Improving Sustainability at WPI by Developing an Energy Monitoring Dashboard

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Date:
9 / 6 / 2022

Abstract

The goal of this project is to reduce utility usage and promote sustainability efforts at Worcester Polytechnic Institute's (WPI) campus by providing recommendations to implement an online resource monitoring dashboard. Case studies and interviews were conducted to determine the key characteristics required for this dashboard. An investigation was also conducted into WPI's current submetering system as well as the financial and sustainability benefits of improving it. Finally, a concept dashboard was created and recommendations were made on how to successfully implement it.

Acknowledgments

I would like to thank my advisor for his insight and guidance throughout this project.

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Additionally, I would like to thank the following individuals for contributing to this project; without their knowledge of WPI's infrastructure, this project would not be possible.

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1 - Introduction

Each year, the need for better sustainability practices in our community becomes more imperative. Sustainability is meeting the current generation's needs while preserving future generations' natural welfare. It consists of three central pillars, social justice, environmental conservation, and economic development (ASU). Advancing these pillars is essential in combating more significant problems that will affect us and future generations, such as climate change. Recently, colleges have increased their focus on these issues through their research programs and implementing sustainability into their curriculums.

In their most recent sustainability plan, WPI has pledged to be “committed to taking on a leading role in meeting these global sustainability challenges” (WPI’s Sustainability Plan, 2020). WPI’s current enrollment has nearly doubled since 2000 (Office of Institutional Research, 2020)(Andrews, 2000). As the number of students increases, so does the demand for water and electricity. In 2010 WPI used 68 million gallons of water. The demand for water increased to nearly 90 million gallons in 2018 (pre-pandemic) (Sustainability Report, 2020). Similarly, energy usage increased from 24 million kWh in 2010 to about 28 million kWh in 2018 (Sustainability Report, 2020). For WPI to accomplish its sustainability goals, it would benefit from a more robust energy monitoring system.

Part of several colleges’ sustainability plans was the implementation of an energy monitoring dashboard. Colleges such as Case Western Reserve, California Polytechnic Institute, and RIT have implemented dashboards similar to the one proposed in this IQP and, as a direct result, have seen significant decreases in energy usage across their campuses. These positive results suggest that dashboards can increase awareness surrounding energy usage and positively affect the behavior of the users.

Previous IQPs have explored the concept of an energy monitoring dashboard. In 2018, a group explored the feasibility of a dashboard and conducted a survey to analyze the attitudes of the student body and faculty around the implementation of an energy monitoring dashboard (Mancinelli, et al. 2018). Only 1% of people surveyed believed that an energy monitoring dashboard would not benefit student projects and research (Mancinelli, et al. 2018, p. 23). The survey also found that 25% of people were partial to an online dashboard compared to 5% who exclusively wanted a physical dashboard; 57% of people surveyed wanted both types of dashboards (Mancinelli, et al. 2018, p. 24).

There are three main methods for developing an energy monitoring dashboard: purchasing one from a third-party company, modifying a third-party dashboard, and creating one from scratch (Salmon, et al. 2016). The student project mentioned above weighed the benefits of each method. However, it mainly focused on implementing EcoScreen, a physical dashboard developed by Automatic Logic Inc that could be installed across campus (Mancinelli, et al. 2018). Their approach was helpful, however, there currently exists the need to research other existing services or develop an in-house online dashboard.

My IQP focuses on developing a public-facing online dashboard for monitoring energy usage on WPI’s campus. This dashboard will allow students to conduct sustainability research on campus, improve mindfulness towards energy consumption and demonstrate

WPI's commitment to sustainability. This project analyzes improvements that can be made concerning WPI's current submetering and resource monitoring systems. Finally, it concludes with recommendations for future projects that will aid in actualizing an energy monitoring dashboard at WPI. Specifically, the goals for this project are as follows:

1) Identify potential needs and uses of this dashboard for WPI students, the facilities department, and the Office of Sustainability.

2) Analyze WPI's existing resource monitoring system and make recommendations for improvements in submetering based on the input of the previously mentioned groups.

3) Develop a method of extracting data from *WPI's submeters* such that it can be used for the dashboard.

4) Design a dashboard using this data and outline essential features.

2 - Background

This section analyses the sustainability goals set by WPI's sustainability plan and the STARS system that implementing a dashboard can improve. WPI's existing electrical submetering system is also discussed. Finally, case studies of three benchmark schools that have implemented similar dashboards are analyzed, and it is determined that they positively affect energy usage reduction.

2.1 - WPI's Sustainability Plan and Reports

WPI's Sustainability Plan was adopted in 2014 and outlined goals to progress toward a more sustainable campus and engage the community by 2025 (Sustainability Report 2019-2020, 2020, p. 2). The goals in the plan were guided by three complementary tenets of sustainability "environmental stewardship, economic security, and social justice for all people" (Sustainability Report 2019-2020, 2020, p. 2). One of the goals of this plan is to "reduce water and energy consumption and waste generation through promoting operational efficiencies and positive behavior change" (Sustainability Report 2019-2020, 2020, p. 16). A subsection of this goal involves communicating sustainability initiatives to the campus community through signage and messaging. Additionally, WPI wants to increase the frequency with which it reports on its sustainability efforts (Sustainability Report 2019-2020, 2020, p. 38). An energy monitoring dashboard will directly show the effects of sustainability initiatives and frequently communicates energy usage, promoting behavioral changes in the campus community.

The only system WPI has for publicly reporting energy usage is an annual sustainability report that WPI's Office of Sustainability releases. This report highlights sustainability-related courses, projects, research opportunities, and WPI's water, energy, natural gas, and emissions usage. These usages are not taken from WebCtrl. Instead, they are calculated based on the monthly bills for each resource. An energy monitoring dashboard would improve these reports and provide a more robust energy report more frequently.

2.2 - STARS system

Any project regarding sustainability on a college campus would be amiss not to mention STARS. The Sustainability Tracking, Assessment and Rating System (STARS) is a "transparent, self-reporting framework for colleges and universities to measure their sustainability performance" (About STARS). STARS was designed to incentivize sustainability efforts for college campuses and facilitate information sharing between colleges (About STARS). Participants in the STARS program receive a rating based on their efforts, these ratings are Platinum, Gold, Silver, and Bronze (About STARS). These ratings are calculated from scores in five categories: "academics, engagement, operations, planning & administration, and innovation and leadership" (About STARS).

As of May 22, 2020, WPI holds a Gold STARS rating (Worcester Polytechnic Institute Reports, 2020). An energy monitoring dashboard can bolster WPI's STARS rating in the engagement and operations categories. For engagement, the scoring criteria EN2 and EN4 would be most relevant (STARS 2.2 Credit Checklist). EN2 involves including sustainability information in student orientation, while EN4 grades the quality of the sustainability publications by the campus (STARS 2.2 Credit Checklist). For operations, there are multiple criteria related to the disclosure of resource usage information, such as OP1, OP5, and OP21, which assess the college's disclosure of natural gas, energy, and water usage, respectively (STARS 2.2 Credit Checklist).

2.3 - Submetering and ALC

Utility submetering is the division of utility usage tracking to individual buildings on a property or campus (Harroun, 2021). These submeters typically track energy, water, and natural gas usage (Harroun, 2021). WPI currently uses WebCtrl to monitor HVAC systems and utility submeters across campus. WebCtrl is an online service purchased from Automated Logic "that provides facility managers with software tools to keep occupants comfortable, manage energy conservation measures, identify key operational problems" (WebCtrl Building Automation System). WebCtrl is only available to facilities employees and select students who need it for research.

WPI's system uses a main electrical meter that branches into E-mon D-mon submeters connected to the electrical infrastructure of buildings across campus. Modern submeters can relay information to WebCtrl's server every fifteen minutes through a communication protocol known as BACnet (About BACnet). Of the nearly 70 properties that WPI owns, only the following 16 buildings have BACnet compatible submeters; Alden Hall, Atwater Kent, Boynton Hall, Rubin Campus Center, Daniels Hall, Innovation Studio, Goddard Hall, Harrington, Morgan Hall, Olin Hall, Recreation Center, Salisbury Labs, Stratton Hall, Power House, and Gordon Library. (Buildings & Facilities Locations)(WebCtrl).

The WPI facilities department uses this system to detect anomalies in energy usage, water usage, and temperature that may be problematic. Publishing this data through a dashboard would allow faculty and students to visualize anomalies such as large spikes from using certain equipment or energy usage disproportionate to the number of people using the building. This can encourage users to be mindful of their energy usage and conserve energy in each building.

2.4 - Energy Monitoring Dashboards

Energy monitoring dashboards are software that displays utility data in a simple and engaging format. These dashboards allow users to visualize energy usage quickly and analyze data trends over time. While the dashboard does not directly reduce energy usage, it can make users more conscious of their energy usage, which causes adjustments in their energy-related habits accordingly. When an energy monitoring dashboard was installed in the Red Brick Dormitories of California Polytechnic State University in 2011, energy savings were as high as 20% from the previous year's baseline (Zombro, 2013). The following year the Red Brick Dormitories were awarded as the most "green" dorm on the campus (Zombro, 2013). If WPI were to implement a web-based dashboard that is easily accessible, then it is likely that improvements in energy usage would be seen across the campus.

WPI uses other colleges similar in size, location, and student population to their own to benchmark specific performances. These colleges are Case Western Reserve (CWRU), Northeastern, Rensselaer Polytechnic Institute (RPI), Rochester Institute of Technology (RIT), and Stevens Institute of Technology (Benchmark Institutions, 2020). Only Case Western Reserve and RIT have energy monitoring dashboards of the institutions above. Their dashboards were used as case studies in the sections below.

2.4.1 - Case Western

Case Western Reserve's energy dashboard and initiatives are similar to this project. In 2011, energy monitoring dashboards were installed in various buildings on campus and were available to be viewed online (Green on the screen, 2011). These dashboards show current energy usage, year-to-date energy usage, costs, equivalents, and energy produced by the campus' solar and wind power (Green on the screen, 2011). These dashboards were installed to make students more conscious of their energy usage and modify their behavior to make the campus carbon-neutral by 2040 (Green on the screen, 2011). Case Western also uses these dashboards as part of an annual sustainability contest called CWRU Unplugged! Dormitories and Greek Houses on campus compete to have the greatest reduction in energy over two weeks (CWRU Unplugged! 2021). The most recent winner of the contest was CWRU's Alumni House, which reduced its energy usage by 4.56% (CWRU Unplugged! 2021). If a dashboard is implemented at WPI, similar contests can be held between dormitories to help reduce energy usage. Unfortunately, the dashboards at CWRU are not available to the public.

2.4.2 - RIT

Over the past ten years, RIT has made significant improvements in sustainability; while their campus has grown 16.1%, they have reduced their energy usage by 15.9% (Energy). Part of this program to reduce energy usage on campus was the implementation of an energy usage dashboard in certain buildings so that the occupants can visualize the energy they are using (Energy). Like CWRU, this data is available online for RIT students and faculty but not for the general public. However, a dashboard showing the energy produced by their solar panels is available to the general public. This dashboard was developed by AlsoEnergy, a utility monitoring service similar to Automated Logic. The dashboard shows a graph of energy produced for the current day. However, this can be expanded to five days, week, month, year, and lifetime (AlsoEnergy, 2022). The dashboard also shows the theoretical equivalents for the energy saved (AlsoEnergy, 2022).

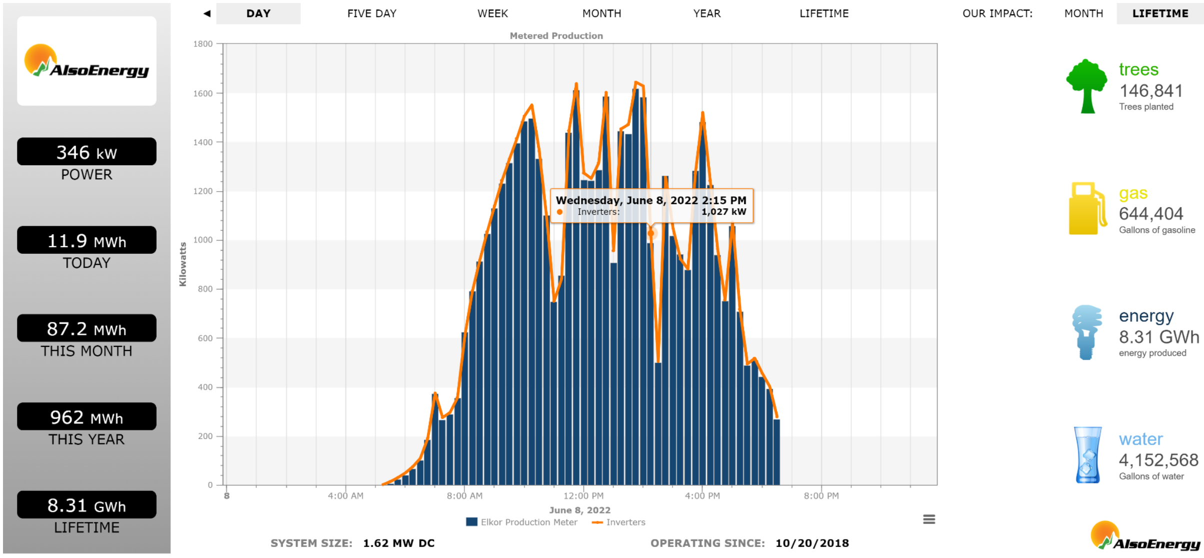

Fig. 2. RIT's dashboard for tracking energy generated by their solar panels (AlsoEnergy, 2022).

