________

Please list on the back any additional electrical devices (like printer, alarm clock iron, coffee maker, stereo, etc.) and how many hours they are in use per day on average.

Please remove this slip and return it to the box to be entered in the raffle.

e-mail:

Appendix 2: Wattage of Appliances

Appliance	Wattage
Regular Lightbulb (Table Lamp, Floor Lamp)	60 watts
Energy Efficient Lightbulb	15 watts
Mounted Lightbulb	26 watts
Desktop (Awake)	74 watts
Desktop (Asleep)	21 watts
Laptop (Awake)	44.28 watts
Laptop (Asleep)	4.42 watts
Cell phone plugged in wall	0.14 watts
Cell phone charging	2.24 watts
Television	110 watts
Hairdryer	1875 watts
Mini-Fridge (3.5 cubic feet)	6.5 kWh/week
Mini-Fridge (mini-fridge/microwave)	5.58 kWh/week
Mini-Fridge (Smith College Energy Star)	5.09 kWh/week
Washer	7,860 watts
Dryer	4,400 watts
Fan	250 watts
Coffee Maker	1200 watts
Alarm Clock	12 watts
Stereo	400 watts
DVD player	25 watts
Electric Kettle	1500 watts

Humidifier	80 watts
Printer (on)	15 watts
Printer (standby)	2 watts

Appendix 3: Breakdown of Survey Response

House	Capacity	Sample Size	Response Rate
Baldwin	77	17	22%
Chase	57	19	33%
Cutter	81	31	38%
Duckett	37	8	22%
Hopkins	18	10	56%
Hubbard	53	21	40%
Morris	68	15	22%
Morrow	84	42	50%
Talbot	80	28	35%
Wilson	102	19	19%

