Reducing Power Consumption by Identifying Key Issues

Exploration in Energy Saving

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ABSTRACT

Throughout this project we visualized the energy data for Watt Family Innovation Center. The visualizations allowed us to identify and address issues that Watt is having with its‘ energy consumption. We looked at the correlation between outside temperature and HVAC power in order to discover that the two have a moderate correlation, meaning outside temperature can be used as a factor for HVAC to be able to control its‘ own usage. We also explored the relationship between occupancy and receptacle data to find that each floor has a strong correlation, which will allow the building to take preemptive measures for high occupancy times. Lastly, we found that by being able to turn off the media lights we could reduce the cost of lighting by nearly $4,000 a year.

KEYWORDS

Energy Saving, Innovation Center, Data Analytics

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1 INTRODUCTION

The goal of this project is to identify and explore patterns in power consumption for the Watt Family Innovation Center with the intention of reducing the annual power and utility cost of the building. By doing this we are able to identify where electricity is being wasted, and attempt to find the minimal amount needed in order to maintain a reasonable comfort level. Currently, 44% of all domestic energy consumption in the US is being used by HVAC control for buildings [3]. Watt is enabled with meters that read the consumption every 15 minutes in kWh for the following 5 subsets of energy use; HVAC, isolated ground, receptacle power, lights (by floor and media lights) and emergency power. The readings for these subsets occur by floor, and the lighting data can be broken down by room. This information can be used to identify issues that are occuring in Watt in relation to any of the power systems. In 2016 the total utilites cost, for electricty alone, was just over $100,000. A large portion of this is used for the media lights, which currently have a minimum usage of 10 kWh, as well as the HVAC system since the building heats up very quickly due to the amount of natural light that enters the building. Being able to identify inefficiencies in the power system through past data is a quick way to reduce energy consumption and utility costs. In order to do this we will be using SAS Visual Analytics to identify issues as well as statistical analytics to find relationships within the data consumption of Watt.

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2 BACKGROUND

Since Watt is an innovation center they are striving to have state of the art technologies for everything from the basic utility systems to the active 3D hiper-wall in the auditorium. Being that everything in the building is so new, it is expected that some issues will arise. One of the issues that is currently being worked on is the media lights that was given to Watt from Phillips as the largest display of LED net lights in North America. One unexpected issue with them is that even when nothing is being displayed they still use 10 kW per hour. The building was opened in January of 2016 which means that there are still many things that need to be worked through and that are being monitored constantly in the hopes that Watt will be able to run utilties on its own in the near future. From the 3D printer lab to the surveillance room equipped to help people with any technological issues they may have, Watt is striving to make newer technology accessible to all of its students and faculty. This is why there is so much focus on developing and monitoring all the power that is consumed by the building. The reason why the minimum consumption in this building is so high (100 kWh) is because even when the building is empty many resources are still being used wirelessly. Also, due to the devoted staff and cleaning crews the building is only empty from 3 through 7 in the morning.

3 RELATED WORKS

Many different techniques have been established for finding ways to turn normal buildings into smart buildings. Most methods consist of setting up neural networks all around the building in order to have accurate occupancy, temperature, and light readings. Once that data is collected there are different strategies for how to use that data to get the building running on its own. One study discusses the advantages and disadvantages of the different types of predictions methods, which are statistical, engineering, and artificial intelligence [2]. The advantage to our approach is that it does not require a strong understanding of the physical structure of the building, nor an understanding of complex AI methods. It simply requires a reliable data recording system for each power subset, and the ability to visualize and analyze the data to address problem areas and systems within the building. This means that the past data needs to be both accurate, and there needs to be enough of it to establish patterns in the buildings‘ power consumption. This study discovered that the most influential way to reduce electricity use was to create a predictive algorithm for the building to run on in order to reduce fluctuations in energy use. The variables that they found to be the most influential to their prediction were the season and whether or not it is a work day. The reason that this study‘s methods are not substantial enough for Watt is because many of the technology in Watt is new, so it takes time to establish the best way to save power for each device. From another study we learned that having more accurate occupancy readings makes it easier to predict and control HVAC and lighting systems [1]. They used passive infrared sensors (PIR) and reed switches in order to gain accurate readings for the different rooms around the building. These sensors are more complex and return a larger amount of data than the ambient light and motion sensors that Watt is equipped with. Ambient light sensors are able to sense how much natural light is entering the room and can dim depending on how much is present at the present time. However, the motion sensors are not able to tell how full the room is, meaning it doesn‘t help for predicting HVAC. Watt is using other techniques for finding patterns in occupancy levels, such as class schedules, and counting the number of people for more specific data. From building to smart building discusses how adding sensors allowed for them to discover patterns and adjust the electricity accordingly [4]. Since Watt already has lighting sensors the goal is to find the most energy efficient way to power lights while not causing discomfort to the people in the building. Using the sensors and the data previously collected will help us to discover ways in which we can adjust and improve the electricity consumption of Watt.

