Monitoring and Presenting Energy Consumption to Increase WPI Sustainability Efforts

Sustaining WPI Project Center
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Abstract

The purpose of this project was to develop a proposal for the implementation of an Energy Monitoring Dashboard at Worcester Polytechnic Institute (WPI). The team analyzed the current WPI energy monitoring systems to determine a feasible, cost-effective way to raise awareness about energy usage on campus. The team also investigated the utility of additional energy monitoring dashboards on campus and the long-term benefits the dashboards could provide.

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1 Introduction

According to the University of California, Los Angeles, "sustainability is defined as the physical development and institution operating practices that meet the needs of present users without compromising the ability of future generations to meet their own needs, particularly with regard to use and waste of natural resources" (What is Sustainability, n.d.). Similar to UCLA, WPI is dedicated to implementing sustainability practices, and in particular energy sustainability practices and programs to demonstrate its "commitment to the preservation of the planet" [WPI 2017].

One sustainable practice WPI has implemented is the development and installation of energy monitoring systems. Energy monitoring is a technique that can be used to assess energy consumption by recording energy usage over time and comparing that usage to historical, local, or standard rates. Energy monitoring is enhanced by implementing energy monitoring dashboards, which WPI's Facilities Department have expressed an interest in pursuing. Figure 1 depicts a simple energy monitoring dashboard.

Specifically, an energy monitoring dashboard is a graphical interface between users and consumption data that enables users to analyze resource usage such as energy, gas, and water. The energy usage information from a monitoring dashboard allows users to make informed decisions towards adjusting and optimizing energy efficiency for buildings. Examples of these adjustments include turning off lights, HVAC systems, and computer systems during times when not required.

Based on previous studies conducted at similar colleges, energy monitoring dashboards could inspire the WPI community to be mindful of their energy consumption, indirectly resulting in energy savings. A dashboard that compares, for example, a building's energy usage to its historical data could tell the story to its inhabitants that energy is being used irresponsibly, if more energy resources are being used on a given day. With this on display, the habits of the building's tenants would hopefully notice and adjust their habits to be more sustainable, saving WPI financial and energy resources.

Finally, energy monitoring dashboards could provide project experience to students through dashboard maintenance and research for optimal dashboard design. There is energy usage data for around a dozen buildings on campus, as well as submetering of certain floors and areas; there could be a dashboard for each location currently being metered, and this would ultimately make WPI more sustainable with energy resources. Student-driven dashboards would correspond to WPI's project-based curriculum strategy and sustainability goals.
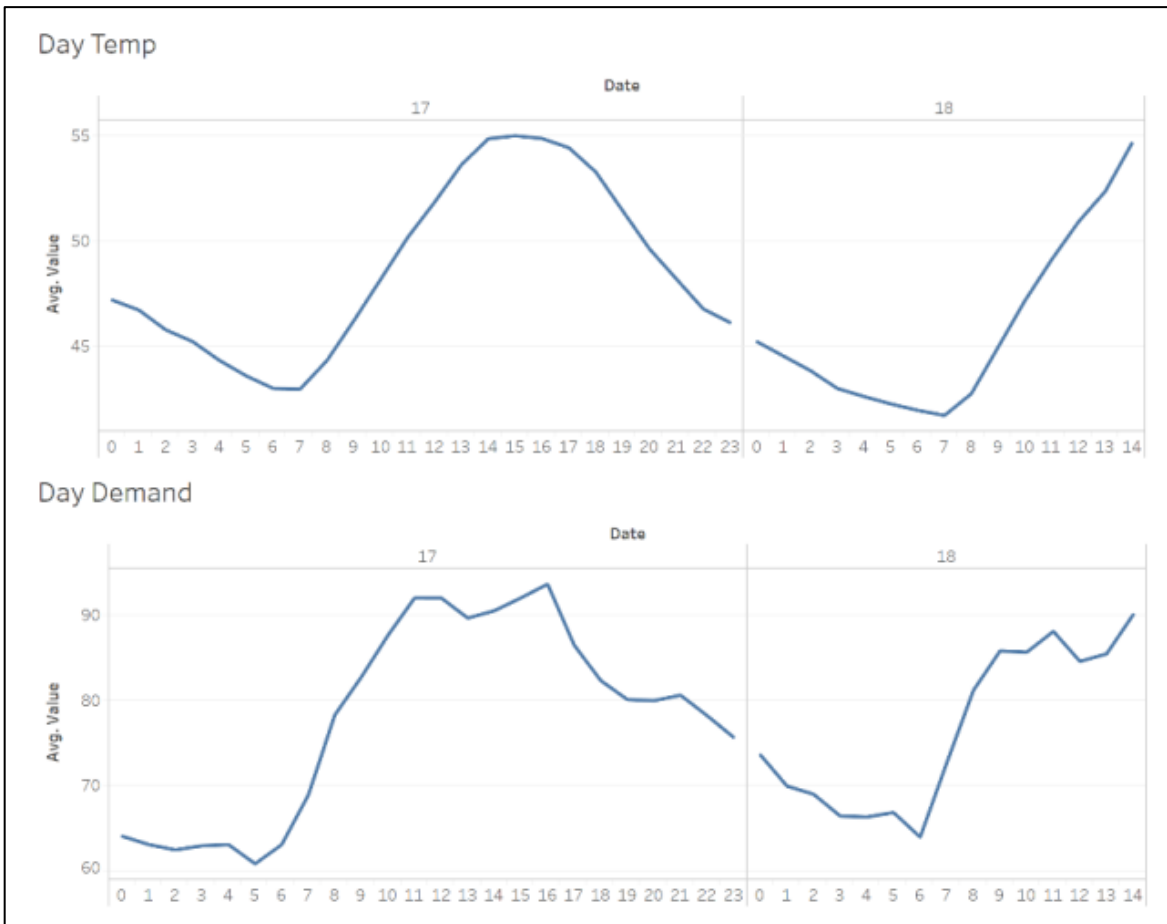
Figure 1: Energy monitoring dashboard in Tableau.

Project Statement

The goal of this project was to implement an energy monitoring dashboard at WPI to raise public awareness of energy usage, ultimately increasing energy sustainability. Specific objectives identified to achieve this goal included:

- Analyze the sub-metering energy monitoring systems on campus and assess whether a dashboard monitoring system can feasibly be installed
- Gauge the WPI community's interest using a survey
- Design and test proof-of-concept dashboard options
- Form recommendations and instructions to the WPI community on continuance of dashboard implementation

Specific methods we implemented to address the goals and objectives are detailed in section three. In the remainder of this report, we will present the benefits resulting from displaying a dashboard, our proof of concept dashboard mockups, student feedback on the dashboard, and future recommendations.

2   Background

This section provides readers with information concerning energy monitoring systems, dashboards, and WPI's sustainability plans and efforts. Several case studies are also described to illustrate the benefits of an energy dashboard to other universities.

Colleges and universities are enacting sustainability initiatives to make their campuses greener and more environmentally sustainable. For example, Clark University received multiple awards for their initiatives on environmental sustainability with technologies as seen on the university's website at https://www2.clarku.edu/offices/campusSustainability/energyuse/cogeneration.cfm like their Cogeneration plant biofuel synthesis and installing energy efficient appliances. Worcester State University and the Massachusetts Institute of Technology follow similar paths in their efforts of becoming more energy efficient and carbon neutral; these will be described in depth in Section 2.7: CASE STUDIES (*Worcester State University,* 2018; *Massachusetts Institute of Technology,* 2018).

