Final Project Report

Analyzing Energy Consumption of 2015 between Porter Hall and Hunt Library

F6 12-752 Data-Driven Building Energy Management

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(Sort Alphabetically)

Abstract

In order to better save energy and improve sustainability in campus, this project analyzed the dataset of energy consumption from two campus buildings - Porter Hall and Hunt Library, during a whole year of 2015. To easily assess and calculate the large dataset, language of Python and pandas were used in this project. From our analysis, the electricity consumption reached its peak value around 12:00 pm; and its lowest value around 5:00 am on average in one day. In addition, both Porter Hall and Hunt library's electricity usage in winter was much higher than that in autumn and spring, whereas the summer electricity consumption between these two buildings were quite different from each other. Overall, the average electricity consumption of Hunt library was more than that in Porter Hall due to its larger building area.

1. Introduction

According to the survey and estimation made by EIA, there was 40% of the total energy consumed by either residential or commercial buildings in 2015 [1]. Consequently, it is relatively significant to save more energy among buildings in order to achieve sustainable and energy-efficient development. Analyzing the current energy use sectors and divisions among different buildings can serve to further deploy any effective energy saving methods. Therefore, this project analyzed the energy consumption in two different buildings in CMU campus - Porter Hall and Hunt Library.

Based on the Sustainability Tracking, Assessment and Rating System program operated by AASHE, Carnegie Mellon University achieved silver level among the rating system in 2015, which was just around the average compared to other institutions [2]. Its score on Building Energy Consumption category was only 2.24 over 6, which indicated that the overall energy efficient level in CMU still needs to be improved and thus it is reasonable to choose the analyzing model from CMU campus. In addition, Porter Hall was constructed much earlier than Hunt Library. This also provides enough contrast on our analyzing model.

2. Background and Approach

2.1 Background

In our project, the energy consumption, especially electricity consumption, in Porter Hall and Hunt Library was analyzed and compared based on the language of pandas and python in addition to the datasets of these two buildings obtained from course 12-748.

Porter Hall is the oldest construction in CMU campus, which was built in 1905 when CMU was first established. The site is an urban location with connections to Oakland where the public transit is available. The building was designed creatively to use the existing building to maintain the campus's open space. Although it is an old building, it was rebuilt decades ago with new HVAC equipment, lighting power reductions, control ventilation added. This building was certified to be LEED Silver in 2009, especially 100 classrooms in Porter Hall, which has many green features. Innovation credit was given for the exceptional amount of green power purchased and low emitting materials were used [3]. There are daylight and views in nearly all spaces. All of these features create a high quality-learning environment and are able to save electricity during daytime.

Hunt library was built in 1961 and it is the first and only central library in CMU. Mr. and Mrs. Roy A. Hunt donated the funds to build Hunt Botanical Library to house Carnegie Tech's library and Mrs. Hunt's collection of fine and rare botanical books. This construction is equipped with latest HVAC equipment for heating, ventilation and air conditioning.

2.2 Approach

In general, our group used Github and ipython notebook as our python IDE to dispose and analyze the data. Pandas is also a convenient way to deal with these large datasets, where the most common method we applied to the analysis was groupby and regression tree. All of these were used to plot the diagram and filter the outliers.

3. Dataset

The Dataset used in this project was given by Professor Bertrand Lasternas - a research Associate of school of Architecture in CMU. The original form of this dataset was Excel. However, since we used python and pandas to deal with the analysis in this project, our group member changed it to csv form so that it can be recognized and changed easily on Jupyter Notebook. This dataset was consists of electricity consumption of three buildings during 2015 in our campus. These three buildings are Porter Hall, Baker Hall and Hunt Library. Since Baker Hall is similar to the rest two buildings, Porter Hall and Hunt library were finally chosen to find the rules of electricity consumption and the difference between them. Another chosen reason was that Porter Hall is the oldest building, with nearly a hundred years) in our campus while Hunt library is a relatively new one, at least observed by its appearance.

4. Results

We plotted several figures in different dimension to show the condition of energy consumption of both Porter Hall and Hunt library and the figures are shown below:

4.1 Daily consumption

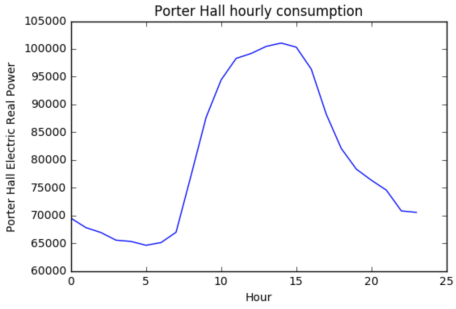

Figure 1. Daily Consumption in Porter Hall

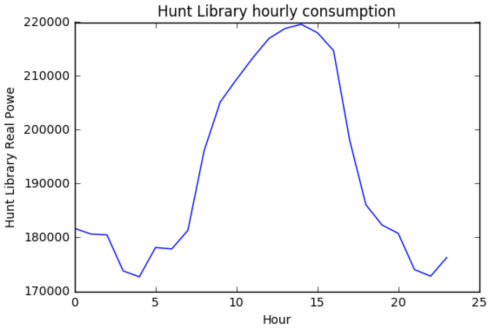

Figure 2. Daily Consumption in Hunt Library

Figure 1 and figure 2 showed the daily electricity consumption of these two buildings. The x-axis represents time of one day and the y-axis represents electricity consumption. According to figure 1, it can be found that electricity consumption of both two buildings had its lowest point in midnight because there were few human activities and barely needed lights or air-conditioner. On the contrary, the electricity consumption reached its peak around 12:00 pm during a day.

4.2 Annual consumption

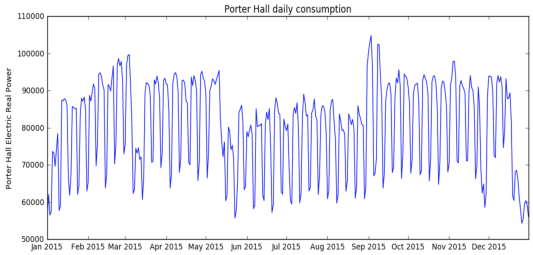

Figure 3. Year energy consumption in Porter Hall

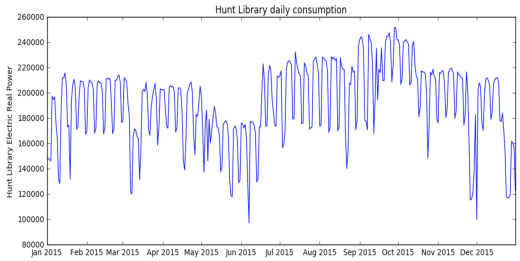

Figure 4. Year energy consumption in Hunt

Figure 3 and Figure 4 showed the condition of electricity usage in the two buildings during the whole year. The x-axis represents month of a year and the y-axis represents electricity consumption. We can easily find that the energy

consumption in winter (from December to February) was higher than that in other time, which might be due to the required heating in winter. Energy consumption in autumn and spring was less than that in summer and winter. In summer, air conditioners were used in Hunt library to cool the indoor air, while Porter Hall did not have equivalent consumptions.