2.4.3- Oberlin Public Schools

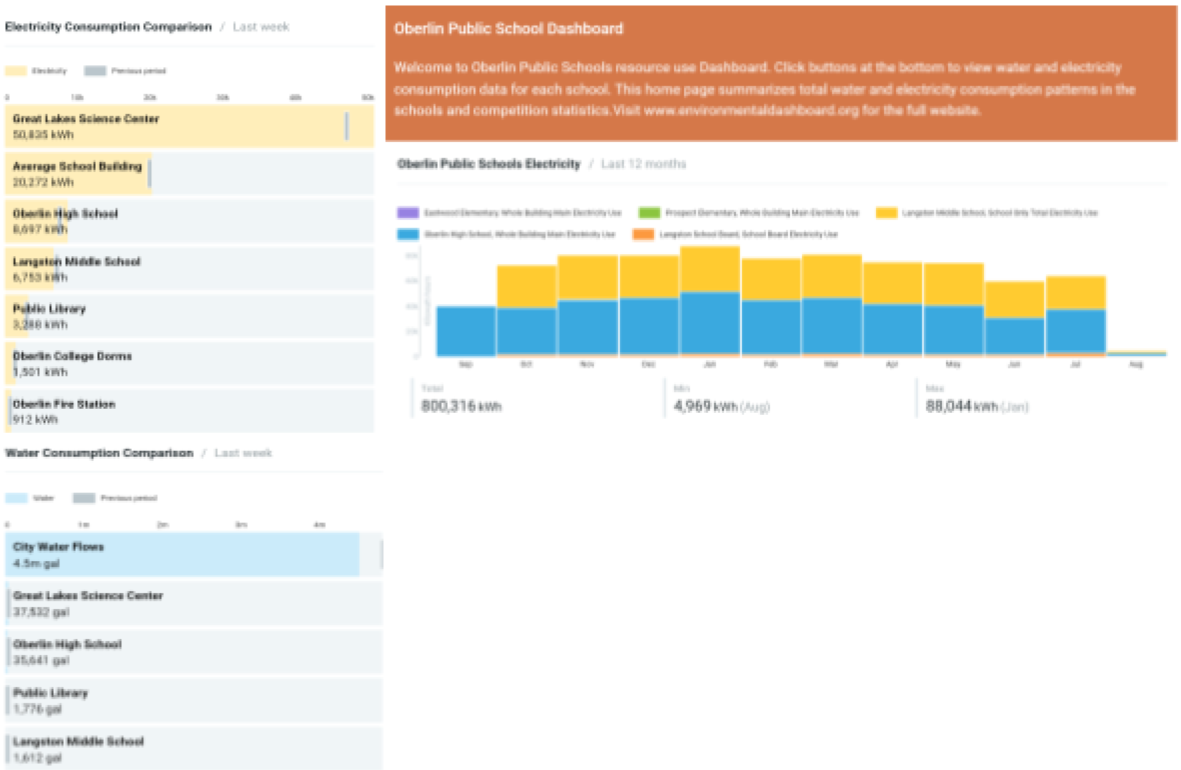

Fig. 3. Oberlin Public School District's dashboard homepage (Oberlin).

An outstanding example of dashboard design is the Oberlin Public School's Dashboard. The dashboard is very user-friendly while also being highly informative. The main page is headed by directions on how to use the dashboard (Oberlin). Below are graphs for the total electricity and water usage for all the buildings that use the dashboard (Oberlin).

The page also includes comparisons between the school buildings and a baseline “average school building” (Oberlin). These features can be seen above in Figure 3.

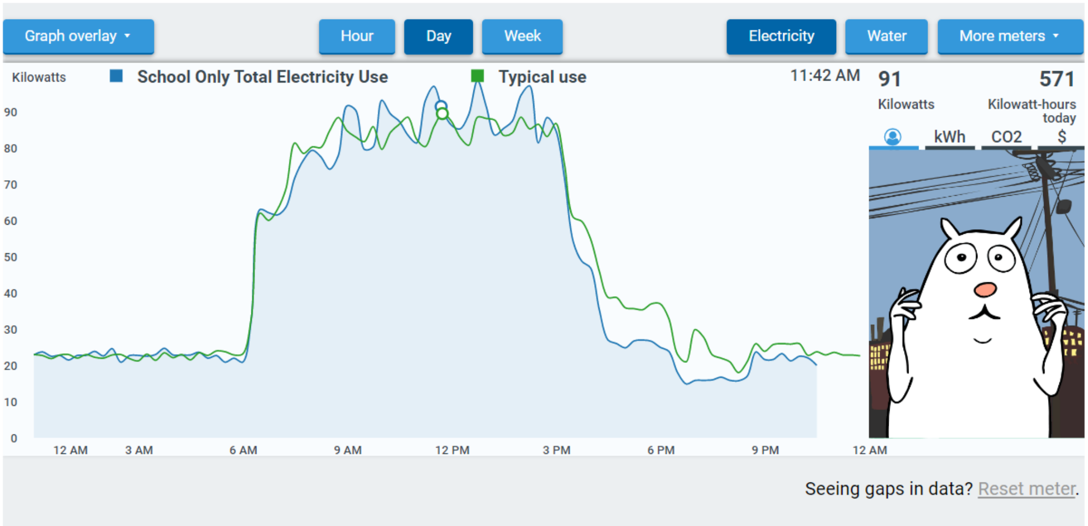

Fig. 4. Graph of energy usage for Langston Middle School (Langston).

The dashboard has subpages for each building in the school district. On each subpage is a brief overview that shows the daily and weekly electricity and water usage for the building (Langston). Also included on this subpage is a more detailed graph showing real-time energy usage that can be expanded from hourly to daily to weekly (Langston). Below this graph is a bar chart showing the distribution of the energy used by different rooms in the building (Langston). This type of granular energy monitoring can help answer the question as to why a building is using more energy than another and help focus sustainability efforts on the areas of a building using the most energy.

2.4.4 - Unity Hall Dashboard

The final case study is a proposed dashboard to be installed in WPI’s new academic building, Unity Hall. The dashboard will be physical and installed in a central location in the building, and it will consist of three graphs (WPI Academic Building, 2020). The first graph is a column chart that compares a baseline to the actual energy over a year, with the x-axis divided into months (WPI Academic Building, 2020). The purpose of this graph is to show the monthly change of energy and keep the actual usage of the building below the baseline. The next graph will show the current demand for the building in real-time. The graph updates every five minutes and shows the data for the entire week (WPI Academic Building, 2020). The final graph is similar to the first; however, it compares the actual energy usage to the amount of renewable energy available (WPI Academic Building, 2020). This graph intends to encourage users to keep the actual energy usage below the renewable energy levels to keep the building carbon neutral. The graphs can be seen below in Figure 5.

This project was proposed in 2020 but has not come to fruition yet. Therefore the effects of this dashboard cannot be determined.

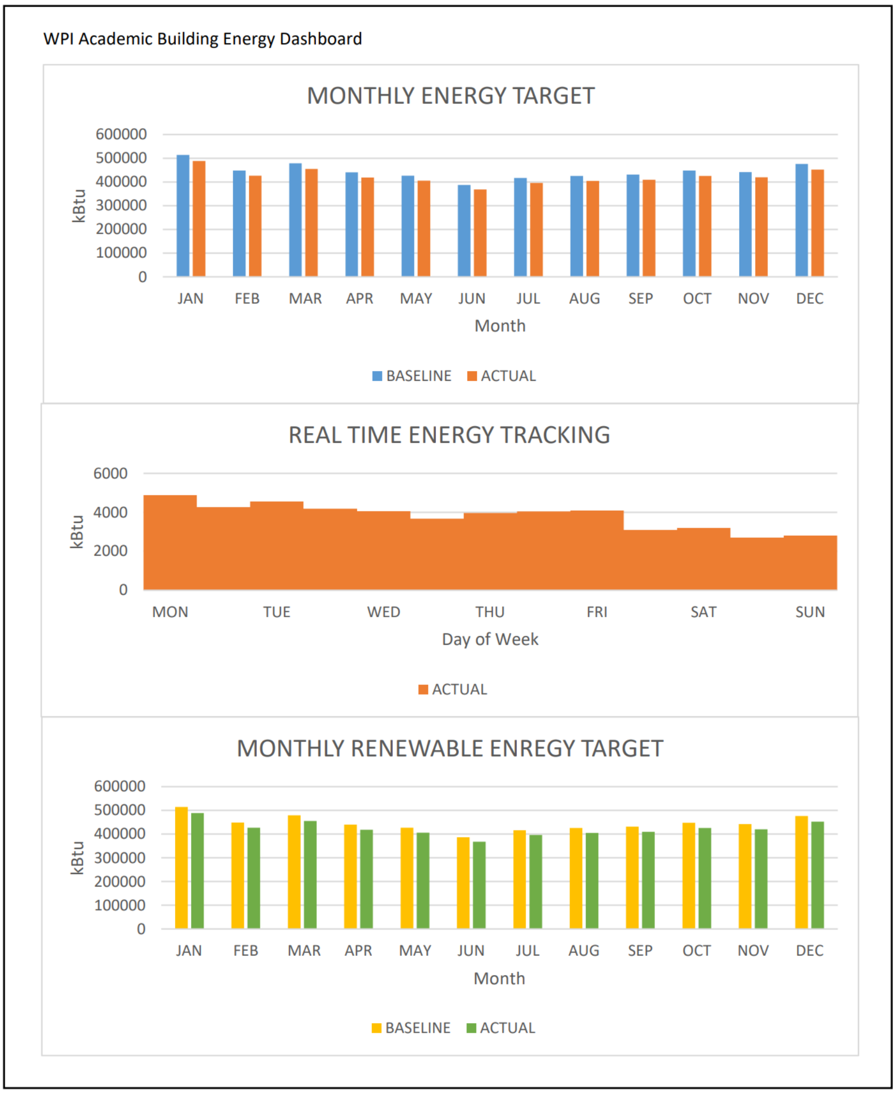

Fig. 5. Example of the Unity Hall dashboard layout (WPI Academic Building, 2020).

3 - Methodology

The goal of this project will ultimately be to reduce utility usage across WPI's campus, thus making it more sustainable. This goal will be accomplished by creating a public-facing dashboard that students and faculty can use. This project provides recommendations for this. The features of this dashboard were determined by interviewing those likely to use the dashboard and analyzing existing dashboard services. Then, a thorough exploration of WPI's submetering system was conducted to aid in creating this dashboard. This data was used to recommend upgrades and data extraction methods for the submeters.

3.1 - Interviewing for Key Features

To develop an effective dashboard, the needs of the demographics most likely to use it should be considered. The groups who will use this dashboard most frequently are the student body, the facilities department, and the Office of Sustainability. Insight from these groups will allow the design of a utility monitoring dashboard to be tailored to their needs, allowing them to use the dashboard productively and ultimately maximize the sustainability benefits of implementing one.

Specifically, I sought to discover what features were essential when designing a dashboard for WPI and how each group of people may use it. I also wanted to learn about current sustainability project tracking methods and how a dashboard can improve these methods.

To gather the input of the different groups mentioned above, personal interviews were conducted. The interviews included the facilities deparment, the Office of Sustainability, and a faculty member with experience advising on-campus student projects. The project included coordination with the Institutional Review Board (IRB). The interviews for this project were conducted through online video call services such as Zoom and Microsoft Teams. These meetings were recorded and transcribed verbatim to be referenced throughout this project. Participants were asked to sign an informed consent form agreeing to this data collection and were consulted in the report preparation process. A copy of the informed consent form and the interview questions can be found in the Appendix. An interview method of data collection was chosen over a survey because the anonymity and scalability of surveys were not necessary for this project. The opinions expressed by the participants were inconsequential and could not be misconstrued or result in negative consequences; thus, anonymity was not required. Furthermore, the intimate scale of an interview allowed questions to be augmented, and the interviewees were more willing to elaborate on their positions.

The first interview was conducted with the director of facilities operations and the manager of energy and sustainability. These individuals were chosen to represent the facilities department positions because they have significant experience with facilities operations. The facilities department has access to WebCtrl. Thus, the dashboard would need features not currently present in WebCtrl, such as data analysis tools and easily exportable data. As seen in the Appendix, questions for this interview regarded features they would like to see for the facilities department, specifically surrounding WebCtrl. The interview also included questions about current sustainability projects on campus and how their effects are monitored.

An interview was also completed with a professor who works in the field of sustainability. This professor was intended to represent the faculty and the student body of WPI. Since a significant amount of students will use this dashboard for sustainability research and projects on campus, the input of an advisor for sustainability projects was important. Questions for this interview mainly included features they would like to see and potential uses for the dashboard.