The vision of WPI's sustainability plan is "to demonstrate our commitment to the preservation of the planet and all its life through the incorporation of the principles of sustainability... by promoting a culture of sustainability [utilizing] our technical strengths" (*WPI Sustainability,* 2018). WPI's three sustainability principles according to the sustainability plan are the following: ecological stewardship, in that "every person's activities must respect the need to preserve [the] natural world"; economic security where every individual has the right to support themselves and their family; and social justice, where the respect and dignity of every human being leads to equal rights and opportunities. To address these principles, in part, the school teaches students how to develop sustainable solutions, ensures that the "principles of sustainability guide our actions and programs," and makes significant contributions to all resources that will help maintain and ensure sustainability by following the goals set forth in the WPI Sustainability plan. The school seeks to "engage in promoting a culture of sustainability to enhance the current and future welfare of [their] communities" (*WPI Sustainability,* 2018*).*

WPI has implemented multiple sustainability initiatives and achievements due to the institution's sustainability plan. These initiatives and achievements include reducing utility consumption by 25% between 2014 and 2018, maintaining a platinum STARS rating, requiring all new constructed campus buildings and renovations to be LEED-certified, and the monitoring of real time energy usage with submetering (*WPI Sustainability,* 2018).

2.1   STARS

The Sustainability Tracking, Assessment and Rating System, also known as STARS, is a transparent, "self-reporting framework" to measure colleges and universities sustainability performance (STARS, 2006). STARS provide incentives to higher education institutions around the world to increase sustainability efforts. These incentives include international sustainability standard for universities to learn from. STARS share sustainability performance of universities to promote competition and awareness in the form of its own scoring system (STARS, 2006).

Scoring for STARS' falls into five categories: Academics, Engagement, Operations, Planning and Administration, and Innovation and Leadership (STARS, 2006). The minimum score for each rating is the

following: Platinum, 85; Gold, 65; Silver, 45; Bronze, 20 (STARS, 2006). Currently, WPI maintains a gold STARS rating since June 2017 for the school's sustainability efforts and performance (Worcester, 2017). These efforts include (but are not limited to) reduction of greenhouse gas emissions, maintaining outdoor air quality, engaging the school's community in sustainability efforts, waste and water management, investment, planning, wellbeing, and food and dining operation (Worcester, 2017). The school's total score was 65, with the following scores for each category found in Table 1.

Table 1: WPI STARS Category Scoring (Worcester, 2017)

Category	Score
Curriculum	26/40
Research	16/18
Campus Engagement	20/21
Public Engagement	13/20
Air and Climate Operations	7/11
Buildings Operations	2/8
Energy Operations	4/10
Food and Dining	2/8
Grounds Operations	1/3
Purchasing Operations	3/6
Transportation Operations	4/7
Waste Operations	6/10
Water Operations	1/6
Coordination and Planning	6/8
Diversity and Affordability	7/10
Investment and Finance	0/7
Wellbeing and Work	4/7
Exemplary Practice	1
Innovation	4

Two of the key areas that this project will focus on is Campus Engagement and Energy Operations. The Campus Engagement category focuses on student, employee and professional development and education, an assessment of the sustainable culture and outreach materials and publications used to advertise sustainability measures on campus. The category is composed of the following sections with their available points: Student Educators Program (4), Student Orientation (2), Student Life (2), Outreach Materials and Publications (2), Outreach Campaign (4), Assessing Sustainability Culture (1), Employee Educators Program (3), Employee Orientation (1), and Staff Professional Development (2) (STARS 2.1, n.d.). Each section aims to have institutions increase sustainability awareness and action through informative campaigns and initiatives. An example of this is that the Student Educators Program requires an "institution coordinates an ongoing peer-to-peer sustainability outreach and education program for students" (STARS 2.1, n.d.); While the Outreach Campaign requires that an "institution holds at least one sustainability-related outreach campaign directed at students and/or employees that yields measurable, positive results in advancing sustainability."(STARS 2.1, n.d.).

Energy Operations accesses an institution's clean and renewable energy initiatives and building energy consumption. This category is made up of the following sections with their respective available points: Building Energy Consumption (6), and Clean and Renewable Energy (4) (STARS 2.1, n.d.). The Building Energy Consumption section requires that an "institution has data on grid-purchased electricity, electricity from on-site renewables, district steam/hot water, energy from all other sources, and gross square feet/meters of floor area"(STARS 2.1, n.d.). The Clean and Renewable Energy section requires that an institution does one of the following: "A) generates electricity from clean and renewable sources on campus, B) uses renewable sources for non-electric, on-site energy generation, C) catalyzes the development of off-site clean and renewable energy sources, or D) purchases the environmental attributes of electricity in the form of [renewable energy certificates], [Guarantees of Origin], or renewable electricity from a certified green power purchasing option." (STARS 2.1, n.d.).

Due to Energy Operations' four out of ten score and Campus Engagement's twenty out of twenty-one score, WPI's ability to engage its student community can be used to enhance energy sustainability efforts through raising energy sustainability awareness. Students both living and working on campus have control over their personal energy consumption. Examples include students turning lights off in their residential dormitories and study areas, closing and opening windows to avoid unnecessary HVAC usage, and shutting down campus computers when not in use. If WPI can inform and influence students to be more conscientious of their energy spending habits then this would indirectly result in energy savings, ultimately increasing the university's Energy Operations efficiency.

2.2   LEED Certification

Leadership in Energy and Environmental Design (LEED) is a voluntary certification national consensus-based rating system for sustainable buildings (USGBC, n.d.). The purpose of LEED certified buildings are to promote sustainability and resource (energy, water, gas, construction material, location) efficiency.

Scoring criteria for LEED certification falls into the following categories: location and transportation, materials and resources, water efficiency, energy and atmosphere, sustainable sites, regional priority, and innovation. Organizations can earn points for their buildings in each of the categories by enhancing sustainability efforts. Examples of the certification criteria include how close the facility or project is to mass transit, if the facility used locally gathered and sustainable materials, installing sub-metering systems, and if energy performance, air quality, and water usage is optimized. Benefits associated with LEED certification include reductions in energy and water usage, reduced maintenance and operation costs, increased air quality, and raised awareness towards recycled material (What is LEED, n.d.). According to WPI's sustainability report from 2017, all future buildings will be constructed to LEED 2007 standards.

2.3   Energy Monitoring Systems and Submetering

Energy monitoring systems are designed to collect data on a facility's energy usage, enabling management to effectively monitor and control the use of energy resources to save money and allow for a building to be more sustainable. Monitoring systems obtain their energy usage data through sub-metering devices.

Water submeters measure liquid flow, natural gas submeters measure gas flow, and electrical submeters are retrofit into buildings to measure energy use. Energy submeters output data that can be easily interfaced to dedicated energy monitoring computer systems. (Lewis, 2005).

The primary types of submeters are KWh meters, demand meters, time-of-use meters, and recording meters. KWh meters such as the one shown in Figure 2 measure electrical energy with consumption noted on the front display of the device; demand meters display peak demand of energy in kilowatts; time-of-use meters separate energy usage based on specific time periods and recording meters store energy usage typically uploading the data to a computer on a programmed schedule (Bovankovich, 2005). All energy meters are usually connected to a system known as DAS, data acquisition server/hardware, which relays the energy consumption information to a host computer for archiving, interpretation, and display (Lewis 2005). Figure 3 below illustrates one type of energy data acquisition system. Submeters (shown in red) would collect energy information, and relay energy data to a device known as a MODBUS that transmits data to a computer through a modem (ICP DAS, n.d.).

Figure 2: E-Mon D-Mon Class 5000 kWh and kW Energy Meter (E-Mon D-Mon, n.d.)

The energy submeters currently installed on WPI's campus are the E-mon D-Mon Smart Energy Meters (EDSM) shown in Figure 2 above (Buonomano, 2016).

Figure 3: DAS Flow Chart (ICP DAS, n.d.)