4.3 comparison between two buildings

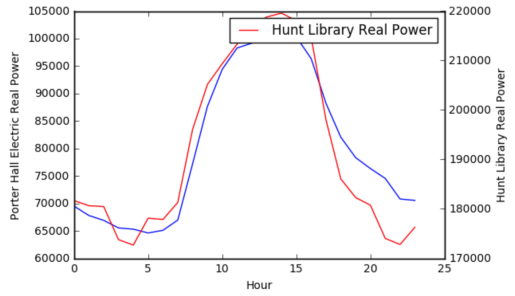

Figure 5. Daily Comparison

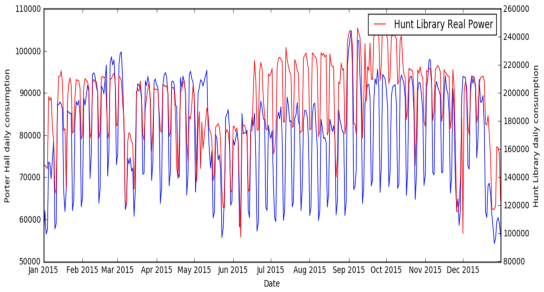

Figure 6. Year Comparison

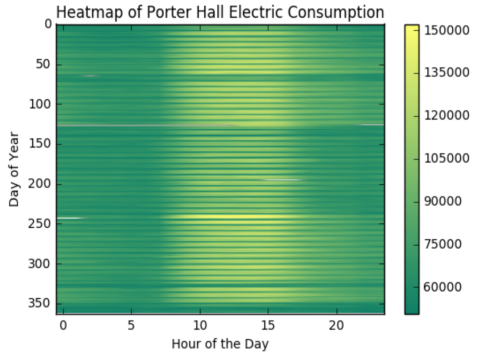

Figure 7. Heat Map of Electricity Consumption in Porter Hall in 2015

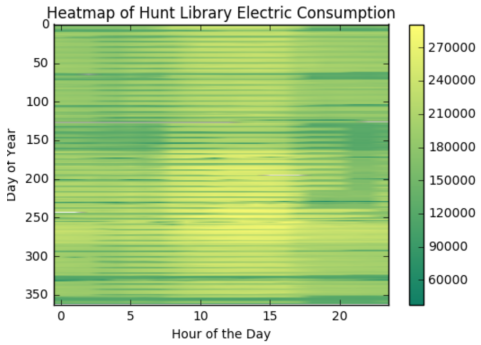

Figure 7. Heat Map of Electricity Consumption in Porter Hall in 2015

Figure 5, 6, 7 and 8 all showed the comparison of energy consumption between Porter Hall and Hunt library. According to figure 5 and 6, it can be found that the average consumption of Hunt Library was higher than Porter Hall. From heat maps that shown in figure 7 and 8, it can be referred from the fact that the color of figure 8 was much lighter than figure 7 that the average energy consumption of Hunt library was higher than Porter Hall.

In addition, the decreasing slope of energy consumption after 3:30 pm in Hunt library was larger than that in Porter Hall, which is an interesting fact that need more study.

5. Discussion

Our initial estimation about daily electricity consumption was that the electricity usage would reach a peak during nights. This is because from our perception, most students will stay on campus, especially in the Hunt Library, during nights or after school. However, our result was quite different from our assumption. Figure 1 and 2 showed that the electricity consumption reaches peak during noon, around 12pm to 2pm. After some group discussion and online research, we figured out that actually the campus would accommodate most students during noon, which can be explained by the fact that most of the classes are scheduled from 10am to 5pm. During this period, most of the classrooms or small conference rooms will be occupied and lights will be turned on to support human activities. Moreover, since there will be more people on campus during this period, more plug-ins will be used for electronic charging.

These reasons can all be applied to both Porter Hall and Hunt Library. Besides, there is a cafe located in Hunt Library, which opens till 7:00 in the evening. The coffee machines and cashier located in the cafe will also increase electricity consumption a lot. From these explanations, it is pretty reasonable that electricity for both buildings will reach a peak during noon.

An interesting fact shown from figure 5, 6, 7 and 8 was that even though Porter Hall has a smaller building area compared to Hunt Library, its electricity consumption was not largely lower than that in Hunt Library. This is might due to the reason that Hunt Library is a relatively new construction and consequently can function more sustainably and energy effective. It is also noticeable that in figure 5, the electricity usage in Hunt Library decreases much more quickly than Porter Hall after 6pm. This can be also explained by the cafe in Hunt Library since the closing time correspond to the dropping point.

Figure 6 also shows an interesting fact that from July to October, Porter Hall's electricity consumption was still similar to its summer electricity usage, which was relatively low compared to the winter. However, Hunt Library's electricity consumption during the same time period was closer to the electricity usage during winter, which was relatively high compared with energy consumption from March to June. According to one of our group member's memory, the temperature in Porter Hall from August to October was much higher than that in Hunt Library, which might indicate that there is either no air conditioner in Porter Hall or the air conditioner's working power is relatively low. As mentioned in the result section, the result of heat map (figure 7 and 8) showed a pretty similar result and fact as discussed before.

6. Validation

The result generated from the data set was not exactly what we predicted and assumed before. Therefore, our group did some research about campus building energy usage and reconsidered the students' behavior. Most of the journal papers we found analyzing multi-purpose academic buildings generated a similar result as we did and our result corresponds to most of the students' study behavior according to Gul and Partida [4]. Even though there are still some facts that cannot be explained currently, overall we still believe that our data and result is pretty validate.

7. Future Work

Some analysis about energy consumption efficiency, which indicates the electricity consumption per unit area, can be made in the future to compare the difference of electricity efficiency between old buildings and new buildings. It might also be interesting to compare the difference in energy efficiency among different building facades.

8. Reference

[1]"How much energy is consumed in residential and commercial buildings in the United States? - FAQ - U.S. Energy Information Administration (EIA)", *Eia.gov*, 2016. [Online]. Available: http://www.eia.gov/tools/faqs/faq.cfm?id=86&t=1. [Accessed: 09- Dec- 2016].

[2]"Carnegie Mellon University | Scorecard | Institutions | AASHE STARS", *Stars.aashe.org*, 2016. [Online]. Available: https://stars.aashe.org/institutions/carnegie-mellon-university-pa/report/2015-02-27/. [Accessed: 09- Dec- 2016].

[3]"Carnegie Mellon University: Porter Hall 100 Renovation - Green Building Alliance", *Go-gba.org*, 2016. [Online]. Available: https://www.go-gba.org/projects/carnegie-mellon-university-porter-hall-100-renovation/. [Accessed: 09- Dec- 2016].

[4]M. Gul and S. Patidar, "Understanding the energy consumption and occupancy of a multi-purpose academic building", *Energy and Buildings*, vol. 87, pp. 155-165, 2015.