Finally, input was collected from the head of the Office of Sustainability at WPI. The Office of Sustainability could benefit from an energy dashboard for compiling their annual sustainability report, as their current method for compiling the data is cumbersome and limited. However, with a dashboard, the Office of Sustainability can publish more frequent reports on energy usage and analyze which buildings can most benefit from improved sustainability practices. Questions for this interview were about why a dashboard has not been implemented and the needs of the Office of Sustainability.

The data from these interviews were used to recommend critical features for a dashboard for WPI. These features were then used when designing the concept for a dashboard.

3.2 - Investigating WPI’s Submetering Systems

For a resource monitoring dashboard to function, it needs to collect utility data from the submeters installed on each of WPI’s properties. However, WPI’s current submetering system is limited concerning exporting data. Thus, upgrades to the submetering systems must be made before a utility monitoring dashboard can be implemented. To understand what upgrades need to be made and their feasibility, a comprehensive understanding of the current submetering systems is required.

The purpose of this section was to understand better the submetering system at WPI, such as how they are being used, their limitations, and the costs involved with upgrading it. It also intended to compare WPI’s utility monitoring systems to other colleges.

Once again, to gather data in this section, interviews were conducted. These interviews followed the same methodology as the other interviews and were chosen for the same reasons mentioned in the previous section. The first of these interviews was conducted with the manager of building controls and maintenance, Kevin McLellan. Mr. McLellan has significant experience with WebCtrl and submetering systems at WPI. This interview aimed to assess WPI’s current utility monitoring infrastructure. The questions consisted mainly of how submeters work and how facilities use them. The questions also included the process and cost of upgrading submeters or installing new ones.

Another interview was conducted with the Vice President of Campus Planning, Eric Beattie. Mr. Beattie offered a unique insight into facilities operations and WPI’s infrastructure. With this interview, I sought to learn about upcoming sustainability projects and how the effects of those projects are determined. I also asked why a more robust utility monitoring system has not been implemented. Mr. Beattie also provided feedback as to which features he would like to see in a dashboard, and this was used for the previous section.

This data was used to analyze the submetering system of WPI and make recommendations to expand WPI's submetering system, such as installing electrical submeters on all WPI's properties and installing water or natural gas submeters. Emphasis was placed on exploring the financial aspect of improvements.

3.3 - Exporting Data

Before a utility monitoring dashboard can use data from a submeter, it must first be exported and stored in a readable format. Storing the exported data will also enable users to download data that can be analyzed by third-party software easily. Presently, there are no such systems for storing data from the submeters.

For this section, research was conducted into methods of extracting data from submeters. The intent was to create an automated system that could export data regularly. However, that turned out to be a significantly larger undertaking than I initially assumed because the technical infrastructure for this does not exist at WPI. To extract data for this project, the data available from WebCtrl was used. This allowed demand data from submeters to be downloaded as a CSV file. However, it cannot be automated. Thus, two available options for automating this process we explored. These options are a proprietary add-on for WebCtrl offered by Automated Logic called *Trend Export* and building a system of Raspberry Pi microcontrollers. There is a significant amount of documentation on creating a Raspberry Pi system for extracting data from submeters. I used this information to outline how to design this system for WPI.

The research from this section was used to make recommendations for future projects to develop a system of exporting data from submeters and storing it on a server where a dashboard can access it.

3.4 - Designing a Concept

For further development of this dashboard in the future, it would be helpful to have a visual representation of an ideal dashboard for WPI. This concept will lay the foundation for future projects and allow groups to focus heavily on implementation rather than design. Designing this concept led to essential discoveries on effectively presenting data using a dashboard. Specifically, the goal was to determine how to take the results from the previous sections and case studies and turn them into a visual medium. To accomplish this goal, it was necessary to determine the optimal layout for several key features in an engaging and academic way.

The concept dashboard was designed using Google Sheets and Photoshop. The data taken from WebCtrl was used in Google Sheets to create the graphs for the concept. These graphs were then exported as PNGs to be used in the final concept. Most of the design was done in Photoshop. Google Maps were used as a reference for designing the interactive map. The data collected from the interviews and case studies were heavily referenced when creating the concept. Results from this section would be used to make recommendations for the optimal design for a dashboard that future projects can use.

4 - Results

This chapter includes an analysis of key features that are needed for an effective dashboard. The data for these key features was collected from interviews and case studies of other institutions that successfully implemented a utility monitoring dashboard. Also included is a review of WPI's submetering system and the cost of improvement as well as potential savings from a dashboard. Finally, research was conducted into methods of extracting data from submeters and two potential solutions are proposed.

4.1 Interviews and Key Features

The first set of interviews were conducted to determine important characteristics different demographics would want in a potential dashboard. This is coupled with analysis of case studies to make conclusions about the optimal design for a dashboard.

4.1.1 Ron O'Brien and Nicole Luiz Interview

An interview was conducted jointly with Ron O'Brien and Nicole Luiz. Ron O'Brien is the director of facilities operations at WPI (Staff Directory: Ron O'Brien). He primarily manages maintenance, repairs, custodial, and grounds services at WPI. He also oversees the budgets and resource allocation for construction projects on campus. Nicole Luiz is the energy and sustainability manager at WPI (Staff Directory: Nicole E Luiz). She is a WPI alum responsible for developing and implementing energy projects. Both Ron O'Brien and Nicole Luiz work closely with WPI's Office of Sustainability.

The purpose of this interview was to gain insight into what features the staff, specifically the facilities department, at WPI would like to see in a dashboard, as well as the current sustainability initiatives and how they are being tracked. The following is a summary of the interview.

Nicole Luiz and Ron O'Brien agreed that having a dashboard would greatly benefit WPI's sustainability plans. Many goals within the sustainability plan involve reducing energy in certain areas on campus. Still, some areas lack a robust system for monitoring energy, so there may not be a way to measure energy savings. Currently, the only way the facilities department measures changes in energy are through monthly bills because not enough WPI properties have the submeters required to be accessed on WebCtrl.

One of the main benefits of improving the energy monitoring systems and implementing a dashboard would be increased knowledge of WPI's campus and its energy use. A dashboard would be able to identify abnormal spikes in energy and allow the facilities department to remedy the problem quickly. Furthermore, having it available to the public can influence their behavior and decrease personal energy usage. The dashboard can also confirm the energy savings estimates for sustainability projects on campus. Some features Ron O'Brien and Nicole Luiz believe can benefit the facilities department are a graphical representation of energy usage that can be filtered through various time frames. Public accessibility would also be beneficial since the WebCtrl software is restricted to staff and select students. Thus the dashboard should be visible to the general public, and the data should be downloadable in a usable format.

4.1.2 Derren Rosbach Interview

This interview was conducted with an environmental and sustainability professor at WPI, Derren Rosbach. Professor Rosbach teaches the Great Problem's Seminar: The World's Water, as well as a variety of other courses regarding environmental and civil engineering (Staff Directory: Derren Rosbach). His research focuses mainly on the human impacts on the environment and sustainability policy (Staff Directory: Derren Rosbach). Professor Rosbach is also part of WPI's Office for Sustainability.

This interview was aimed to learn how energy-related student projects are currently conducted at WPI and to determine the features of a dashboard that can be used for future sustainability projects on campus. The following is a summary of the interview

Professor Rosbach has advised between 50 to 100 projects regarding sustainability at WPI, many of which involved the need for energy data. He stated that this data has historically been difficult to access or non-existent. Improving the submetering system at WPI and implementing a dashboard would fix this problem. A dashboard can also improve awareness of energy usage, which can affect behavior and ultimately can help achieve sustainability goals, save money, and reduce carbon emissions. Professor Rosbach suggested that a dashboard should use the smallest time increment possible when displaying the data to represent energy usage accurately. He also believes that equivalencies and visuals would help the general public relate to energy usage and cause them to be more invested. However, it was also mentioned there must be a balance between user-friendliness and academic usage. A dashboard that is too simple yet easily understood may not be useful for academic projects. At the same time, an overly complex dashboard can alienate users and not affect their behavior.

4.1.2 Input From the Office of Sustainability

While a formal interview was not conducted with Paul Mathisen, the head of the Office of Sustainability at WPI, he did offer some critical input for developing and implementing a dashboard. Below is a summary of his responses. This input was collected because the Office of Sustainability has a large stake in sustainability on campus and they will be the ones to advocate for and promote a dashboard.

Prof. Mathisen believes that there are significant benefits of implementing a utility monitoring dashboard at WPI; which include better understanding resource allocation across campus, increased awareness of energy usage and it can serve as a valuable tool for facilities. Despite these benefits, he feels that because of lack of awareness and that the financial returns of a dashboard have not been clarified. This may explain why a dashboard has not been implemented yet.

Effectively engaging and communicating with students will be critical in the implementation of a dashboard. Prof. Mathisen said that communication, time-commitments and differing priorities are the largest barriers in getting students to participate in sustainability efforts. Emails, posters, social media and reaching out to student organizations has been effective in getting student to participate. Thus these methods should be used to promote the dashboard.

Finally, Professor Mathisen believes the following characteristics are important for a utility monitoring dashboard. It should provide real-time data so that users can clearly see the effects of their behavior on utility usage. This data should also be expandable between different time periods so that long term effects of sustainability initiatives can be seen. Also, an easy to navigate graphical user interface should be included.

4.1.3 Summary of Interviews on Key Features

From the interviews, several features were requested that each group had in common. The most frequently mentioned feature was a way to visualize real-time data, such as a graph that displays energy usage over a variable period. Another important feature would be a way to download the data from the dashboard easily. Finally, considerations must be made to make the dashboard usable in both an academic and personal sense.

4.1.4 Details on Data Visualization for a Dashboard

Since most of the interviews requested that the dashboard include a way to visualize the data, case studies were analyzed to determine the most effective method of communicating the data. In particular, a research project was done In 2016 by students at UC Davis to iteratively design a dashboard that accomplished this objective. One of their main goals was to design a dashboard to be simple and usable without over-simplifying what was being conveyed (Salmon, et al. 2016). This study concluded that a map-based dashboard was more enjoyable and informative than a bar graph (Salmon, et al. 2016, p.7). An example of this type of dashboard is shown in Figure 6. The map-based dashboard was also perceived as significantly more trustworthy than a bar graph dashboard (Salmon, et al. 2016, p.7). These findings contradict the case studies in Section 2.4, which all used bar graphs to convey their data. If WPI uses a map-based dashboard then there is potential for more engagement and greater energy savings than these institutions.

Fig. 6. UC Davis's CEED Map-Based Dashboard (Salmon, et al. 2016).

However, bar graphs should still be included in the dashboard because they are superior for academic analysis. Bar graphs can also convey data over time unlike an exclusively map-based design. These graphs do not necessarily need to be visible at all times for a casual user.

Another important consideration when developing a dashboard is to avoid emotionally loaded colors or language when comparing buildings (Salmon, et al. 2016). In an early prototype of their dashboard, building icons were colored on a scale from green to red, corresponding with low to high energy usage. This implied that certain buildings were worse for using more energy when many factors determine a building's energy usage. When shown this version of the dashboard, students were curious as to why certain buildings used more energy than others and what contributed to energy usage (Salmon, et al. 2016, p.7). Thus an explanation of a building's energy usage should be included on a dashboard.

4.1.5 Summary of Key Features

In summary, an effective dashboard should include the following features:

- Public facing
- Map-based user interface
- Exportable data
- Energy intensity scale
- Brief overview of energy usage and contextualization
- Real-time electricity and water usage graphs
- Historical electricity and water usage graphs
- Comparisons between buildings and a baseline
- Introduction on how to use the dashboard

4.2 WPI’s Submeter System and Expansion

The next set of interviews were conducted with Eric Beattie and Kevin McClellan. The interview with Mr. Beattie was to understand facilities operations on a macro level. Mr. McClellan’s interview was more focused towards the technical side of submetering. Inputs from these interviews were then used to analyze WPI’s submetering system and determine the costs of improving the submeter system.

4.2.1 Eric Beattie Interview

The next interview was with the Vice President of Campus Planning, Eric Beattie. Mr. Beattie oversees the operational performance of campus planning, facilities operations, construction, and sustainability infrastructure (Eric Beattie, 2018). He works closely with the Office of Sustainability and has implemented multiple sustainability projects at WPI.

The purpose of this interview was to learn about the upcoming sustainability projects at WPI and the ways that WPI currently monitors its energy use, as well as improvements that can be made to that system.

In recent years, WPI has replaced fluorescent light bulbs with LED light bulbs across campus and installed variable speed drives on electrical motors in the power plant. They also improved the HVAC system in several buildings. The funds from these projects came from WPI’s Green Revolving Fund, which grants sustainability projects a certain amount of money based on how much they save the campus compared to a baseline (Sustainability Report, 2020). The amount of energy saved is based on a theoretical model because not all WPI’s properties are submetered, so measuring the actual energy savings is impossible. Improving the WPI submetering system will allow for more informed decisions and a way to verify the energy models. These improvements will also increase awareness of potential problems in buildings.