The E-Mon D-Mon meters relay their information every fifteen minutes to the energy monitoring system developed by and purchased from Automated Logic known as "WebCTRL", recording voltage, kilowatts and current, storing the data on WPI's private network (Buonomano, 2016). The E-Mon D-Mon meters are installed in the following buildings: Alden Memorial Auditorium, Atwater Kent Laboratories, Boynton Hall, Rubin Campus Center, Daniels Hall, Gateway Park, George C. Gordon Library, Harrington Auditorium, Olin Hall, Sports and Recreation Center, Sanford Riley Hall, Salisbury Laboratories, Stratton Hall, Washburn Shops, and the WPI Waterhouse.

Figure 4 below is an example of how an energy monitoring sub meter is connected into a building's wiring. Modern submeters use current sensors (CTs) mounted to a building's breaker (Bovankovich, 2005). The green clips shown in Figure 4 attached to the breaker (in black and white) represent the current sensors. These sensors sense the magnetic field produced by the current flow in the wire. The white box to the left in Figure 4 is the E-mon submeter and outputs readable energy information (E-mon D-mon Sub, n.d.).
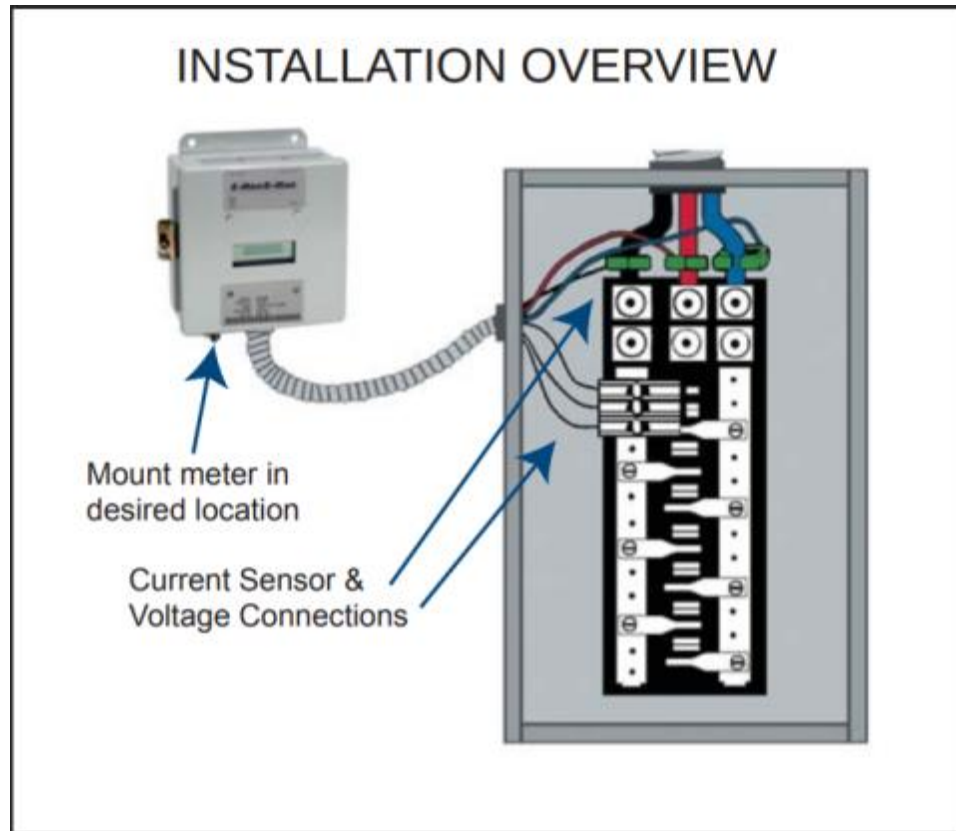
Figure 4: E-mon Electric Submeter Sensors Diagram (E-mon D-mon Sub, n.d.)

In addition to the energy sensors, an energy monitoring system usually includes one or more energy dashboards to display the information collected to the public and to provide facility staff with detailed information that can be used to analyze areas of inefficient energy usage within an infrastructure. With a dashboard facilities personnel can take the appropriate action to optimize energy usage. For example, if a dashboard displays an area having a consistently high energy consumption across all hours of the day, even when student or faculty traffic is low, then facility staff could act to minimize energy consumption. These efforts might include shutting down lights, projectors, and computers along with any heating and cooling devices.

2.4   Benefits of an Energy Monitoring Dashboard

Energy monitoring supports reducing energy costs by displaying energy resource use, easing energy management, and revealing wasteful systems, resulting in an average savings of 5% for small businesses (Carbon Trust, 2007). It is difficult to concretely prove that energy monitoring dashboards save energy usage and money; yet energy dashboards can be used to raise public awareness of energy usage in order to reduce overall energy consumption and therefore the cost of energy use.

One study conducted at the Carnegie Mellon University in 2012 evaluated the effects of a mobile energy monitoring tool known as "The Dashboard" on research participants. The researchers investigated "the potential of real-time data stream composition and visualization in the context of energy monitoring"

observing if informed participants would make varied decisions compared to uninformed users (Yun, 2014).

Thirteen participants were engaged from different homes, ranging from the ages of 27 to 43, and who were regular *iPad* users (in order to view the dashboard) (Yun, 2014). Participants were pleased with the dashboard's easy to use interface, frequently checking and customizing the dashboard to their liking. For example, participants with solar panels identified what data was relevant and convenient, such as weather data to optimize energy consumption and production, then reconfigured the dashboard's user interface to display that information. By contrast, other participants had difficulty interpreting the dashboard information and only monitored an energy graph without any reference to indicate whether energy was being saved or inefficiently used (Yun, 2014).

According to Yun et al. the average consumer is inexperienced on intangible resources such as electricity; but researchers believe individuals can be persuaded into making energy efficient sustainable choices by increasing awareness and utilizing information visualization. The Yun et al. study also discovered that individuals are readily willing to share energy information and support each other since inexperienced users tend to have no reference towards the information that is presented. Those same individuals that share their energy consumption data (both experts and inexperienced users) are equally likely to exchange help, expertise and trouble-shooting (Yun, 2014). This sharing of information and experiences proves valuable as it promotes community support, competition, and like-mindedness. Implementing an energy consumption dashboard tool would then not only raise awareness of consumer's consumption habits, but also alter their perception towards being more energy efficient and sustainable. Installing a dashboard tool in a group setting would also prove more effective towards achieving this goal since it would likely instill competition and tension among individuals to strive towards being the most efficient.

Opponents of energy dashboards argue that these tools are not an effective way to save energy without an accompanying initiative. According to Clay Nesler, vice president of global energy and sustainability at John Controls, "the coolest dashboard in the world won't save one BTU of energy if somebody doesn't grab a wrench and fix the equipment, adjust an operating schedule, or take action to improve the infrastructure," (Lacey, 2013). People must be involved and active to initiate change for better energy usage.

2.5   Foisie Innovation Studio

WPI is in the process of building "a hub for WPI's project-based curriculum," the Foisie Innovation Studio and Messenger Hall (Foisie Innovation, 2017). Figures 5 and 6 show digital representations of the completed exterior (upper figure) and Hive lobby (lower figure) of the Foisie building. The Institute plans for the building to be finished in early Fall of 2018; it includes new academic spaces, classrooms, an innovation and entrepreneurship center, and a global impact lab. The $49 million 78,000 square-foot building will house 140 students in its three-floor residence hall.

According to WPI's Sustainability Report from 2017, Foisie will be constructed to LEED standards resulting in the building being sub-metered (WPI Sustainability Report, 2017). No indication has been released whether the building's energy consumption information will be made readily available to the public. Displaying an energy monitoring dashboard in this facility then would address this issue resulting

in increasing Foisie's LEED certification and STARS rating indirectly by increasing energy sustainability awareness. Foisie will potentially be a high visibility area due to the building being a recently constructed academic space and dormitory, making the facility a significant option for consideration.