4 METHODS

Once I received the data that included the breakdown of isolated ground, receptacle, HVAC, and lighting I began by cleaning the data and arranging it in a way that SAS Visual Analytics could interpret. Since the meter readings were recorded in 15 minute intervals it was important to reduce the readings down to the hour in order to facilitate with interpreting the data. The data was recorded in kWh, which means the readings are the average use over an hour in kilo-watts. Since the building is so new, not all of the meters were working properly so the usable data that remained was from April 20, 2017 at 3pm until May 31st at 9am. This left us with about 5 weeks of data that switched between the spring and summer session at Clemson. The change in session is important to note since the usage of the Watt Center is highly correlated with the amount of students and faculty on campus. After the dataset had been properly set up, I uploaded it into SAS VA. Since all of the data is dependent on time that became the most versatile variable to use. I was able to look at time series for each of the different resources by floor. This of course brought up other issues with the data, for example the 4th floor is not open to the public so its‘ use is minimal. Also, the isolated ground power is nearly 1000 times higher in the basement and 1st floor due to data storage and how the building was routed, making visualizing that resource difficult, due to scale. The next step was to create interactive dashboards that allow students and faculty to better understand the consumption of the Watt Innovation Center. Once the dashboards were set up, we were able to look at the data with the project manager of Watt, Tim Howard, and discuss the largest trouble areas in the building. We decided to focus on the HVAC, receptacle, media lights and cost savings from the sensors attached to the lights. The relationships that we decided to explore were HVAC power and outside temperature, along with receptacle use and occupancy levels. We also looked into potential future savings in both energy and cost if able to fully turn off the media lights during certain hours, and current yearly savings from the overhead lights in the building.

5 ISSUES

Throughout this project, the main issue has been how SAS Visual Analytics reads the data spreadsheets. In order to plot the majority of graphs in the program, the data needs to be accepted as categorical, so a lot of time was taken by trying to rearrange the original data set so that time, floors, and resources were all categorical variables. Since I had so much trouble with getting my data inputted correctly the majority of my graphs in the dashboards are bar graphs and time series, because time was accepted as a categorical variable. These give a lot of information about the resources that Watt uses but I would have liked to be able to create more plots that allow for closer looks of how each floor of the building compares to the other floors by all the different resources. Another issue that was encountered was getting the dashboards to be accessible to both students, and people looking for areas of the building to improve. A lot of information was needed to make the dashboards understandable for students, but some information seemed repetitive for building managers to be looking at while searching for issues that the building may be having. We were able to find a middle ground by adding text boxes to explain the major ideas, while leaving plenty of room for graphs that helped to assess where the majority of power is being used.

6 RESULTS

6.1 HVAC Power

Once the outside temperature data was collected for NOAA‘s National Climatic Data Center, regression analysis between the HVAC power and the temperature showed a moderately strong relationship for weekdays. Weekends were excluded since Watt is closed, and runs on a non-occupied mode to reduce power usage. A log transformation was done to both the HVAC power and the outside temperature since HVAC power is not a normally distributed. From this linear model, shown in Figure 1, we received a correlation coefficient of .53, an r-squared value of .28 and an equation of

$$f(x) = -1.82 + 1.337x \tag{1}$$

where HVAC depends on outside temperature. In SAS, we created dual axis time series to show how the patterns of outside temperate and HVAC power match up throughout time. Figure 2 shows one week (Monday-Sunday) of temperature (Fahrenheit) and HVAC power (kWh), which demonstrates how temperature could be used in the future to have HVAC run without intervention from staff.