WPI has plans for multiple sustainability projects soon. There are plans to overhaul the powerplant on campus to improve its efficiency and potential investments into on and off-campus solar farms. Given the method by which WPI funds sustainability projects, it is important to have a way to measure the value of these projects. A dashboard for monitoring energy use would be a feasible method for this. Energy dashboard projects have been proposed in the past; however, they lacked clear objectives and values that would enable them to move forward. Mr. Beattie suggested that a successful dashboard should include a tangible, easy-to-understand interface that can influence the user's behavior. The dashboard should also have detailed, real-time data that can be expanded for various periods. This data should also be easily exportable for projects and analysis.

4.2.2 Kevin McLellan Interview

This final interview was conducted with Kevin McLellan who is the manager of building controls and maintenance at WPI (Staff Directory: Kevin McLellan). Mr. McLellan primarily oversees HVAC-related projects and maintenance. He has significant experience with WebCtrl and metering systems. This interview was conducted to gain insight into WPI’s current submetering system and the feasibility of improvements. The following is a summary of this interview.

The primary use of the submeters present on WebCtrl is to measure the decrease in energy usage during a curtailment. Curtailments are orders from an electricity company that involve lowering unnecessary power to decrease the strain on the electrical grid during abnormally high energy usage. The current submetering system works for this process because the required energy reduction can be seen on the campus' main meter. WebCtrl is ineffective for measuring energy reduction for any building because only a few buildings are directly monitored on WebCtrl.

WPI historically had a more robust network of submeters. However, the software they used became unsupported, and only a handful of these older submeters were BACnet compatible. The buildings with BACnet electrical meters have been added to WebCtrl and all new buildings. The list of these buildings can be found in the table below:

Table 1:

Complete List of Buildings Monitored by WebCtrl

Atwater Kent	Harrington Auditorium
Boynton Hall	Morgan Hall
Ruban Campus Center	Olin Hall
Daniel's Hall	Recreation Center
Innovation Studio	Salisbury Labs
Gordon Library	Stratton Hall
Goddard Hall	

There are only two water submeters on campus (WebCtrl, Accessed 2022). One for the swimming pool located in the Recreation Center and another for the water fountain at the center of campus. Mr. McLellan has used the water fountain's submeter to identify underground leaks that otherwise would have been unnoticed. The submeter allowed these minor problems to be corrected quickly and before critical issues occurred.

Upgrading the old submeters to be BACnet compatible is expensive and complicated, and there are no noticeable fiscal returns on their own; thus, most have not been upgraded. Mr. McLellen estimates that a new submeter and installation cost would be approximately $5000. The estimates to add a water meter to a building are significantly lower, at approximately $2000. The price discrepancy is because the water meter is less expensive, and installing an electrical submeter is significantly more challenging and cannot be done live. These values are supported by the U.S. Environmental Protection Agency which estimates the "average installed cost of an electricity sub-meter with data acquisition software is about $6300 per location" (Sub-Metering Energy Use in Colleges, 2002).

4.2.3 WPI's Submeter System

In order for a utility monitoring dashboard to function it needs to collect data from submeters. Most submeters on WPI's campus lack the ability to transmit data, so before a dashboard can be installed, improvements must be made to the submetering system.

An IQP from 2016 compared WPI's energy submetering systems to its benchmark institutions and discovered it was "15-25 years behind peer institutions in advanced energy monitoring systems installation" (Adams, et al. 2016, p. 35). Cornell University started its energy monitoring program in the 1980s, and Clark University started in 2001 (Adams, et al. 2016, p. 35). WPI has not modernized its energy monitoring system since this IQP was submitted, meaning they are significantly behind their peer universities.

As stated previously, upgrading this system would involve significant financial and labor investments with no clear returns. However, some benefits of improving the submetering system include verifying utility bills and energy project estimates, identifying problems with utilities, and for research projects on campus. Furthermore, when coupled with the implementation of an energy monitoring dashboard, upgrading the submetering system can benefit the university financially through improved sustainability practices. As seen in the case studies. Institutions that have installed dashboards have seen decreases in energy use of five to twenty percent for each building included on the dashboard.

Table 2 shows the estimated financial returns on implementing a utility monitoring dashboard and improving the submeters for each of WPI's properties. The data was extracted from utility bills for the 2021 fiscal year, and a conservative estimate of five percent savings from the baseline were used with an estimated $7500 to install new submeters. The value of $7500 came from Kevin McLellan's interview and the EPA. The savings of five percent were the approximate annual energy savings per building from CWRU's dashboard. The raw data used for this table can be found in the Appendix. Properties such as WPI Townhouses with multiple submeters had their utility data consolidated to a single value.

Table 2:

Utility Costs for WPI's Properties

Building	Address	Electricity ($)	Water ($)	Potential Annual Savings from Baseline ($)	Time to Recuperate Installation Cost (Years)
West St. Main Meter	West St.	868,416.89	122,520.10	49,546.85	<1
Project Center	West St.	-	29,793.03	-	<1
Campus Center	206 West St.	-	24,710.01	-	<1
Higgins Lab	190 West St.	-	14,388.56	-	<1
Harrington Auditorium	204 West St.	-	10,948.06	-	<1
Olin Hall	208 West St.	-	10,000.26	-	<1
Goddard Hall	210 West St.	-	9,722.65	-	<1
Boynton Hall	West St.	-	8,393.85	-	<1
Gordon Library	209 West St.	-	7,636.39	-	<1
Stratton Hall	185 West St.	-	3,472.55	-	<1
Atwater Kent	215 West St.	-	1,288.71	-	<1
Salisbury Labs	West St.	-	1,135.01	-	<1
Alden Hall	180 West St.	-	1,031.02	-	<1
Gateway	60 Prescott St.	283,008.53	26,041.28	15,452.49	<1
Recreation Center	100 Institute Rd.	153,228.65	32,544.81	9,288.67	<1
Faraday Hall	75 Grove St.	69,433.39	44,143.25	5,678.83	1.3
Stoddard Complex	Hackfeld Rd.	66,500.64	16,647.40	4,157.40	1.8
WPI Townhouses	Park Ave.	67,588.46	12,108.22	3,984.83	1.9
Mass Academy	85 Prescott St.	63,620.42	-	3,181.02	2.4
East Hall	30 Boynton St.	58,813.39	-	2,940.67	2.6
Founders Hall	26 Boynton St.	46,820.53	-	2,341.03	3.2
Ellsworth Apts.	85 Institute Rd.	20,249.82	11,273.34	1,576.16	4.8
Elbridge Apts.	Elbridge St.	21,672.57	6,042.25	1,385.74	5.4
Fuller Apts.	79 Institute Rd.	19,016.50	6,612.39	1,281.44	5.9
Schussler Apts.	Schussler St.	17,875.74	2646.57	1,026.12	7.3
Trowbridge Apts.	Trowbridge St.	13,210.28	1,955.39	758.28	9.9
Gateway Garage	31 Garden St.	12,098.62	14.5	605.66	12.4

Table 2 (Continued):

Utility Costs for WPI's Properties

Building	Address	Electricity ($)	Water ($)	Potential Annual Savings from Baseline ($)	Time to Recuperate Installation Cost (Years)
President's House	1 Drury Lane	9,213.49	780.32	499.69	15.0
Facilities Building	37 Lee St.	8,151.16	863.11	450.71	16.6
67 Wachusett	67 Wachusett	5,540.81	1,115.55	332.82	22.5
Counseling Center	157 West St.	2,435.52	174.06	130.48	57.5
2 Elbridge & 9 Boynton St.	2 Elbridge & 9 Boynton St.	1,793.74	1,019.22	140.65	53.3
Hughes House	15 Regent St.	1,750.61	302.22	102.64	73.1
Einhorn Apts.	Einhorn Rd.	1,626.19	1,516	157.11	47.7
53 Wachusett	53 Wachusett	316.19	174.06	24.51	306.0

† Buildings highlighted in yellow have a BACnet electricity meter. A green highlight indicates both electrical and water meters.

4.2.4 Example Calculation

The following equations show how the estimated annual savings and time to recuperate costs were calculated.

*Potential Annual Savings = 0.05 * [Electricity($) + Water($)]*

The equation above simply uses the estimate of 5% savings, and multiplies it by the sum of yearly utility costs for each building.

Time to Recuperate Costs = 7500$ / Potential Annual Savings

This equation uses the estimated installation cost of $7500 for new submeters and divides it by how much money the building will save once they are installed to determine how long it will take to pay itself off. This is a rough estimate because it was determined for each building individually, when in reality the savings from other buildings can be reinvested to offset costs.

4.3 Extracting Data Methods

The goal of data extraction is to take the demand of each building and save it as a file on a designated server whereupon the dashboard can use it. Due to time constraints and technical limitations, an automated system for downloading and uploading data for the concept cannot be included with in the scope of this project. For the concept, trend data was directly downloaded for use. This was accomplished by using WebCtrl's built-in manual download feature for the demand of each property currently listed on WebCtrl. This is not a viable solution for a real-time dashboard; thus, two alternative methods are outlined below.

4.3.1 ALC's Trend Export Add-On

As power is supplied to a building, it initially flows through its main meter, where the demand is recorded and can be used for billing. However, certain submeters are equipped with circuits that can communicate with control boards, such as the ones used by ALC. From here, data is transmitted to WebCtrl, where Automated Logic's Trend Export add-on can be used to export the data from the submeter. This add-on allows users to "specify, manage, and export trend data from the WebCTRL building automation system" (Trend Export, Accessed: 2022). This add-on can be programmed to download data from WebCtrl at scheduled intervals and stored on a server hosted by WPI's IT department (Trend Export, Accessed: 2022). The data from the submeter will now be in a readable format and can be used by a dashboard. This process of data transmission can be seen below in Figure 7.

Fig. 7. Block Diagram showing the path of demand data through WebCtrl.

WebCtrl only collects data from submeters at a minimum of every fifteen minutes. This means the lowest latency possible for a dashboard using ALC's Trend Export add-on will also be fifteen minutes. This is arguably sufficient to be considered a real-time dashboard as a shorter time interval will not be significantly more meaningful given the goals of this dashboard.

4.3.2 BASpi System

Alternatively, as power is supplied to a building and routed through the main meter, a BASpi controller can be used to collect the demand data from the submeter via an ethernet connection. A BASpi board is an expansion board for a Raspberry Pi, which are microcontrollers that can be programmed for various tasks (BasPi-IO, Accessed: 2022). The BASpi board allows a Raspberry Pi to serve as a BACnet network (BasPi-IO, Accessed: 2022). Data collected from the BASpi can then be wirelessly transmitted to a server where it can be stored and accessed by a dashboard.

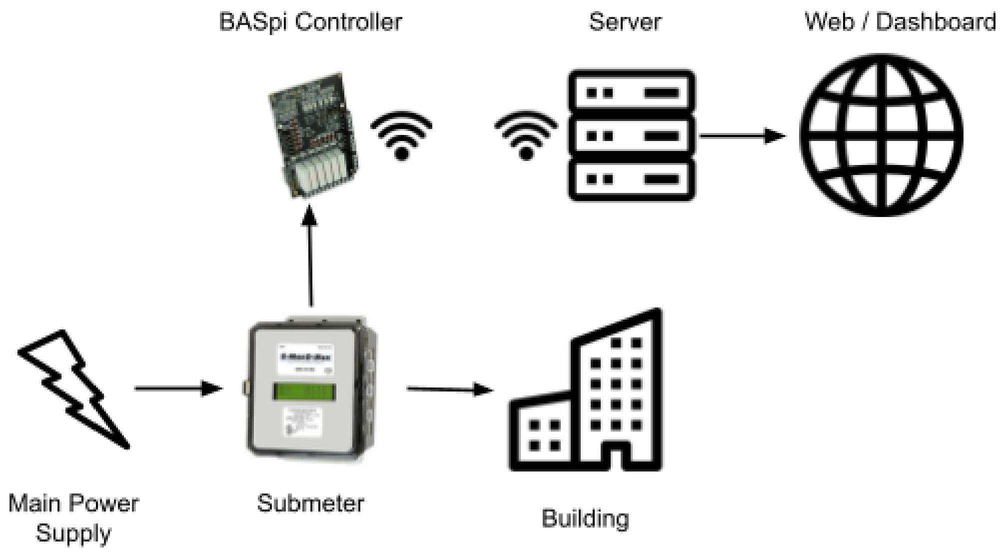

Fig. 8. Block Diagram showing the path of demand data through a BASpi system

These boards come equipped with free firmware and programming tools that can be used to schedule data transmissions (BasPi-IO). The BASpi board is inexpensive relative to the cost of a submeter and should be simple to install. This method would mean that the data could be exported directly from the submeter rather than through third-party software like WebCtrl. This system also allows for more flexibility in how frequently the data is collected and transmitted.

4.3.2 Comparisons Between Methods

Table 3 shows the advantages and disadvantages of WPI implementing each method mentioned previously. This table can be used when determining which method should be implemented for an energy monitoring dashboard.