Figure 5: Foisie Innovation Studio Exterior (Foisie Innovation, 2017)

Figure 6: Foisie Innovation Studio Hive Lobby (Foisie Innovation, 2017)

2.6   Case Studies

WPI uses nine peer colleges and two aspirant colleges to benchmark performance measures. WPI selected these colleges in 2016 based on their similar size, enrollment, programs offered, or were considered to be aspirational (Benchmarking, n.d.). The nine peer colleges are: Carnegie Mellon University, Case Western Reserve University, Clarkson University, Drexel University, Illinois Institute of Technology, Rensselaer Polytechnic Institute, Rochester Institute of Technology, Stevens Institute of Technology, and Tufts University (Benchmarking, n.d.). The two aspirant colleges are the following: California Institute of Technology, and Massachusetts Institute of Technology (Benchmarking, n.d.).

Universities with similar campus size (80 acres) and student population (4,432 undergraduate, 6,642 total) that have constructed energy dashboards serve as assets for WPI to learn from and discern best practices. Optimizing the utility and influence of a real-time energy monitoring dashboard requires an in-depth analysis of the effects energy dashboards have on institutions to fully understand the benefits of a dashboard. Aspirant and peer institutions who have installed dashboards had priority in selecting colleges to analyze within this study followed by colleges similar in size and student population to WPI.

Massachusetts Institute of Technology

Massachusetts Institute of Technology (M.I.T.), is one of WPI's aspirant institutions due to the engineering institution's elite status, tied for fifth according to National Universities and Best Value Schools (How Does MIT, n.d.). The institution's campus size is 166 acres and has an undergraduate student population of 4,547, both far larger than WPI's (The Campus, n.d.; Enrollments, n.d.). One of M.I.T.'s plans surrounding sustainability is their "[Plan for Action on Climate Change](#)", which focuses on the responsibility that the institution has on minimizing the emission of carbon dioxide, methane, and other greenhouse gases (About MIT, n.d.). The institution constructed its own personal web portal, titled "Energize_MIT", in 2017 that displays energy data to its students as part of the school's "Plan for Action on Climate Change" (Chandler, 2017). The "Energize_MIT" dashboard focuses on interactive sets of graphic visual information and downloadable datasets to involve students and faculty. The dashboard's information is limited only for student, faculty, and staff viewing, and remains unavailable to the public (Chandler, 2017).

Carnegie Mellon University

Carnegie Mellon University has an undergraduate population of 6,804 (14,528 total) and a campus size of 140 acres, both similar to WPI's (Carnegie, 2017). A student team developed a dashboard similar to M.I.T.'s, named the ID-O, the Intelligent Dashboard for Occupants, which allows users to monitor their energy usage (Workplace, n.d.). Figure 7 shows one custom ID-O.
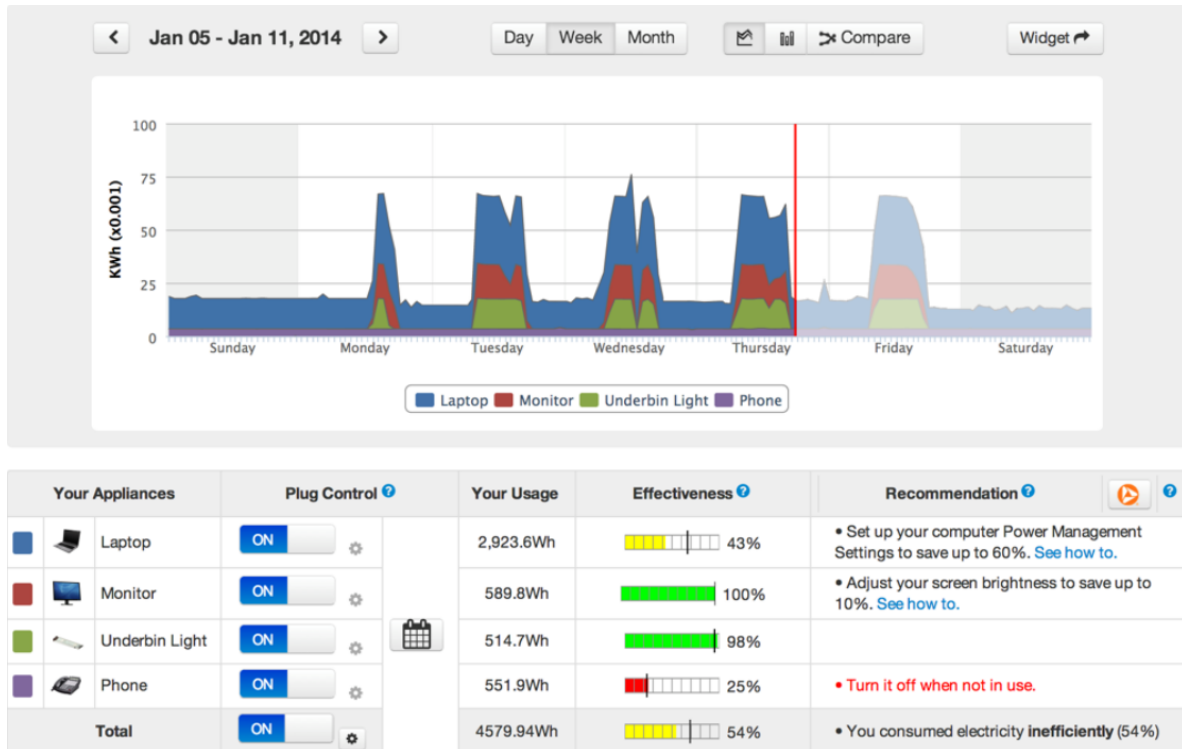
Figure 7: Carnegie Mellon's Intelligent Dashboard for Occupants (Design of a Dashboard, n.d)

The student team analyzed the effects associated with the ID-O by providing and observing employees of an undisclosed Pittsburgh corporation with the dashboard. The study shown that users of the dashboard were far more aware and active about their energy spending habits. One employee group that was granted a customizable user interface ID-O saved an average of 35.4% in plug load energy consumption. Another employee group that could see their energy usage but had no control over the dashboard saved an average 9%; an employee group that could see their energy usage and could control usage through online controls saved 20.2%. The employee control group that had no access to the ID-O also saved an additional 3.6%, possibly out of being aware of their energy usage (Workplace, n.d.).