Appendix 4: Student Energy Consumption

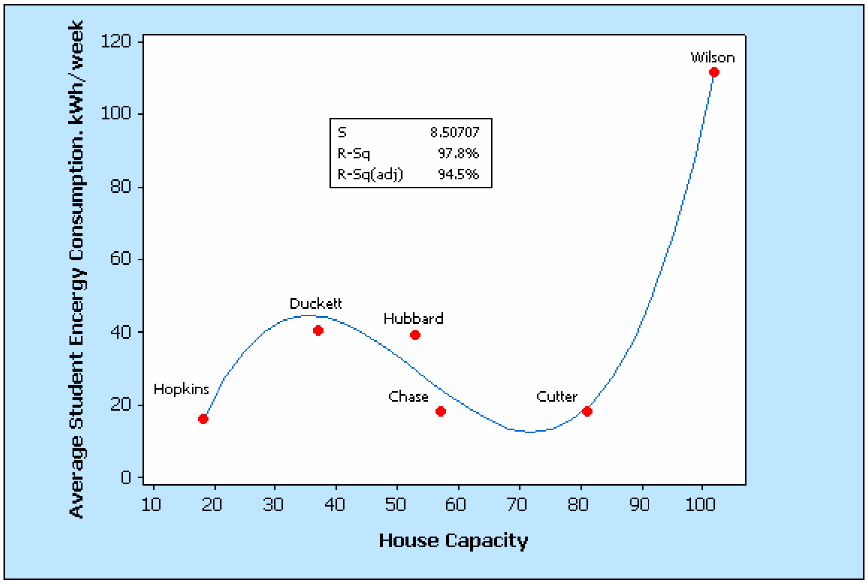

Figure 1: Consumption by House Capacity

P-value=0.03, f-value= 29.92, n-value=108

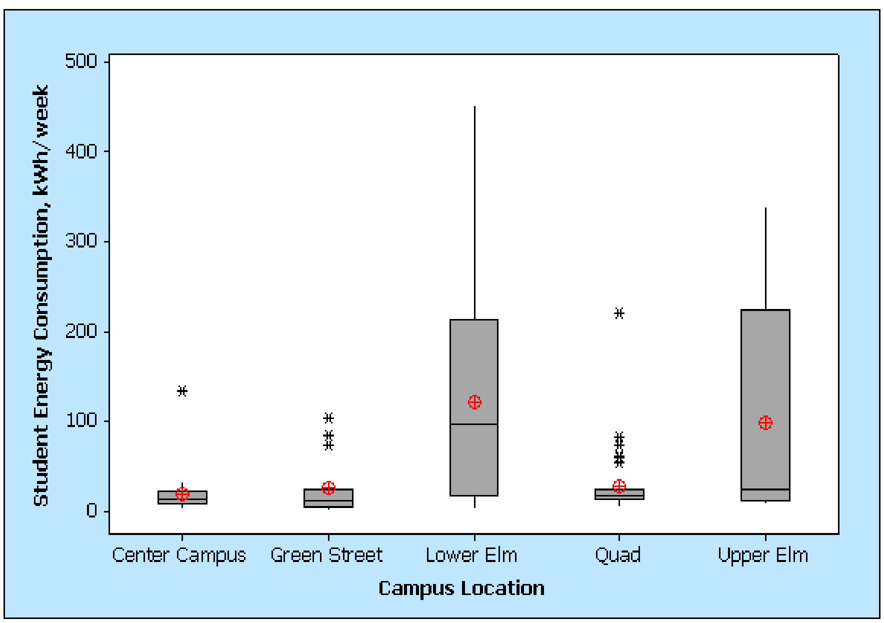

Figure 2: Consumption by House Location.

The red dots inside the bars represent the median energy consumption (kWh/week), the bars represent standard deviation, and the black stars represent data that is out of the range.