Table 3:

Advantages and Disadvantages of Submeter Data Export Methods

	ALC Trend Export	BASpi
Advantages	WPI already uses ALC's services and has technicians trained in using them ALC control boards already exist in most WPI properties	Lower Latency Less expensive Can wirelessly transmit data Can be used alongside ALC's control panels
Disadvantages	15 minute latency Expensive to install if a building does not have an ALC control board WPI may not use ALC in the future	New system that would require further research

5 - Recommendations

The following section contains recommendations made based upon the data collected in this project. Its recommended that all submeters be upgraded to have BACnet compatibility, any future dashboard should follow the concept design in this section and once implemented the dashboard should be actively used to reduce utility usage.

5.1 Submetering Upgrades

WPI properties without BACnet compatible submeters should be upgraded such that they can be monitored through WebCtrl or similar services.

WPI's current submetering system is outdated and desperately needs to be upgraded. The institution is currently decades behind its peers regarding energy monitoring, and improving the submeters is the first step in catching up (Adams, et al. 2016). It is recommended that WPI continue to upgrade its current electrical submeters to ones with BACnet capabilities. Furthermore, water submeters should be installed on all of WPI's properties. The data from these meters can be used to verify utility bills, identify problems, research projects, and a utility monitoring dashboard. While it was not within the scope of this project, further research should be done into expanding the submetering system to include natural gas meters on WPI properties.

Assuming that these system upgrades cannot be completed simultaneously for all properties at WPI, buildings with the highest utility usage should be prioritized. Higher utility usage corresponds to more traffic; thus, collecting data from these buildings will maximize the benefits of an improved submeter system and a utility monitoring dashboard. It is highly recommended that Gateway be improved first as it has the highest electricity usage of any single building owned by WPI. Next, electrical and water submeters should be installed for residential complexes such as Faraday Hall, WPI Townhouses, East Hall, Founder's Hall, and Ellsworth Apartments. These properties use the most water and a considerable amount of electricity. Since these properties are residential, most of their energy usage is behavioral; thus, these properties have the potential for a significant reduction in utility usage.

Finally, it is recommended that a system for storing data from the submeters is developed. WPI's IT department should host a server where data can automatically be stored. Further IQPs or MQPs should develop a method of extracting data from submeters through WebCtrl's Trend Export or a Raspberry Pi network. Data from the submeters should be stored in an appendable file rather than individual files. Data stored on this server can be easily accessed for research projects or by a dashboard.

5.2 Dashboard Implementation

A real-time, public-facing utility monitoring dashboard should be developed to promote better sustainability practices and offset the costs of upgrading submeters. The dashboard should follow the concept design closely and include the features outlined in this section.

The figures in this subsection are a concept layout of a dashboard I designed. The results of this project were used to determine the features and layout; thus, following a similar design in the future is recommended. The electrical data shown in the concepts were taken from WebCtrl from July 8 through August 8. The water data was taken from bills for the month of July 2021.

Figure 9 shows the main page for the concept dashboard on WPI's website. Some key features include a large, interactive map that shows the current demand for each building. Buildings with higher demand are colored darker than buildings with low demand, which avoids the emotional implications of a multicolored intensity scale. To the left is a collapsable display that includes a graph and totals of the utility usage. This graph compares each building on campus and can be expanded from daily usage to weekly to monthly.

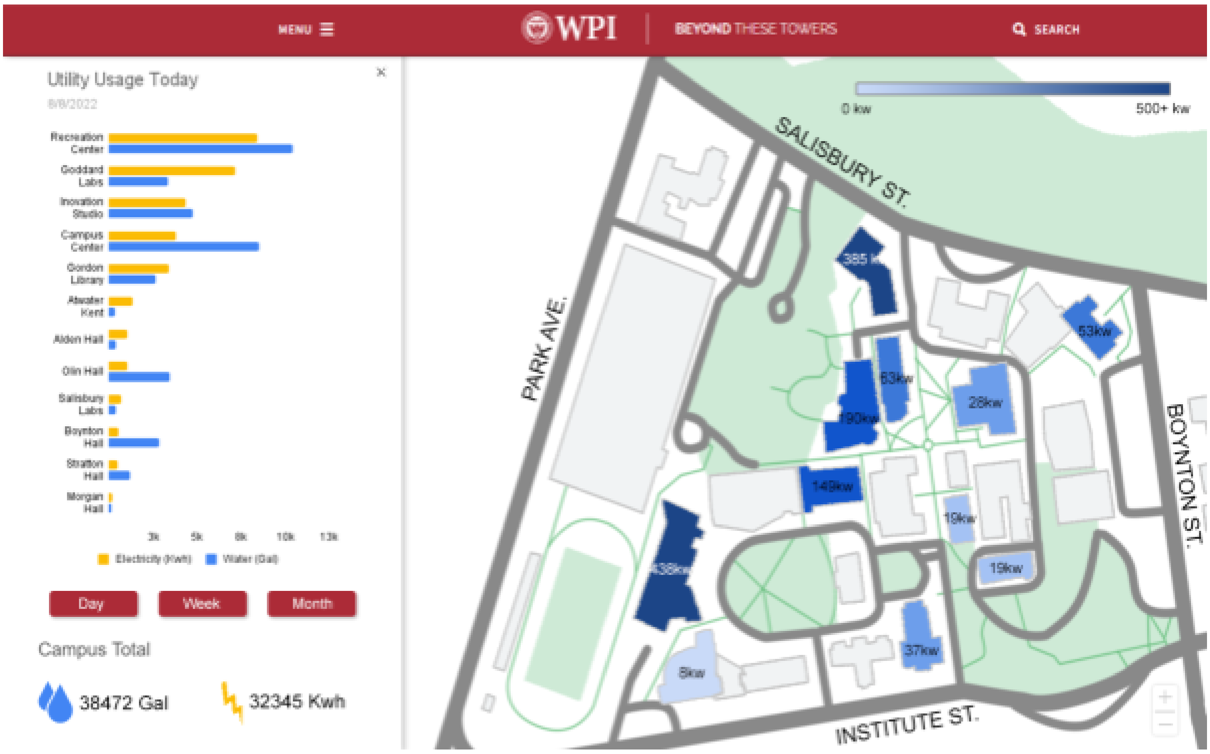

Fig. 9. Concept showing the main page for WPI's dashboard

Figure 10 shows a subpage for the dashboard. The campus map remains visible while the subpage is open to allow users to switch between buildings easily. The subpage is headed by a picture of the building and its name. Below is a graph showing the real-time demand. This graph can also be expanded from day to week to month. Finally, the subpage has two download links. The CSV link will download the data, and the PNG link will download an image of the demand graph. The features in Figure 10 were taken from the interview with Derren Rosbach who suggested the dashboard be balanced between casual and academic use. The map-based part has been shown to be the most user-friendly way to display data, while the detailed demand data plot and download features allow for academic use.

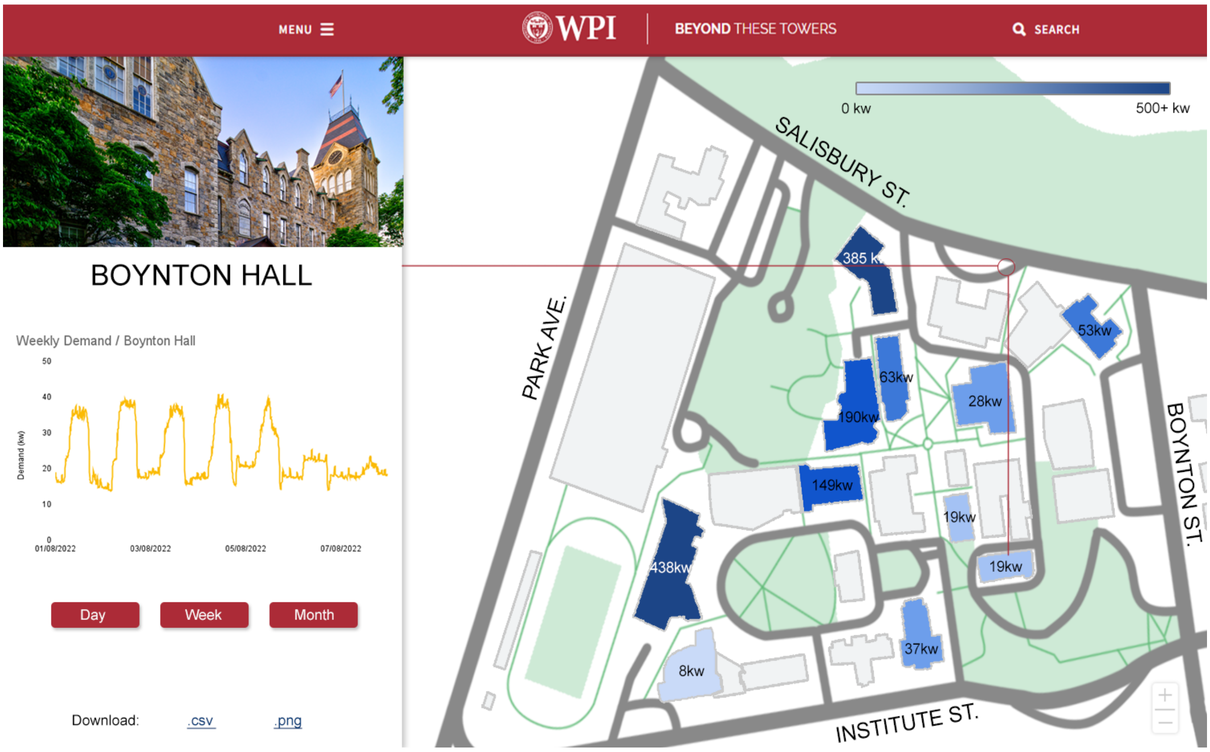

Fig. 10. Concept showing the Boynton Hall sub-page for WPI's dashboard

The concepts above show an ideal dashboard for the currently available data, however, if the submetering system is improved, the following features should be included:

- The ability to switch between electricity and water demand on the map
- A water demand graph on each subpage
- A baseline building for comparison on the main page
- Equivalencies for electricity and water usage
- A pie graph showing how electricity is allocated in each building

5.3 Dashboard Usage

Once implemented, the dashboard should be actively promoted and used to incentivize energy conservation efforts on campus.

To effectively engage the WPI community to use the dashboard, it should be easily accessible. The dashboard should be available on WPI's website as a link under the "menu" tab of the header. This allows the dashboard to be easily located and seen by the greatest number of people. Additionally, the dashboard will provide the Office of Sustainability with a method to more quickly produce reports thus, weekly or monthly sustainability reports can be distributed to the community through WPI's website, WPI's social media, or emails. Increasing the frequency of sustainability messaging is a goal in WPI's sustainability plan, which can be accomplished through these reports and the dashboard.

The Office of Sustainability can also host energy conservation competitions to increase community engagement and encourage them to use the dashboard frequently. Energy conservation competitions are commonplace among institutions with energy monitoring systems. As stated previously in this report, Case Western University hosts annual competitions between dormitories. The winning dormitory receives a tree planted in their name (CWRU Unplugged! 2021). These competitions have been shown to decrease utility usage in participating buildings significantly.

The competition can be promoted using emails, posters and WPI’s social media accounts. It should be clearly stated in these promotions that the goal is to reduce energy usage in each building and should include common approaches to reduce behavioral energy usage and links to the dashboard. Depending on the duration of the competition, a baseline should be created. For example, for a year-long competition, the previous year’s data should be used as a baseline. After the competition ends, the building with the largest percent decrease in energy usage will win a prize. It is recommended that these competitions be held between residential properties as they have the most potential utility savings and the savings can be attributed to a specific group of people.

Table 2 shows that WPI can expect to save approximately $100,000 annually from baseline utility costs with the proper dashboard implementation. This money can be used to fund the prizes for competitions, hire a technician to develop and maintain the dashboard or be reinvested into other sustainability projects on campus.

Further research can be conducted into the most effective ways of communicating sustainability reports and promoting a dashboard. This research should also investigate the most effective incentives for energy conservation competitions. It is recommended that a survey be conducted with students and faculty to determine this.

6 - Conclusion

Creating and implementing a web-based resource monitoring dashboard at WPI and appropriate engagement efforts with students will positively impact the energy usage on campus, as evident through similar programs at other schools. First, WPI’s submetering system must be upgraded to be on par with its peer institutions. A system for extracting and storing data must be developed. Then a public-facing utility monitoring dashboard can be implemented. Accomplishing these goals will place WPI ahead of its peer universities regarding energy monitoring and transparency. This dashboard can financially benefit WPI and accomplish its sustainability goals by engaging the community to conserve electricity and water. The dashboard will also be a powerful tool for student projects and the facilities department.

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Appendix A - Interview Questions and Consent Form

Interview Questions - Sustainability Professor (Derren Rosbach)

The purpose of this interview is to determine potential future projects that can benefit from an energy monitoring dashboard. This interview will be referenced when designing the dashboard and making recommendations for future projects.