Prescott College

Prescott College is a liberal arts, environmental studies, social justice, and science institution based in Arizona. The school's undergraduate enrollment as of 2017-2018 is 356 and has a campus size of 13 acres (How Does Prescott, n.d.); it is not currently one of WPI's peer institutions, but the school maintains one of the resident halls in the U.S. with a LEED platinum certification (Prescott College, n.d.). The Village Residence Halls at Prescott College holds the platinum Leadership in Energy and Environmental Design, being the first LEED platinum certified building in Yavapai County Arizona. Some of the Village Residence Halls' sustainable achievements include diverting and recycling 550 tons of construction waste from the building; a rainwater catch and container system for food production and landscaping was also implemented in the building (Prescott College, n.d.).
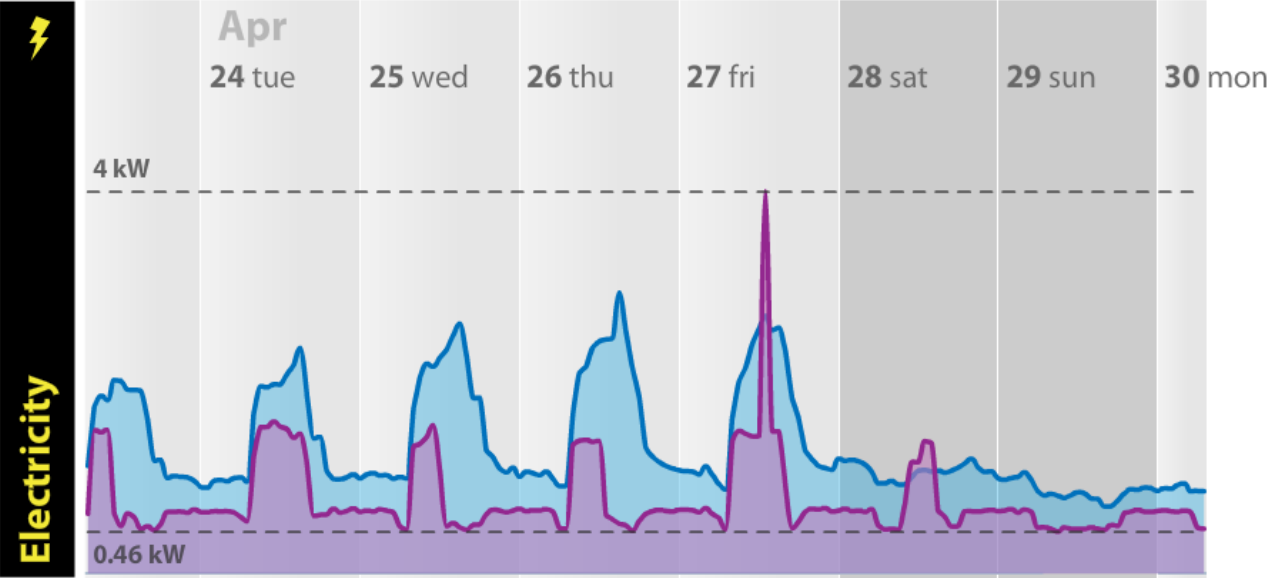
Figure 8: Prescott College's Pulse Energy Dashboard (Campus Energy, n.d.)

Prescott College has installed a campus wide energy dashboard, as shown in Figure 8, with the help of Pulse Energy to support students, staff, and the public towards understanding real-time energy consumption and solar energy generation. The dashboard provides energy usage information of 16 different campus locations in set time intervals of days, weeks, or months; the dashboard's interface displays energy usage information in both kWh and percent increments or decrements depending on the user's selection. Each location selected redirects users to their personal dashboard page identical to the one in Figure 8, presenting their energy usage information (Campus Energy, n.d.).

Western Michigan University

Western Michigan University (WMU) has won the Second Nature Climate Leadership Award and achieving a gold STARS rating in 2014 (Sustainability Report Western, n.d). WMU 's undergraduate total campus population is 17,936 and a campus size of 1,289 acres with 171 buildings as of 2017, both far larger than WPI's (Western Michigan University, 2017; Fast Facts, n.d.). The university installed a set of physical dashboards as seen in Figure 9 in various buildings on campus in 2014, and then proceeded to hold residence hall challenges to promote sustainable energy usage.
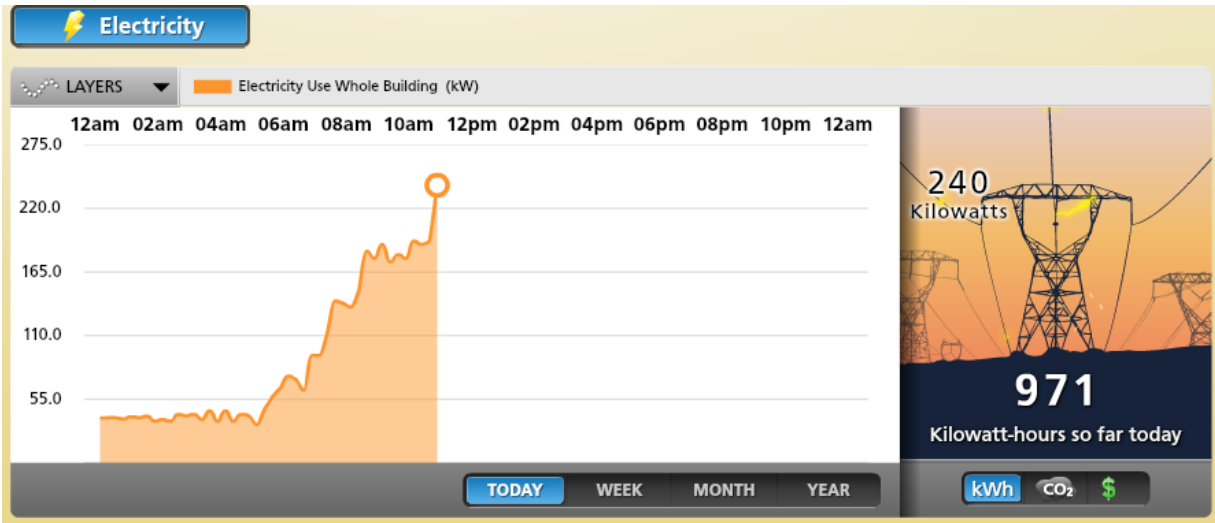
Figure 9: WMU's Lucid Energy Dashboard (Buildingdashboard, n.d.)

2.8   Summary

 "The idea is that building occupants will see how much energy the building is consuming and be inspired to conserve"(Energy Dashboard System, n.d.). Implementing and investing in an energy monitoring dashboard increases energy sustainability awareness among students and faculty resulting in increasing energy efficiencies and decrease costs associated with energy waste. The expenditures for installing an energy dashboard are justified due to the resulting minimum 5% energy savings and recovered funds from a facility that is more actively energy managed. College institutions who have installed energy dashboards such as Carnegie Mellon and Prescott College are evidence to this fact, showing staff, students, and faculty being 35% more energy efficient. If WPI is to follow in the footsteps of its peer institutions and its own green sustainability plan, displaying an energy monitoring dashboard would be an appropriate feasible step forwards towards achieving this goal.

3 Methodology

This Interactive Qualifying Project explored the energy monitoring systems currently in place on campus and proposed implementation of an energy monitoring dashboard (EMD). This project was based upon a four-step process:

- Analyze the sub-metering energy monitoring systems on campus and assess whether a dashboard monitoring system can feasibly be installed
- Gauge the WPI community's interest using a survey
- Design and test proof-of-concept dashboard options
- Form instructions to the WPI community on implementing a dashboard

3.1 WPI Energy Monitoring Systems Analysis

To confirm the feasibility and implementation of energy monitoring on campus, meetings with Bill Grudzinski, Chief Engineer of WPI; Jim Bedard, Director of Construction Projects; Kevin McLellan, HVAC Technician; and Will Grudzinski Jr., IT Systems Engineer of WPI were required to determine the logistics and possibility of a project that could feasibly implement an EMD on campus (Appendix B). If WPI has access to the energy data metered by ALC, then EMDs may be able to be feasibly implemented. Alternatively, if the energy data is property of ALC, then custom dashboard options would not be a possibility and we would have to pursue ALC's dashboard solution, the ALC EcoScreen.

After discovering that WPI has access to the metered energy data, we began analysis on their HVAC controls and monitoring system, WebCTRL, to determine dashboard implementation feasibility. We outlined the available data, noting all the locations being metered, and investigated how the data is formatted to determine a solution. As a recommendation from William Grudzinski Jr., IT Systems Engineer at WPI, we evaluated that the Tableau dashboard creation tool would be the optimal solution.

These meetings were followed by additional meetings with Vice President and Chief of Staff, Marketing and Communications, Amy Morton, as well as Vice President of Campus Planning Facilities, Eric Beattie, to assess the feasibility of our dashboard's implementation.