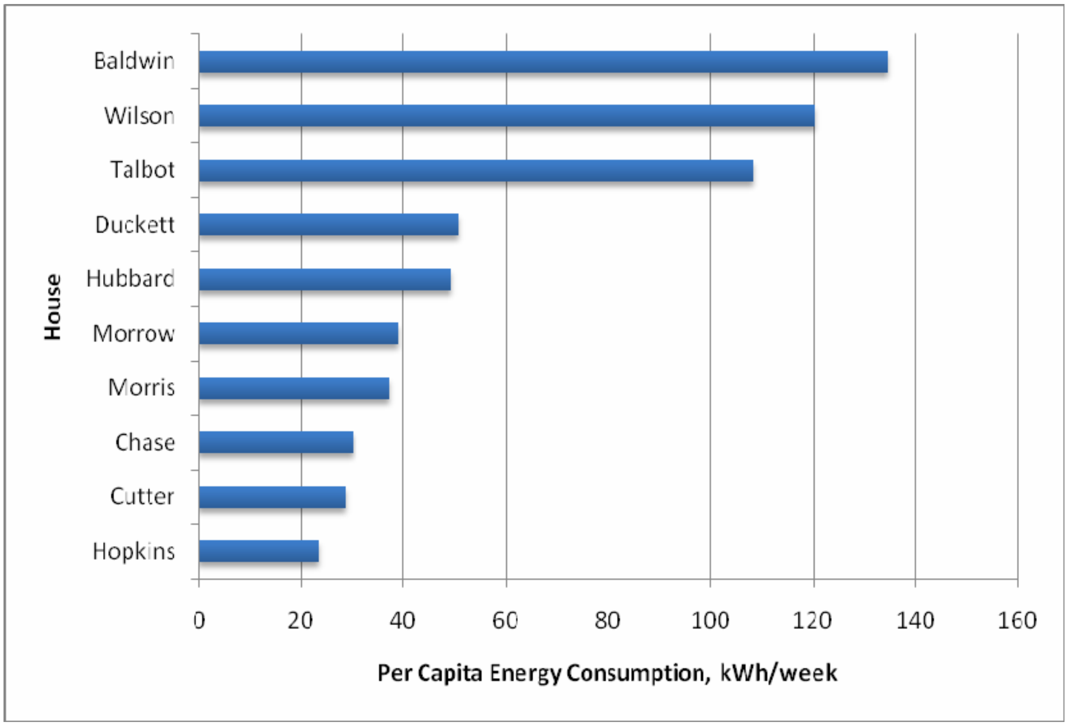

Figure 3: Per Capita Energy Consumption (kWh/week) by House

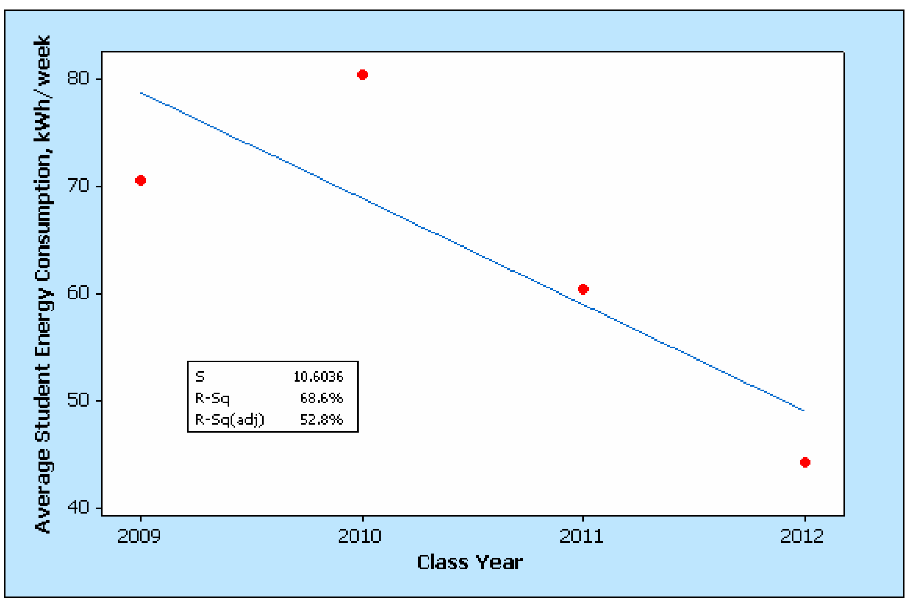

Figure 4: Consumption by Class Year.