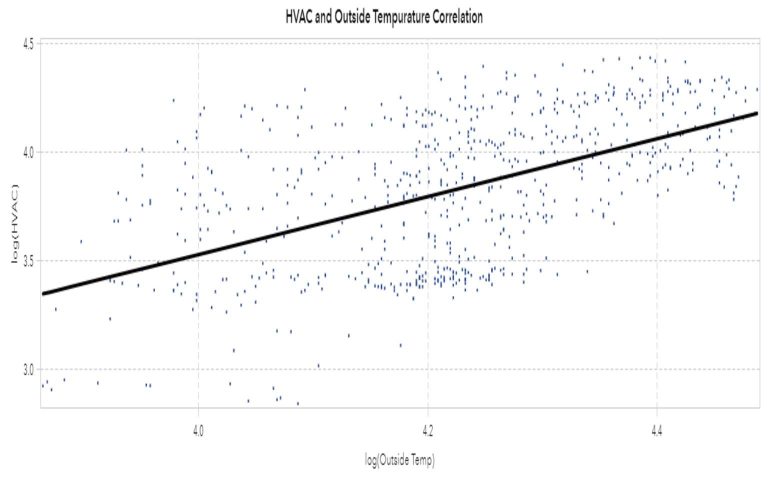

Figure 1: Linear model of the log transformed hvac power and outside tempurature.

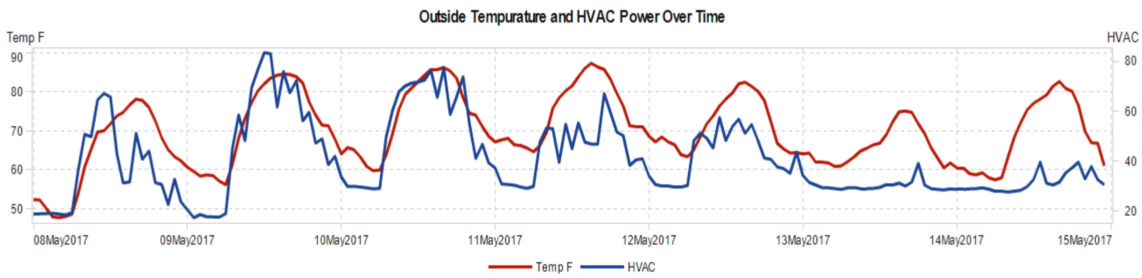

Figure 2: Time series showing the similarity with patterns in HVAC power and outside temperature.

6.2 Receptacle usage according to occupancy

I received the occupancy data that is collected every 30 minutes from 3pm till midnight during the school year, and 9am till 5pm throughout the summer in order to monitor the usage of the building. From this data, I was able to find a linear model for 1st, 2nd, and 3rd floors in Watt, but found that a non-linear fit was much higher for total building usage. Figure 3 shows the analysis done for the total receptacle power dependent on the total occupancy, the terms receptacle and outlet were used synonymously. This best fit model returned a r-squared value of .61 and has the equation:

$$f(x) = 1.453 - 0.0038x + 0.0338x^2 \tag{2}$$

Noting that a log transformation occurred before preforming analysis on this data. We saw that the second floor had the strongest correlation of .80, with a r-squared value of .64 and the first floor had the weakest correlation of .67, however all three floors had a strong correlation. From this analysis we are able to drill down on time periods where receptacle power may be overused on certain floors. The first floor has the lowest correlation due to the cafe that has two freezers and vending machines which must be running all the time. One item, which needs to be noted is that it is possible more people are wirelessly connected to building that could cause a surge in receptacle power usage.

6.3 Lighting Cost Reductions

The last exploration that occurred with the Watt data was looking at cost differences if we were able to turn off the media lights during certain hours (midnight-6am on weekdays and all hours during weekends). Figure 4 shows potential savings (in dollars) per day. The current daily minimum cost is around \$12. If these changes are implemented we could see a reduction of utility cost around \$3,949 per year. When Watt was built, LED lighiting along with ambient light and motion sensors were used for all overhead lighting, so we explored the cost savings that those have enabled. Current yearly cost for lighting (excluding media lights) is estimated to be \$3,615. If Watt used fluorescent lighting without sensors, estimated yearly costs for utilities would be \$26,100. If Watt used LED lighting but without the sensors, the lights would have to be 100% on with no ability to dim or turn off by themselves which would put the yearly cost around \$10,956. This means that by using LED lights along with ambient light and motion sensors reduce the annual utility bill by \$22,485.