3.2 Dashboard Feedback Survey

A survey was sent out to the WPI student population, staff, and faculty to obtain feedback concerning the installation of an energy monitoring dashboard on campus. Included are questions (listed in detail in Appendix E) that would provide information on what students desired in terms of an EMD, how the institution wanted this technology to be presented, and if people believed a dashboard would raise energy sustainability awareness.

Energy monitoring dashboards rely on appealing to a specific audience to be an effective tool in reducing energy usage. The WPI community has three main demographics to appeal to; the general student body, faculty and staff, and visitors to WPI, including potential new students.

The primary audience is the general student body (both undergraduate and graduate) at WPI. These 6,642 students (How Does WPI, 2018) can increase WPI's energy efficiency since the majority of students live on campus. Displaying an energy monitoring dashboard to students living on campus provides the benefit of exploiting energy saving techniques and encouraging more energy efficient and sustainable decision making in everyday living. These energy saving techniques would be presented through the use of supporting infographics and relevant usage trends included on the energy monitoring dashboard.

The secondary audience is the faculty and staff at WPI. An energy monitoring dashboard has multiple benefits for this demographic. First, it reaches the faculty and staff in the same way that it reaches students, in presenting everyday energy saving techniques. Second, the faculty and staff can utilize the energy monitoring dashboard as a teaching utility, being able to have students monitor WPI energy usage and teach further sustainability practices. Lastly, it would allow the facilities management a more user-friendly way to perform in depth performance analysis on campus buildings' inefficiencies.

The tertiary audience is the potential new students to WPI. Presenting these energy consumption visuals portray WPI as an advanced "green" STEM institution that is conscientious of its energy spending habits. The effects on incoming students are secondary to a dashboard designed for the WPI community, and as such the survey results below depict the feedback from students and faculty and staff at WPI.

The survey, created in Qualtrics, was distributed amongst WPI students, faculty, and staff using Facebook and Greek house connections, and faculty/staff email aliases, respectively. The variety of the survey subjects helps gain an understanding of how the separate groups (staff, faculty, students) feel regarding energy sustainability and monitoring. Knowing how faculty and staff differ in opinion to students regarding these matters would allow us to further asses how an energy monitoring dashboard should get implemented, and if it would be valued at all. Our goal for number of survey responses was a minimum of 150 total with the hope of at least half of the responses by students, and the other half by faculty and staff combined.

A series of questions in our survey addressed student's opinions on campus sustainability and were aimed to provide us with a numerical understanding of WPI sustainability awareness and activity. From this data we gathered whether there is a need to increase sustainability awareness as a means to make WPI more sustainable overall. Additionally, the survey addressed what specific initiatives students, faculty, and staff would like to see implemented at WPI, providing us with data on whether an EMD would be supported and utilized on campus.

The questions relating specifically to energy monitoring dashboards begin by providing the respondents with a brief explanation of what an energy monitoring dashboard is, along with an example image of an ALC Eco-Screen. Respondents were then asked if they would like to see this dashboard implemented and why, as a means to provide us with an actual gauge on if the dashboard would be supported. Additionally, respondents were asked questions on their preferences for dashboard characteristics, allowing us to make recommendations for future dashboard projects. Lastly, there is a question directed for faculty and staff asking if EDMs could assist in future research, teaching, and projects, which gave us insight on the future of what dashboards could do for future WPI students from an educational standpoint.

Qualtrics was initially used to analyze the survey data, as the software's 'Reports' tool provides useful infographics and statistics of the survey responses. The data was then later exported to Microsoft Excel to create the finalized visuals for this report.

3.3   Dashboard Design

After analyzing the current energy systems on WPI's campus and pulling out energy trend data, we created low-fidelity Energy Monitoring Dashboards (EMD). Following recommendations from the Facilities Department (Appendix C), we used Tableau to extract and display static energy trend data from WebCTRL as a proof-of-concept for a live, automatically updated dashboard that we are prevented from actualizing. The automatic energy trend data exporting add-on provided by ALC would solve this issue but requires the assistance from IT to setup. By creating these mockup dashboards, we plan on gaining support from IT to assist with the setup so that live dashboards may be created in the future.

The dashboards created were designed to be low-fidelity due to the complicated nature of the energy data and Tableau interactions. Additionally, we performed a case study on other institution's dashboards for knowledge on effective dashboard layouts and strategies, paving the way for higher fidelity dashboard implementation in the future; we determined anything higher in fidelity could not easily be accomplished. The desired dashboard features found in other institutions' dashboards require more knowledge, data, and analysis than what can be achieved within the scope of this project.

The case study analysis we performed analyzed EMDs implemented by other, similar institutions. The contents of these dashboards were investigated to determine the dashboard contents that were most effective in inspiring a positive change in a user's sustainable habits regarding energy consumption. We accomplished this by comparing and extracting the similarities between the contents of the different dashboards, resulting in a set of features deemed to be essential for high-fidelity dashboard creation.

3.4   Instruction Guide

An instructional guide on how to create EMDs with Tableau at WPI was created to be used by members of the WPI community interested in creating their own EMDs. The goal of creating this guide is to lay the foundation for dashboard creation so that the WPI community may easily create their own without having to understand the complicated backend systems on campus. The guide details how to get access to and download data from WebCTRL for use in Tableau.

4 Results and Analysis:

This section presents the results from analyzing the current WPI energy monitoring systems, results from our survey, and an overview of the dashboard options. The results presented below are used to present evidence that supports the recommendations presented in Section 5.

4.1 Existing WPI Energy Monitoring Systems

As explained in section 2.2 of this report, WPI has existing energy monitoring systems that record campus buildings' energy usage with Automated Logic Corporation's (ALC) WebCTRL system. WebCTRL also allows facilities to control other HVAC and water systems, including air vents, water pumps, fans, and more on campus. This system can be accessed through an internet browser provided the user has been granted access.

As shown in Figure 10, WebCTRL allows facilities to monitor things such as temperatures of certain rooms (given there are thermometers on the network). Depicted is the temperature breakdown of rooms in the Campus Center building, using a heat-map to portray relative temperatures. B. Grudzinski from the Facilities Department mentioned that this saves energy resources by allowing facilities to adjust heating as needed, for example Campus Police knows if a student left a window open in their residence by noting any light blue rooms on the heat-map, allowing them to close the window to avoid heat loss.
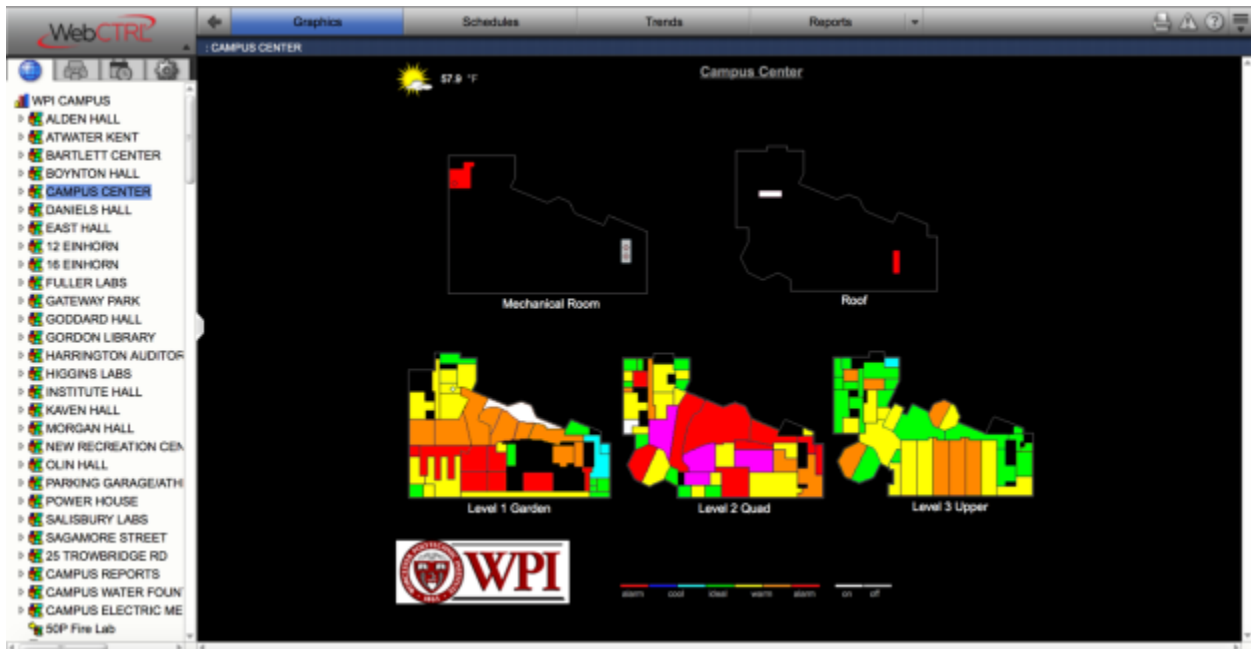