- What projects have you advised in the past? (Particularly regarding sustainability)
- What do you think would be the benefits or disadvantages of a dashboard?
- Would an energy monitoring dashboard be useful for future projects on campus?
- How important is tracking energy usage in regards to sustainability practices?
- Would projects that attempt to reduce WPI's utility usage benefit from this dashboard?
- What types of projects do you think could benefit from an energy monitoring dashboard?
- What features would be useful for sustainability projects? Would easily accessible data be helpful?

Interview Questions - Facilities Department (Ron O'Brien, Nicole Luiz)

This interview aims to determine what the Facilities Department needs from an energy monitoring dashboard. This interview will be referenced when designing the dashboard and used when discussing future projects.

- Have you considered implementing an energy monitoring dashboard before?
- What do you think would be the benefits of a dashboard?
- Does the facilities department have any specific energy reduction goals?
- Is WebCtrl used to track energy usage data and analyze energy reduction goals?
- What tools and features would you want from an energy monitoring dashboard?
- How do you think the facilities department specifically can use this dashboard to reduce energy usage on campus?

Interview Questions - Office of Sustainability (Paul Mathisen)

The purpose of this interview is to determine what the Office of Sustainability needs from an energy monitoring dashboard. This interview will be referenced when designing the dashboard and used when discussing future projects.

- Have you considered implementing an energy monitoring dashboard before?
- What do you think would be the benefits or disadvantages of a dashboard?
- Does the Office of Sustainability have any specific energy reduction goals?
- What are the current methods of tracking energy usage?
- Do you think more frequent energy reports would help improve sustainability?
- What data would you want for publishing reports?
- Do you think data alone would convince students and faculties to change their behavior around energy usage or would visuals be helpful?
- Would energy conservation contests be feasible? Would you be interested in conducting said contests if a dashboard was implemented?

Interview Questions - Head of Building Management (Kevin McLellan)

The purpose of this interview is to gain insight into WPI's existing submetering systems, particularly the logic behind where they are installed, and determine whether expanding the system would be necessary and feasible. This interview will be used when discussing potential improvements to the submetering system.

- What are submeters and how often do facilities use them?
- What type of submeters does WPI use (electric, water, natural gas)?
- Why are those particular types used or not used?
- Where are these submeters installed?
- Why is the submetering limited to those properties?
- How difficult is it to install new submeters?
- Do you think WPI can benefit from expanding its submetering system?

Informed Consent Agreement

Investigator: Benjamin Rajotte

Contact Information: bcrajotte@wpi.edu

Title of Research Study: Improving Sustainability Efforts Through The Development of an Energy Monitoring Dashboard

Sponsor: Professor Mathisen

Purpose of the study: This study aims to gather data regarding the development of an online energy monitoring dashboard at WPI.

Procedures to be followed: Participants will initially be asked to read and sign this consent form. Then questions will be asked by the investigator either in person or via an online calling service such as Zoom. Their responses to these questions will be recorded verbatim. These interviews will be the entire duration of the subject's participation in this study.

Risks to study participants: There are no foreseeable risks or discomfort for participating in this study.

Benefits to research participants and others: There are no benefits to the subject

Record keeping and confidentiality: The investigator and IRB will keep a record of this study. The records will include a transcript of the participant's interview and it is expected that sections of the transcript will be included in the final report of this project.

Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee, and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of an injury: This research does not involve more than minimal risk of injury or harm thus no compensation need be provided. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

Investigator: Benjamin Rajotte, Tel. 978 227-2538, Email: bcrajotte@wpi.edu

IRB Manager: Ruth McKeogh, Tel. 508 831- 6699, Email: irb@wpi.edu

Human Protection Administrator: Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures whenever they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

______________________________ Date: _____________________
Study Participant Signature

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Study Participant Name

Appendix B - Transcripts

Ron O’Brien and Nicole Luiz Interview Transcript

Ben Rajotte (Investigator); First off, have you considered implementing an energy monitoring dashboard before?

Ron O’Brien (Director of Facilities Operations): I'm happy to answer that. Yes, that was one of the first things we considered when I took over my role two years ago. I know it was only two years ago, but it was a critical piece to understand where we are and identify incremental changes associated with our various projects. It's a key aspect of achieving our sustainability goals.

Nicole Luiz (Energy and Sustainability Manager): Yeh, I would agree. I’ve seen other IQPs that have done something similar in the past, although I wasn’t in my position before April. But I agree that it's definitely important to be able to easily measure so we know if we’re hitting our goals.

Ben Rajotte: That’s the next question actually, does the facilities department have any specific energy monitoring goals currently, or are you just using the WPI sustainability plan?

Ron O’Brien: Nicole, I’ll defer to you on this.

Nicole Luiz: Yeh I’ll say that you’re right about that, Ben. There aren’t any specific facilities goals besides the *operations and facilities* part of the sustainability plan. I know you’ve seen the five-year sustainability plan and there are a handful of goals in the facilities and operations section. I don’t believe that energy monitoring is a specific goal. Still, there are a lot of tasks and goals related to reducing energy so being able to do the energy monitoring will give us better insight. We had a meeting this past week and we were looking at one of our goals related to IT infrastructure and how much energy our servers are using in Fuller Labs. The issue is that we have a goal in this specific area but we don't have good metering data on that area. So it's hard for us to look at what our baseline was and reduce from it if we don't have that data to work with. So it's not a specific goal, but it is embedded in the goals - it's like a task we need to do in order to achieve our other goals.

Ben Rajotte: How are we currently tracking energy between buildings? Are facilities using WebCtrl to do that or are we using bills?

Ron O’Brien: Through bills. We have submeters in various buildings but we’re not utilizing them. We should be. This IQP and future IQPs should help us get there.

Ben Rajotte: Related to the dashboard, since facilities do have Webctrl. What kind of features would you want from a dashboard that WebCtrl does not offer? Something like more accessible data or being public -

Nicole Luiz: I think that's a good one honestly. Having students or the public be able to see and assess the data and be able to download it and play around with it. We were talking earlier in this conversation that we'd have to jump through hoops to get certain WebCtrl things through IT. So not to say it would be impossible through WebCtrl but it could potentially be easier if we had something separate from that.

Nicole Luiz: I also think that if you're looking for other features, the ability to easily look at the data set and look from year to year or month to month and be able to easily navigate between different time parameters and have the flexibility in how you view the data since many people are probably interested in viewing the data in different ways. I think having a variety of ways the data can be viewed and filtered would be helpful.

Ben Rajotte: This isn't a question I had before but why don't we use WebCtrl more often to track energy? Are the bills more convenient somehow?

Ron O'Brien: I think it's ignorance. I don't know how to use it, I don't think we have any staff that's engaged in it, we have other fires we have to put out all day long. So part of this IQP could be training us in how this could work and the best way to utilize this information and use WebCtrl.

Nicole Luiz: And I don't think all the data we have in bill format is the same we can find in WebCtrl. Because if it is in WebCtrl it has to have some control component and we have buildings and spaces that don't have that level of control so we're just deferring to the bills.

Ben Rajotte: What do you think would be the benefits of an energy monitoring dashboard?

Nicole Luiz: To echo some of the stuff we talked about before, being able to measure our energy data makes it easier to reach our goals in a variety of ways and it can help if there are specific buildings or areas that we have submeters on that more granular information can provide more insight into potential problems or areas that are using a lot of energy for no explainable reason. So it can help open up areas of "ok we're seeing this space is using a lot of energy and were not sure why and we can investigate it more". And if we don't have that level of granular energy monitoring information we might not know there is an issue in that building. So information is power and gives you a lot to work with.

Ron O'Brien: As we said before, as we implement projects, we can mark the progress with monitoring. And then making it open to the universe, other people can see and a fair amount of our energy use is behavioral, so we can influence the behavior of people and we can create a feedback loop. I think that is an interesting aspect too that can benefit the university.

Ben Rajotte: Going off that, how do you think facilities specifically can use this dashboard to improve sustainably on campus?

Ron O'Brien: It's the classic operation "you can't improve what you don't measure" so having the feedback - we kind of cover a fair amount of this question with your last one. I think without feedback and without seeing what our actual use is and how changes impact or reduce our use, we can never really forecast our goals, we can never predict what it would cost to do something we could never effectively put plans together to reduce our energy use and reduce our carbon footprint.

Ben Rajotte: Does the facilities department have any sustainability projects coming up?

Nicole Luiz: We are actually in the process of developing a large number of lighting projects. So upgrading existing fluorescent lights to LED. So we know this will create a certain amount of energy savings and after the project is complete it would be really nice to compare a before and after. What the energy use is in specific buildings where we're changing the lights. Just to confirm because we're working with contractors and they give you an energy savings estimate based on the fixtures that they're putting in but it would be good to confirm those numbers and that information and see it reflected in both the energy monitoring system and our bills to confirm that were saving what we're hoping to save.

Eric Beattie Interview Transcript

Ben Rajotte (Investigator): Have you worked on an energy monitoring dashboard in the past or seen similar projects be proposed?

Eric Beattie (VP of Campus Planning): I have not actually. We had talked about doing it on a few different projects but I don't think we've ever actually gotten one online before.

Ben Rajotte: Why do you think it hasn't gone through yet?

Eric Beattie: It could be that the objectives weren't completely clear about what are the benefits, why are we doing this, and because the value wasn't clearly spelled out. I think people just moved on and the work never got completed.

Ben Rajotte: If we were to implement an energy monitoring dashboard, what features would you want to see in it?

Eric Beattie: I think part of the challenge we have in engaging with a lot of people to take energy conservation seriously is that they can't relate. They understand the big picture, that it's important and we should try not to wastefully consume energy. But I think people often don't know that things that they do will make a difference and it's just not tangible for them. So I think if the public, we'll say, our guests, our students, our faculty, our staff could actually see a measurement of a building's energy. And I think it should be more than that, probably, but I think to actually see something that's happening in real-time and the ability to trend it backward could help people to see that the energy consumption on campus is significant and it may get people engaged enough to try to reduce and shut the lights off and all these different things that can add up when everybody does it.

Eric Beattie: I think that's one of the benefits. The other is just general access to the data, for people to be able to analyze and do scenarios and forth. To have that in a more conveniently retrievable place or a format that is more useful for people would also serve student projects well. It can serve some of our staff well to make better decisions with more accurate, detailed information.

Ben Rajotte: Do facilities track energy usage in regards to their sustainability projects? If so, how do they do it?

Eric Beattie: The answer is yes. And when you say sustainability projects, like we've implemented a number of energy conservation projects over the last several years. Is that what you're talking about?

Ben Rajotte: Yes. I think the most recent was changing to LED lightbulbs.

Eric Beattie: Yes, we've done that a few times in different buildings. We do a lot of other things too. Installing variable speed drives on motors to reduce motor electrical consumption, HVAC improvements, and stuff like that. So when we do those, what we have been doing for the past three or four years, if you're familiar with the funds that WPI has, they established an internal account to fund energy conservation projects and the concept for that is - we do a lighting upgrade project and it results in saving $50,000 a year in electricity purchase then the university will credit that account $50,000 a year as long as that project is returning that benefit. That allows that fund to sustain itself and the money is available to fund the next project it is a neat concept to quickly move energy efficiency projects forward. And we talked a lot, three or four years back, about measuring the actual reduction in energy consumption in a building against a baseline so we would know how much money should be credited to that green revolving fund. The challenge we ran into was that some buildings have submeters and a lot don't. Several of the buildings are aggregated together in a larger primary meter so you can't actually measure the reduction of energy of a project very well. So, what we agreed on was that we would use an energy model to calculate what the theoretical energy savings are and use that to determine how much funds would be transferred to the green revolving fund. So if we had a more accurate way to measure and determine savings from projects you can verify if your model is predicting it correctly. We just concluded that there is no good way to do that currently. We would spend so much time and money setting up submeters to be able to measure savings or having somebody do all that work we decided the simpler way would be to assume it's close enough and use that to transfer the funds.

Ben Rajotte: Do you believe that the benefits of upgrading WPI's submetering system would outweigh the cost?

Eric Beattie: I think I do. It would certainly allow us to make better-informed decisions and we can verify usage and validate our assumptions. I do believe in it. To better control buildings, to identify where there may be problems that resulted in higher energy consumption and if we knew about it, we could find it and address it. I think there are a lot of benefits to additional metering beyond what we have now. There is a cost involved there, so weighing the costs and benefits would be a valuable thing to do. I don't know if we've ever formally considered how much more metering would benefit us and what would that cost and if there is an actual payback to that investment.

Ben Rajotte: Which buildings do you think would benefit most from upgraded submeters?

Eric Beattie: I think that any building that doesn't have it currently there could be benefits. I suspect that the older buildings may not have any submetering. Residence halls are interesting - the institution that I had worked at before I came here had submetering for each residence hall and they used to do these competitions so that the students were encouraged to conserve energy and by tracking it there was a competition to see which of the residence halls could conserve energy the best and the winners got prizes. So you can promote conservation by using the meters in residence halls.

Ben Rajotte: What college was it?

Eric Beattie: Syracuse.

Ben Rajotte: Were the students able to see the energy usage or did they just find out at the end of the year?