7 CONCLUSIONS

Throughout this exploration of the Watt Family Innovation Center energy data, we were able to identify problems that are currently

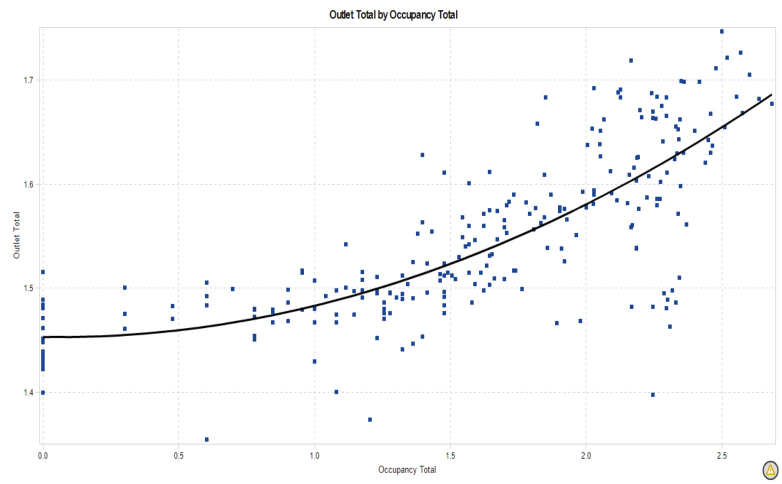

Figure 3: Best fit model for the log transformed receptacle power and occupancy.

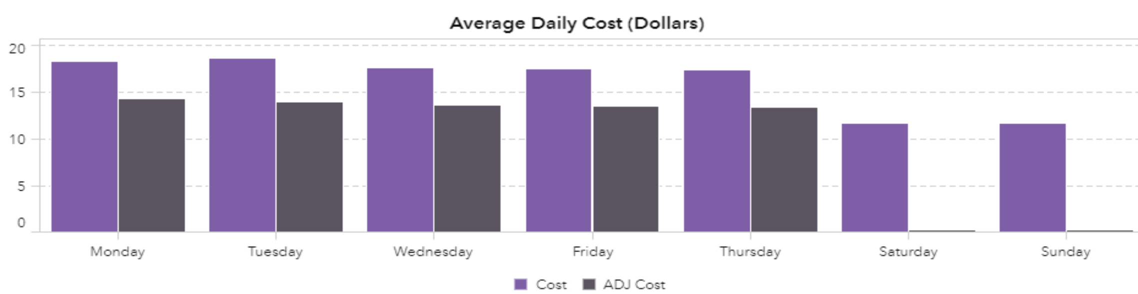

Figure 4: Average daily cost for the media lights with and with out adjustments

causing the utilities to be around $8,000 per month. The most expensive aspects of powering Watt include the media lights and the HVAC system. During this study we found that cost of the media lights could be cut in half if given the ability to completely turn off the lights when not in use. The media lights are so expensive since the current minimum usage for the lights is 10 kWh, which is why being able to turn them off gives such significant cost reductions. When exploring the relationship between outside temperate and HVAC use we are able to see that temperature could be used as a predictor for setting the HVAC to run automatically. If able to get the HVAC to run according to temperature we hope to see reductions in the amount of excess energy used to cool or heat the building. In the furture we hope to train the building to understand the correct comfort level based off of the outside temperature, and potentially class schedules. We also hope to use the high correlation of receptacle usage to occupancy levels in order to predict future usage, and control for high occupancies times in the building. Looking forward, we hope to discover other technologies and predictors which could help improve the cost and efficiency of Watt. One example of this would be to equip the building with class and event schedules so that it could cool rooms before a large amount of people enter which currently causes rooms to overheat. Since the building is relatively new the overall goal is to reduce the utility cost, and eventually get the building to run the utilities without the need of correction by staff.

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