Figure 10: Example of Automated Logic WebCTRL service displaying the temperature in the Campus Center

The view-only access to WebCTRL allows for energy usage trends to be displayed and downloaded, enabling a user to use third-party software like Tableau to create dashboards. After meeting with Bill Grudzinski, Jim Bedard, Kevin McLellan, William "Will" Grudzinski Jr, IT Systems Engineer at WPI,

and Richard Candage, ALC sales representative (Appendix C), it was determined that there were two potential options for creating an energy monitoring dashboard: either ALC provides their own solution, or we produce our own. The first option was to use the Automated Logic Corporation's (ALC) EnergyReports™ Eco-Screen® Edition dashboard system, which is a piece of software developed by ALC that supports the existing ALC systems on campus [United Technologies, 2018]. The second option was to use existing technologies (i.e. dashboard creation tools, custom software, etc.) to create EMDs using the energy data available from WebCTRL. Choosing one option over the other required consideration on which dashboard solution is more realizable.

In choosing which dashboard option to explore, costs and benefits of both options were considered. If one chose the ALC solution, the school would have a high-fidelity dashboard designed by software engineers at the third-party company Lucid, a company that started from initiating dorm competitions on energy savings using EMDs. This dashboard would be entirely maintained by ALC and would require little WPI supported maintenance; only light training would be required to have a privileged user decide what data and pre-developed visuals to have on the screens. These dashboards, described as "seamless" and "easy to use, and easy to understand the comparisons [between energy consumption and a baseline comparison] made" have been shown effective in saving energy resources, estimating 2.1 million kWh saved in a university competition (Schaffhauser 2013). The user-friendly interface can be seen in Figure 11. The benefits of this dashboard seem enough to justify its cost, however in meeting with Bill, it was discovered that the last 2016 IQP that attempted to have this implemented did not gather enough support from WPI to get funding.

If WPI were to choose a custom dashboard solution, custom development of an EMD would require research on energy data displaying techniques for sustainable purposes, as well as the actual implementation of the dashboard; creating visuals, choosing which data to display, etc. These dashboards would be created by WPI students and would have to be maintained by them too, adding more levels of complexion and fragmentation. Additionally, in meeting with B. and W. Grudzinski, it was discovered that to get the energy data to be displayed live as measurements are taken, an additional software add-on, the Trend Export Add-on, would have to be purchased from ALC. B. Grudzinski said that he has purchased the add-on after discussing our project, although there are technical barriers that prevent us from setting it up. Specifically, knowledge on the File Transfer Protocol (FTP) is required to upload the .csv files to a server, which requires additional computer networking knowledge. W. Grudzinski says that it may be something the WPI IT department has to do, or maybe a more technically focused student team.

Table 2 details the dashboard options and their efficacy. Assuming custom dashboards have a future at WPI, most of the downsides of the custom dashboard option can be ignored as teams improve their designs and contents over time, moving away from low-fidelity prototypes to high-fidelity prototypes[1] and eventually a final product. If future groups work to produce dashboards with better infographics and

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[1] *Low and high-fidelity prototypes*: User interface prototypes created in the graphical user interface engineering world can be either low or high in fidelity. A prototype that is low in fidelity is meant to expand the concepts of a design into something visible or tangible; an example is a sketch of a user interface or even a bare-bones interface without much functionality. A high-fidelity prototype is meant to be more functional and closer to a final product (Pernice 2016).

cards, then the only downsides are maintenance and implementation. Further, it may be futile to attempt to gather support for WPI to fund the ALC EcoScreen due to past failed attempts at such. From this cost-benefit analysis following our WPI energy system analysis, we conclude the best option for EMDs at WPI are for student groups to develop their own.

Table 2: Dashboard options

	Cost	Fidelity	User-friendly	Implementation	Maintenance
ALC EcoScreen	High	High	High	Low	Low
Custom Dashboard	Low/none	Low, future potential	Low, future potential	High	Required

Figure 11: Automated Logic Eco-Screen (Building Can, 2011)

If an EMD were to be implemented on campus, considerations for its location are necessary. In meetings with Vice President, Chief of Staff, Chief Marketing Officer, Amy Morton, Dean of Undergraduate Students, Arthur Heinricher, and Vice President, Campus Planning Facilities, Eric Beattie, it was determined that there were multiple suitable locations for displaying the dashboard, primarily the Foisie Innovation Studio for being in planning and construction. The studio's abundance of televisions and small screens could provide a place for the dashboard to be displayed.

4.2   Dashboard Feedback Survey Results

This subsection discusses the results of a survey distributed to the WPI community in April 2018 with a total of 187 responses. The survey was answered by 98 students (53%) and 86 faculty and staff members (47%). This balance between students and faculty and staff is important in determining the audience to the energy monitoring dashboard.

Campus Sustainability

Only 44% of the WPI students (43 of the 98 respondents) who responded to our survey feel as though they participate in activities aimed at making WPI more sustainable as seen in Figure 12.
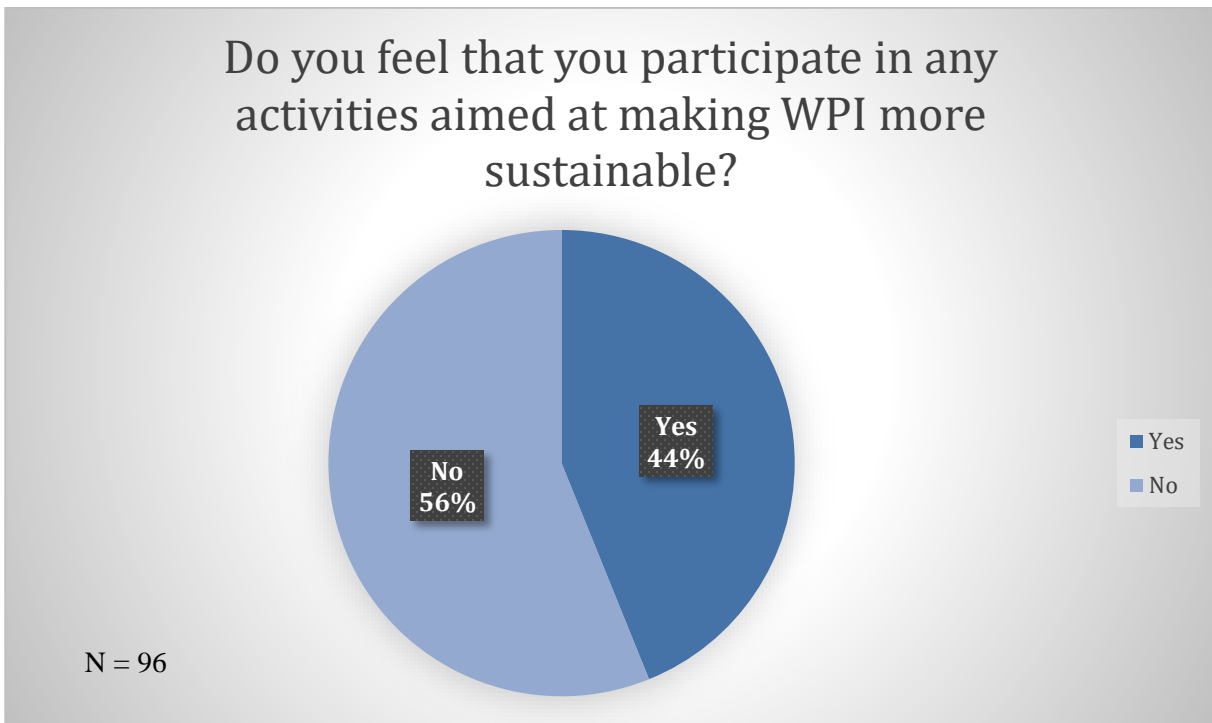
Figure 12: WPI community participation in sustainability practices