Eric Beattie: I don’t remember exactly, but I believe the students were allowed to see the data, hopefully in real-time. I’m not quite sure how that was set up.

Ben Rajotte: What sustainability projects does WPI have in its future, or specifically the facilities department?

Eric Beattie: So we’re beginning a pretty long-term relationship with a company that’s going to help us advance our carbon reduction goals. A lot of that is working on better efficiency in buildings to improve that we’re looking to overhaul and upgrade the powerplant with a more efficient system and hopefully, there will be emerging things we can do with renewable energy that can help us get away from natural gas - which is our primary fuel. We’re looking to do co-gen at the plant which can reduce our electrical offtake from the grid. So that will be a plus. We are looking at solar installations on campus as well as off-campus such as an investment in a solar farm that can offset our electrical consumption here. Longer term, this company is doing a lot of development in hydrogen as a fuel source so if that comes along and is an option for us, we can start converting systems over to hydrogen fuel instead of natural gas. Geothermal is another thing in the discussion. So there are a lot of different things around energy both renewable and improving efficiency.

Derren Rosbach Interview Transcript

Ben Rajotte: What projects have you advised in the past, particularly regarding sustainability?

Derren Rosbach: I’ve done a lot of projects at WPI that focus on sustainability both on-campus IQPs as well as some off-campus IQPs and I teach at the Great Problems Seminars and do a lot of projects with freshmen around sustainability on campus. I would say 50-100. And one of the classes I teach is specifically about energy and almost every year we do one or two projects specifically focused on energy at WPI. I also taught in the frontiers program. I've had some coordination with WPI facilities and have been on a number of tours and have collaborated with a number of faculty and staff at WPI. I am also on the sustainability committee and do work with them.

Ben Rajotte: What do you use to track energy for those projects or is it more theoretical?

Derren Rosbach: This is one of the main things to think about and inquire about in terms of what data is available. A lot of the projects I’ve done are actually looking at solar panels and thinking about bringing solar panels to WPI. The other work I’ve been doing is potentially bringing a nuclear microreactor to WPI. I had an IQP team look at this last year and they were trying to get information on energy use across campus. One of the challenges was getting access to specific electricity bills as well as information about how much energy was used in other ways. Some of that has to do with knowing who to talk to and going through the process to get access to that information. Some of it is challenging in terms of how that information is tracked whether it is by building. It's not super uniform. Ideally, that information is as fine-grained as possible. So hopefully you could know that information for each building if not more fine-grained so you can track energy use much more specifically. Right now it's kind of in general. Are you actually going to get information about energy use at WPI?

Ben Rajotte: Yeh, right now I’m using WebCtrl, which is what facilities use for HVAC and energy usage, so I was going to work on getting data from there and seeing the feasibility of improving that system.

Derren Rosbach: That would be great and thinking about ways that can be done can be useful. But more data means it takes up more space and can be more difficult to track.

Ben Rajotte: What do you think could be the benefits or disadvantages of a dashboard?

Derren Rosbach: I think the benefits would be that we would have a better sense of the energy we are using. It depends on whether that can be in real-time or monthly, like last month we used x amount of electricity. And that can change behavior. It could help us achieve our sustainability goals. It can help raise awareness and identify the areas where we are potentially wasting energy. We can potentially save money. We can reduce carbon emissions. I think the challenge is if it isn't accurate or if it's leaving out certain information it can be misleading so it is important that the information is accessible and displayed in a way that is as accurate as possible. Finding the right balance of exact numbers versus summarised estimates of energy usage is a challenge and something that needs to be figured out in a way that would be most useful.

Derren Rosbach: For example, if you were to say we use let's say 5 megawatts of energy that doesn't let you understand that there are peak times when energy is used and there are other times where it is not used as much. A year isn't good enough, is a month good enough is a week good enough, is a day good enough? What would be most useful is if the data is there and there are multiple ways to display it so depending on what you need to know and under you can view it in different ways.

Ben Rajotte: What features would be helpful in a dashboard? In case studies, certain dashboards will have equivalencies, for example, X amount of energy is this much oil burned. Do you think features like that would be helpful?

Derren Rosbach: Definitely. Depending on what you’re trying to accomplish with the dashboard and ideally there are multiple things a dashboard can accomplish and be useful for. For example, doing research for projects versus raising general awareness. Having different places to go to get different types of information. Equivalencies are really useful. If you throw out a big number people don't really know what that means but if you say, “we are using as much oil as would fit in a swimming pool,” people could visualize that and that makes a lot more sense to them.

Ben Rajotte: Would an energy monitoring dashboard be useful for projects on campus?

Derren Rosbach: There are a lot of projects that I've advised that would have really benefited from a dashboard if the data is available or if there is a diverse enough set of tools to display that data. If it were more of a dashboard to raise awareness for the general public I don't know if that would be as useful for projects. If it was just "here's how much energy we used yesterday" but it wasn't broken down in a fine grain way, I'm not sure that would be as useful. Or I would say it would be useful for a more limited set of projects.

Ben Rajotte: Do you think that breaking it down more would be less useful for raising awareness or do you think that would benefit both groups?

Derren Rosbach: I think it would help if there was a place to like a more user-friendly area or maybe that's the first interface you can go and just look at broadly in a way that raised awareness if you just want to look at what our energy use is whether that's parents or students or faculty or staff just to get a sense. Then if you could make that more detailed for other purposes that would be very useful. But you don't want a person who is just interested in learning about our energy use in general to go to the website and not be able to access that without jumping through hoops or making it so complex that they can't just go and look at how much energy WPI is using. I think one thing that could really useful for that purpose is having more of a real-time display. I have solar panels on my house and I have an app that lets me see how much energy is being produced at any moment and I can look at it in a bunch of different ways - I can look at how much energy the panels are producing or I can look at a graph that shows throughout the day how much energy is being produced or I can stretch that out the week, the month, the year. This year versus last year versus the year before. That might be something to look at if you've never seen that type of display. It might be a useful example to look at the functionality of something like that. It may be pretty similar to other campus dashboards. Have you looked at other campus dashboards?

Ben Rajotte: Like other colleges?

Derren Rosbach: That could give you another example. I have an app on my phone that came with the solar panels. I don't know if there's a website or something similar you can find of a company or other schools. I'm trying to remember. There's a good school in Ohio. They have a really good energy dashboard. I'll send it to you.

Ben Rajotte: How important is energy tracking in sustainability practices?

Derren Rosbach: I think it is really important both in how individuals behave and seeing how you can possibly have an impact and overtime tracking how the institution is doing in terms of progress towards sustainability goals. If we're not measuring, if we're not keeping track it's more challenging to know. It takes a good amount of work to put reports together every year and gather this data. If this could be a more automated process it would be much more effective.

Kevin McLellan Interview Transcript

Ben Rajotte (Investigator): What are submeters and what do facilities use them for?

Kevin McLellan: Submeters are meters that are on individual buildings throughout the campus they are used for, we use them for energy projects for a baseline. If you were going to do a lighting retrofit and switch to LEDs you can use the meter to show your savings. We use them for - the biggest thing I use them for is curtailments. We do load shed through National Grid. When they are looking for a certain KW for us to shed during heat waves. I use the main meter for the curtailment to know how much were shedding.

Ben Rajotte: What type of submeters does WPI use - electric, water, natural gas, all of the above?

Kevin McLellan: All of the above. We have two water meters, one for the swimming pool, we have a water meter for the fountain on campus so we know if we have an underground break. Electric meters are all over the place. You can see a good percentage of them are on Automated Logic. There is a natural gas meter in the power plant. That is the only one that I know of. We have steam meters. Kilowatt to BTU meters. In any of the newer buildings, we have BTU meters on the heating and cooling systems.

Ben Rajotte: Why do we only have one natural gas meter and not more?

Kevin McLellan: Years ago, the meters that we have are called E-mon D-mon and we had a whole network just for these meters. So everything you see on ALC was on a software platform that became unsupported and the meters would only talk to the E-mon software but some of the meters had a pulse output so I was able to bring those into Automated Logic and some of them we integrated them through Backnet into Automated Logic. We put the meter on the network and were able to pull the readings in. So we stuck with the E-mon D-mon's. There are no particular types that we wouldn't use as long as they - the best type is a Backnet compatible meter, so anything new we would want Backnet which is a third party software in the meter that any automation system can communicate to. ALC works really well with Backnet so we don't have to connect them to the BMS, we basically use a Backnet meter. Anything new is going to be a Backnet meter and we put them on the network and assign them a Backnet device input and we can pull anything from them, voltage, demand, anything that meter can give us, we can pull in. With the old meters that we're using, we can only get the demand through the pulsing. So we can't get the power between phases. But if we do upgrade to the Backnet meters we can get more information.

Ben Rajotte: Have we upgraded any of the buildings?

Kevin McLellan: Yeh, we have upgraded Daniels - that has an upgraded Backnet meter. The Campus Center has a Backnet meter. Harrington does as well. The Rec Center has a Backnet meter. Unity Hall is all Backnet. Gordon Library is Backnet. So we have quite a few that are new.

Ben Rajotte: Why haven't we put most of WPI's properties on Automated Logic?

Kevin McLellan: It's probably a cost thing. So a lot of those that are on the main switch gears in buildings they're not easy to install when you have to put them on a gear because you have to do a shutdown then you have to put the CT donuts around the phases coming into the building. So it's easy to do it on a subpanel, we can do it anytime. But the main feed coming into a building is difficult. For example, the Rec Center we never metered that at all, we didn't have a meter over there, the switch gear came with the meter on it and I was able to buy a Backnet card for the meter and I plugged the card in and pulled it into ALC and put it on the network. I think some of it is funding. I know I have a couple, I have Higgins Lab and Riley Backnet meters installed right now and I have to put them on the network. Those were old E-mon meters that I couldn't pulse out of them so those were like first gen. Those were old and obsolete. We took them out and put Backnet meters in. So I think they tried to get in as many as they could. In any of the new buildings, the meters are built into the switch gear so we just got to put a data drop in and we can pull the info out of them. The older switch gear does not have that so we have to install that.

Ben Rajotte: Do you have a rough estimate of how difficult and expensive it would be to upgrade older buildings?

Kevin McLellan: So the meter itself and the CTs are $2500 to upgrade it then the electrical install is another $1000, the data drop $750. So to be safe, somewhere around $5000. But when they come on the switch gears, it's very cheap. All we need is a data drop. The library they put the new gear in so they had a display on it and were able to put a card in and I was able to pull the main level out of it.

Ben Rajotte: In your opinion, if we could only upgrade a couple of meters in the near future, what buildings do you think would benefit the most?

Kevin McLellan: I think Higgins Lab because that meter was obsolete, I just had the meter installed but haven't programmed it. That's going to be a big benefit. Campus Center we just brought online. Goddard we have. We have quite a bit. Fuller Labs definitely needs to be upgraded.

Ben Rajotte: If we want to put water meters on each of the buildings that could communicate with automated logic, would that be similar in difficulty and price to the electrical meters?

Kevin McLellan: No, I think it would be a little bit easier. It's basically just putting - where the water line comes in, you would put a flow meter and it would be an easy tie-in. It would probably be a little cheaper. That we could do internally in facilities with our staff. We could have a plumber install it so it would be relatively cheap if we buy the meter ourselves. Have our plumbers install it then we can program it into Automated Logic. I would think that would be a lot cheaper. Maybe $1500 for the meter and a few hundred to install it. It really depends on how close an Automated Logic controller is. Then we don't have to add a controller, we can just run a wire from the meter to the controller. ALC has quite a few controllers in each building so we can usually find one we can pull it to. So I think the cost would be pretty low.

Ben Rajotte: What would be the difference in installing them? Why is there such a big difference in price?

Kevin McLellan: Because if we have to shut down switch gears it's a lot more and if we have to add CT donuts to things, we have to shut the gear down and have the building shut down to do it. So there's a lot more involved with it. We can't do those live with power on. That's the problem. All those you see on Automated Logic were done at some point and somebody shut that gear down during a scheduled shutdown and put CTs around the feeders coming into the building. Some meters are metering panels which you can do anytime and be really cheap. But if you wanted one panel and wanted to do the main coming into the building that's where it gets a little pricey.

Ben Rajotte: What benefits would we get from expanding the submetering system?

Kevin McLellan: I think the biggest thing we can use the meters for is energy projects. Having the data is critical. To know what you've been using all along. That main WPI meter does 29 buildings on WebCtrl. That's pretty much everything except for the Rec Center. Pretty much everything is on there so to have that data for each building when you're doing a project just makes it good to have that data available to say "we changed all the lightbulbs and did all these upgrades and now look were saving 100Kw". But you really need the data to do any type of energy project.