P-value=0.172, f- value=4.36, n-value=197

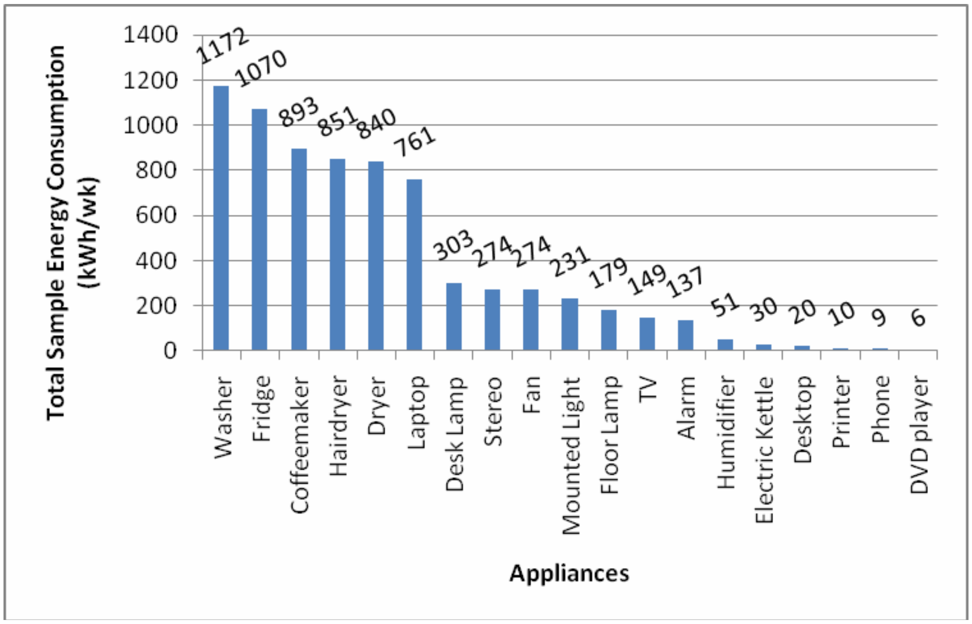

Figure 5: Total Energy Consumption by Each Appliance

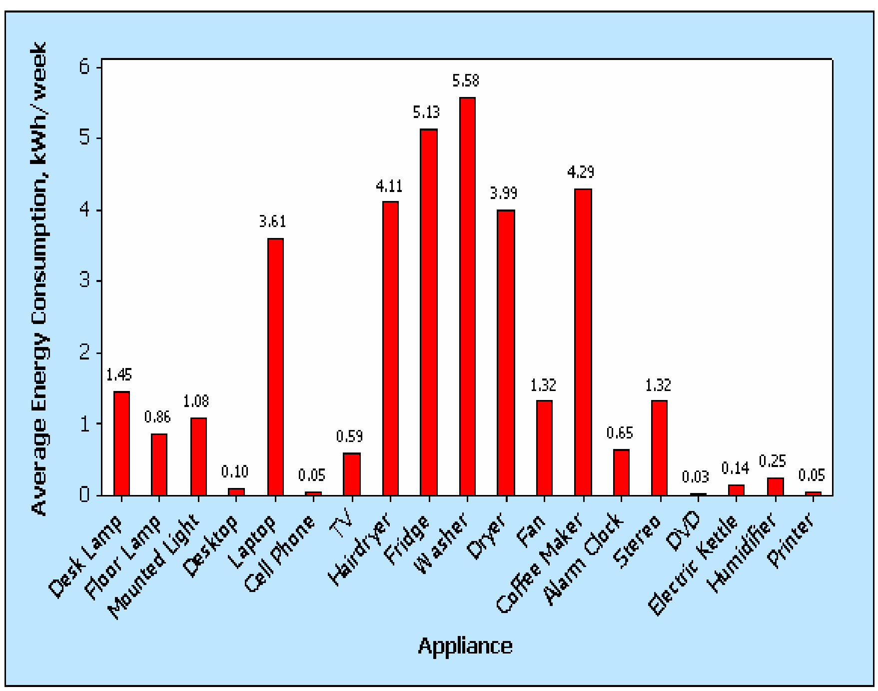

Figure 6: Average Per Capita Energy Consumption by Appliance (kWh/week)

Table 1: Student Consumption of Appliances

Rank	Appliance	# of students (out of 210)
1	≥1 load of washing per week	160
2	>1 fridge	141
3	≥1 coffee maker	17
4	≥1 hairdryer	109
5	≥1 load of drying per week	145
6	≥1 laptop	203

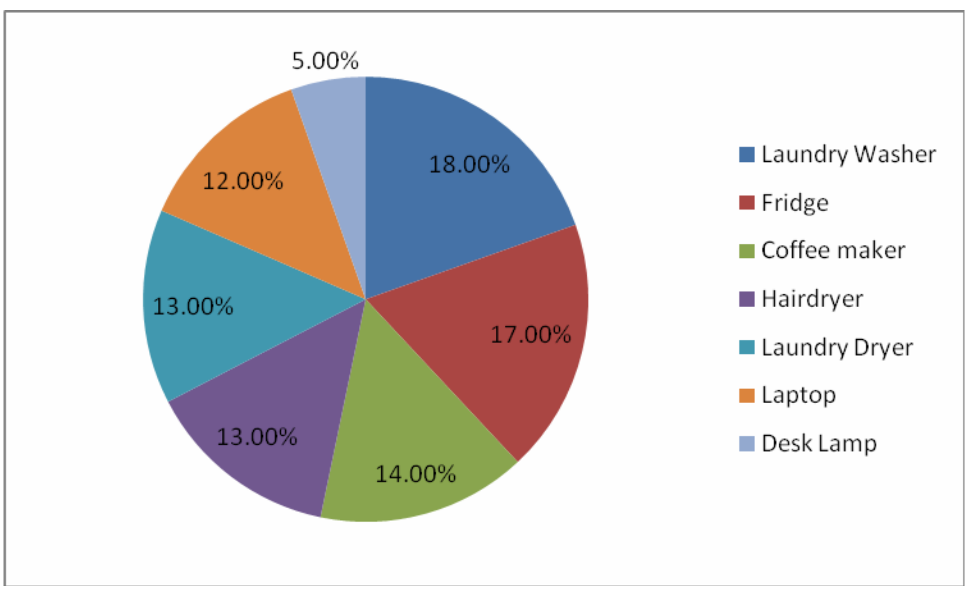

Figure 7: Percentage of Total Sample Consumption Used by Each Appliance

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