Appendix C - Raw Data

FY21 Water Utility Costs

Address	FY21 Total
Kaven Hall - Boynton St.	$ 1,491.32
Institute Hall - 12 Boynton St.	$ 5,964.42
Founders Hall - 26 Boynton St.	$ 36,250.17
East Hall - 30 Boynton St.	$ 26,483.83
10 Faraday St.	$ 44,143.25
Morgan Hall - 90 Institute Rd.	$ 37,464.37
REC CENTER - 100 Institute Rd.	$ 32,544.81
Project Center - West St.	$ 29,793.03
60-68 Prescott - Gateway I	$ 26,041.28
Daniels Hall - Institute Rd.	$ 25,973.43
Campus Center - 206 West Street	$ 24,710.01
Stoddard (A, B & C) - 34 Hackfeld	$ 16,647.40
Higgins Lab - 190 West St.	$ 14,388.56
Foisie Innovation Studio - 100 Institute Rd.	$ 13,761.67
Sanford Riley Dorm - Institute Rd.	$ 13,478.73
Ellsworth - 85 Institute Rd.	$ 11,273.34
Harrington Auditorium - 204 West St.	$ 10,948.06
Olin Hall - 208 West St.	$ 10,000.26
Goddard Hall - 210 West St.	$ 9,722.65
Boynton Hall - West St.	$ 8,393.85
Gordon Library - 209 West St.	$ 7,636.39
Fuller Apts. - 81 Institute Rd.	$ 6,612.39
75-87 Park Ave. (WPI Townhouses)	$ 6,097.30
Fuller Apts. - 79 Institute	$ 5,651.66
15 Sagamore Rd [Quarterly]	$ 3,954.70
Stratton Hall - 185 West St.	$ 3,472.55
75-87 Park Ave. (WPI Townhouses)	$ 2,929.54
10 Faraday St.-Sprinkler System	$ 2,785.53
Fuller Labs -Salisbury St.	$ 2,186.02
75-87 Park Ave. (WPI Townhouses)	$ 2,019.40
8 Elbridge	$ 1,722.50

25 Trowbridge	$ 1,607.27
20 Elbridge	$ 1,488.21
Atwater Kent - 215 West St.	$ 1,288.71
Salisbury Labs - West St.	$ 1,135.01
67 Wachusett	$ 1,115.55
75-87 Park Ave. (WPI Townhouses)	$ 1,061.98
1 Drury Lane-sprinkler	$ 1,053.29
13 Schussler	$ 1,049.99
15 Einhorn	$ 1,039.66
Alden Hall - 180 West St.	$ 1,031.02
22 Schussler	$ 1,027.76
2 Elbridge & 9 Boynton	$ 1,019.22
10 Hackfeld	$ 1,002.51
16 Elbridge	$ 986.62
10 Elbridge	$ 937.73
30 Elbridge	$ 907.19
37 Lee St.	$ 863.11
49 Institute	$ 778.92
23 Hackfeld	$ 738.16
18 Hackfeld	$ 697.48
15 Sagamore Rd/241 Grove St [Quarterly]	$ 611.40
8 Hackfeld	$ 601.44
26 Hackfeld	$ 595.50
17 Einhorn	$ 581.00
11 Einhorn	$ 581.00
12 Hackfeld	$ 548.86
Rec Center Parking Garage- 100 Institute Rd.	$ 499.66
Air Force & Aerospace - 35-37 Institute	$ 435.14
47 Institute	$ 416.47
24 Hackfeld	$ 371.27
Bartlett Center - 100 Institute Rd.	$ 356.24
15 Regent St.	$ 302.22
19 Schussler	$ 220.70
Higgins House - 1 John Wing Way	$ 192.34
27 Hackfeld	$ 185.82

11 Hackfeld	$ 179.94
16 Einhorn	$ 174.06
Institute Rd.	$ 174.06
Higgins Labs - 100 Institute Rd. & West St.	$ 174.06
15 - 17 Schussler	$ 174.06
20 Schussler	$ 174.06
20 Trowbridge	$ 174.06
28 Trowbridge	$ 174.06
53 Wachusett St.	$ 174.06
Counseling Center - 157 West	$ 174.06
12 Einhorn Rd.	$ 174.06
Gateway Garage - 31 Garden St. [Quarterly - Send to Pat Barrows]	$ 14.50
1 Drury Lane	$ 780.32

FY21 Electrical Utility Costs

Address	TOTAL $
1 Drury Lane	9,213.49
10 Elbridge St House	
10 Elbridge, apt. 1, pole 5	910.79
10 Elbridge, apt. 2, pole 5	614.95
10 Elbridge, apt. 3, pole 5	778.56
10 Hackfeld	2,147.59
100 Institute Rd Sports Bldg NEXAMP	153,228.65
11 Einhorn	1,626.19
11 Hackfeld	637.41
12 Boynton	8,894.17
12 Einhorn	2,447.29
12 Hackfield	1,941.56
13 Schussler	1,303.45
13 Schussler, apt. 2	1,000.49
15 Einhorn	4,118.27
15 Regent St.	1,750.61
152 West, pole 5	265.74
157 West, apt. 1	2,435.52
16 Einhorn, Apt. 1	1,350.73
16 Elbridge	3,840.03
17 Einhorn	904.89

17 Einhorn, Apt. 3 pole 6	82.20
17 Schussler, apt. 1	8,364.46
18 Hackfeld, apt. 1	708.26
18 Hackfeld, apt. 2	883.43
183 West Main NEXAMP	868,416.89
19 Schussler	1,530.03
2 Elbridge, Apt. 2	1,258.32
20 Elbridge, apt. 1	2,649.73
20 Elbridge, apt. 2	1,709.73
20 Elbridge, apt. 3	2,836.10
20 Elbridge, basement	290.24
20 Schussler	2,563.14
20 Trowbridge	487.30
20 Trowbridge pole 4	1,359.31
22 Schussler	3,114.17
23 Hackfeld, pole 5	1,597.45
23 Trowbridge, pole 7	1,779.92
24 Hackfeld	1,939.05
25 Trowbridge, apt. 1	4,612.45
26 Boynton pole MH338 (Founders Hall)	46,820.53
26 Hackfeld	2,682.13
27 Hackfeld	7,243.18
28 Trowbridge	4,971.30
30 Boynton St. East Dorm	58,813.39
30 Elbridge, apt. 1	904.02
30 Elbridge, apt. 2	1,043.50
35 Institute	5,792.62
37 Lee St (meter outside warehouse)	2,566.28
37 Lee St (new meter rear of bldg)	8,151.16
47 Institute, apt. 1	716.43
47 Institute, apt. 2	816.38
49 Institute HSMTR pole 3	543.06
49 Institute, apt. 1	7,604.60
49 Institute, apt. 2 pole 3	1,605.40
49 Institute, apt. 3 pole 3	1,418.32
53 Wachusett St.	316.19
60 Prescott Street NEXAMP	283,008.53
67 Wachusett, apt 1, pole1	3,701.23
67 Wachusett, apt 2	1,145.81
67 Wachusett, pole 1	693.77
75 Grove St. (Faraday Hall)	69,433.39

79 Institute Road HSMTR	19,016.50
8 Elbridge, Apt. 1	1,870.24
8 Elbridge, apt. 2	949.84
8 Elbridge, apt. 3	2,016.52
8 Hackfeld, apt. 1	530.67
8 Hackfeld, apt. 2	3,501.60
8 Hackfeld, apt. 3	1,008.59
85 Institute Road HSMTR	20,249.82
9 Boynton St.	1,793.74
95 Institute	41,679.72
Faraday St.	991.10
10 Nashua Street Unit C	773.92
85 Prescott St Unit 1	3,679.29
85 Prescott St Unit 2	6,946.60
85 Prescott St 2 +3FL	24,478.12
85 Prescott St. 4th Floor	3,154.04
85 Prescott St. Mass Acad	13,891.47
85 Prescott St. 3rd floor - Robotics	11,470.90
15 Sagamore Road	2,224.57
15 Sagamore Road	48,736.34
108 Grove Street	7,930.25
108 Grove Street Apt. 22	1,119.80
75 Park Avenue, HSMTR	513.33
75 Park Avenue, Unit #1	359.34
75 Park Avenue, Unit #2	352.83
75 Park Avenue, Unit #3	222.02
75 Park Avenue, Unit #4	585.64
75 Park Avenue, Unit #5	979.74
75 Park Avenue, Unit #6	654.22
75 Park Avenue, Unit #7	321.41
75 Park Avenue, Unit #8	433.45
75 Park Avenue, Unit #9	514.81
77 Park Avenue, HMSTR	1,804.18
77 Park Avenue, Unit #1	435.92
77 Park Avenue, Unit #2	416.59
77 Park Avenue, Unit #3	336.17
77 Park Avenue, Unit #4	885.65
77 Park Avenue, Unit #5	1,007.95
77 Park Avenue, Unit #7	632.88
77 Park Avenue, Unit #8	923.56
77 Park Avenue, Unit #9	597.65

77 Park Avenue, Unit #10	757.69
79 Park Avenue, HOUSE METER	3,448.46
79 Park Avenue, Unit #1	247.86
79 Park Avenue, Unit #2	542.10
79 Park Avenue, Unit #3	
79 Park Avenue, Unit #4	243.82
79 Park Avenue, Unit #5	2,016.46
79 Park Avenue, Unit #6	571.41
79 Park Avenue, Unit #7	1,054.95
79 Park Avenue, Unit #8	506.78
79 Park Avenue, Unit #9	1,337.17
79 Park Avenue, Unit #10	531.15
79 Park Avenue, Unit #11	725.89
79 Park Avenue, Unit #12	756.60
79 Park Avenue, Unit #13	334.03
79 Park Avenue, Unit #14	564.19
79 Park Avenue, Unit #15	274.78
79 Park Avenue, Unit #16	406.54
79 Park Avenue, Unit #17	669.56
79 Park Avenue, Unit #18	226.24
79 Park Avenue, Unit #19	483.80
79 Park Avenue, Unit #20	340.93
81 Park Avenue, HSMTR	1,278.65
81 Park Avenue, Unit #1	638.66
81 Park Avenue, Unit #2	406.96
81 Park Avenue, Unit #3	536.73
81 Park Avenue, Unit #4	468.88
81 Park Avenue, Unit #5	391.50
81 Park Avenue, Unit #6	398.87
81 Park Avenue, Unit #7	951.08
81 Park Avenue, Unit #8	532.59
81 Park Avenue, Unit #9	982.14
81 Park Avenue, Unit #10	510.05
81 Park Avenue, Unit #11	515.66
81 Park Avenue, Unit #12	1,425.09
81 Park Avenue, Unit #13	513.92
81 Park Avenue, Unit #14	701.62
81 Park Avenue, Unit #15	507.22
81 Park Avenue, Unit#16	1,181.70
81 Park Avenue, Unit #17	512.35
81 Park Avenue, Unit #18	612.60

81 Park Avenue Unit #19	594.89
81 Park Avenue, Unit #20	1,323.00
81 Park Avenue, Unit #21	836.84
81 Park Avenue, Unit #22	374.98
81 Park Avenue, Unit #23	503.59
81 Park Avenue, Unit #24	400.85
81 Park Avenue, Unit #25	368.58
81 Park Avenue, Unit #26	352.31
83 Park Avenue, HSMTR	490.40
83 Park Avenue, Unit #1	267.30
83 Park Avenue, Unit #2	358.50
83 Park Avenue, Unit #4	261.03
83 Park Avenue, Unit #5	298.50
83 Park Avenue, Unit #6	
83 Park Avenue, Unit #7	831.41
83 Park Avenue, Unit #8	897.72
83 Park Avenue, Unit #9	306.63
83 Park Avenue, Unit #10	363.66
83 Park Avenue, Unit #11	399.97
83 Park Avenue, Unit #12	239.72
85 Park Avenue, HSMTR	4,476.74
85 Park Avenue, Unit #1	584.95
85 Park Avenue, Unit #2	418.87
85 Park Avenue, Unit #3	275.97
85 Park Avenue, Unit #4	348.16
85 Park Avenue, Unit #5	395.72
85 Park Avenue, Unit #8	461.14
85 Park Avenue, Unit #9	532.67
85 Park Avenue, Unit #10	471.25
87 Park Avenue, HSMTR	846.18
87 Park Avenue, Unit #1	315.59
87 Park Avenue, Unit #2	360.75
87 Park Avenue, Unit #3	404.14
87 Park Avenue, Unit #4	497.66
87 Park Avenue, Unit #5	397.11
87 Park Avenue, Unit #6	414.44
87 Park Avenue, Unit #7	318.83
87 Park Avenue, Unit #8	306.38
87 Park Avenue, Unit #9	420.83
87 Park Avenue, Unit #10	967.65
87 Park Avenue, Unit #11	396.35

87 Park Avenue, Unit #12	241.13
87 Park Avenue, Unit #13	503.38
87 Park Avenue, Unit #14	
87 Park Avenue, Unit #15	698.51
87 Park Avenue, Unit #16	441.55
87 Park Avenue, Unit #17	94.48
87 Park Avenue, Unit #18	366.87
87 Park Avenue, Unit #19	424.94
87 Park Avenue, Unit #20	356.10
87 Park Avenue, Unit #21	296.22
31 Garden St. (Gateway Garage)	12,098.62
60 Prescott St. Unit #1, Gateway Garage Parking lot lights	392.95
60 Prescott St. Unit #2, Gateway Garage Parking lot lights	1,221.41