Although 56% of students felt as though they did not participate in sustainable actions on the WPI campus, many supported a variety of options for initiatives they would be interested in to help make WPI a more sustainable campus. Respondents were asked to select all the initiatives that apply and would like to be seen on campus, with the results shown in Figure 13 below.
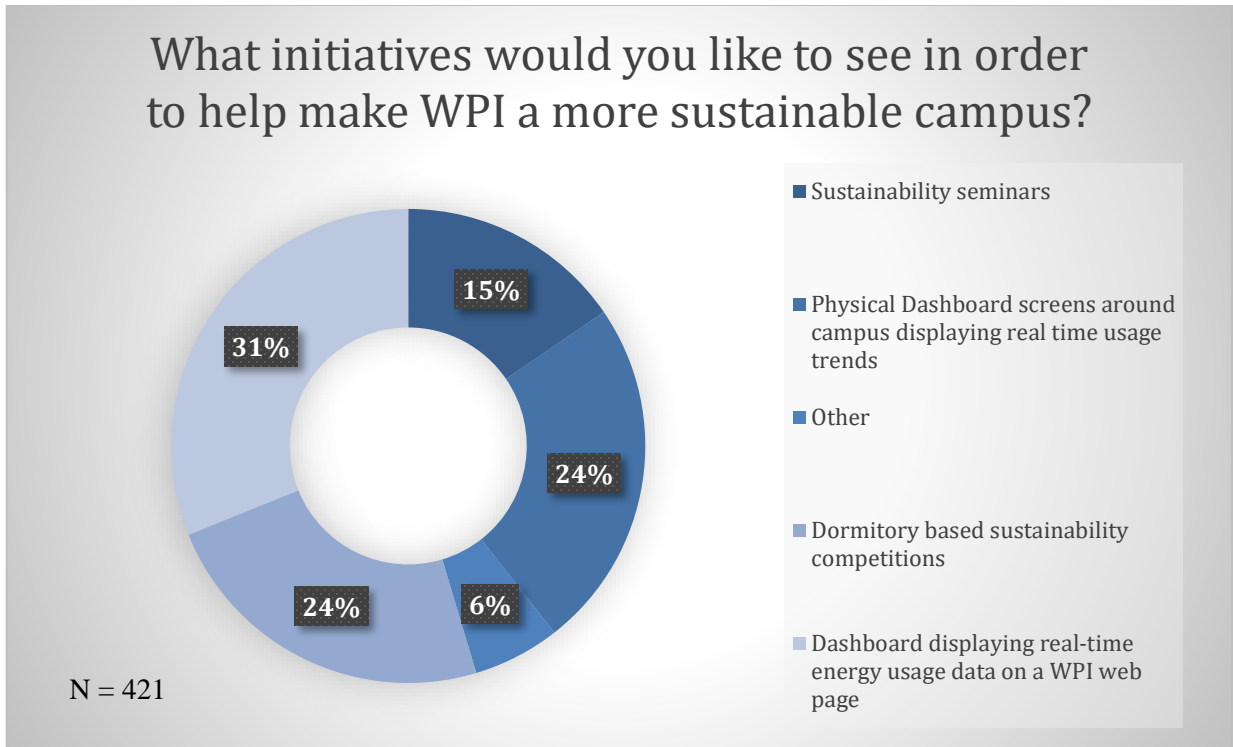
Figure 13: Preference on future sustainability initiatives to implement on campus

As indicated by the responses to this question, the idea of a dashboard displaying real time energy usage data was the most popular, with 55% of people choosing this as a sustainability initiative they would like to see on campus.

Energy Monitoring Dashboard

The following questions provide feedback on the use of an EMD. Only 1% of the faculty and staff respondents believed that an energy monitoring dashboard would NOT be helpful for faculty teaching, research and/or student projects. By comparison, 47% of faculty and staff (37 of the 79 respondents) believe that it would be helpful, and 52% (41 of the 79 respondents) believe there is a potential for it to be, as seen in Figure 14. This tells us that moving forward with the implementation of EMDs is something that would not only be of interest to students, but for faculty and staff as well for educational purposes.
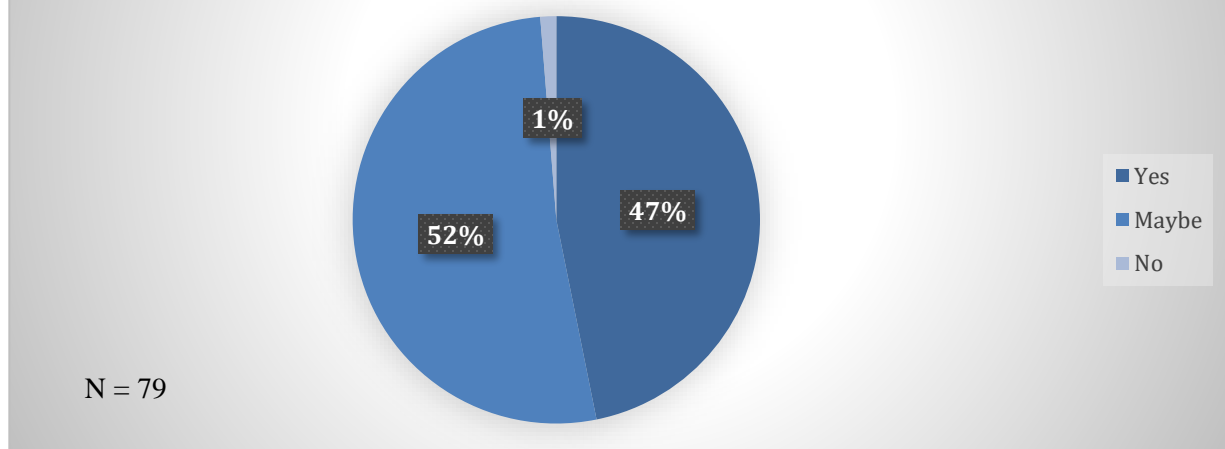
Figure 14: Respondent opinions on the educational value that energy monitoring dashboards can add

Figure 15 below, depicts the respondent's preference to the best location for an energy monitoring system to be located. 57% of respondents prefer to have an energy monitoring system both online and on campus for viewing, while only 12% of respondents were indifferent. In reviewing these results, the interest for an online dashboard outweighs that of a physical dashboard. Therefore, we have concluded that in future projects to further implement this dashboard the focus should remain on creating online EMDs until it can produce results that would allow it to be made into a physical dashboard located somewhere on the campus.
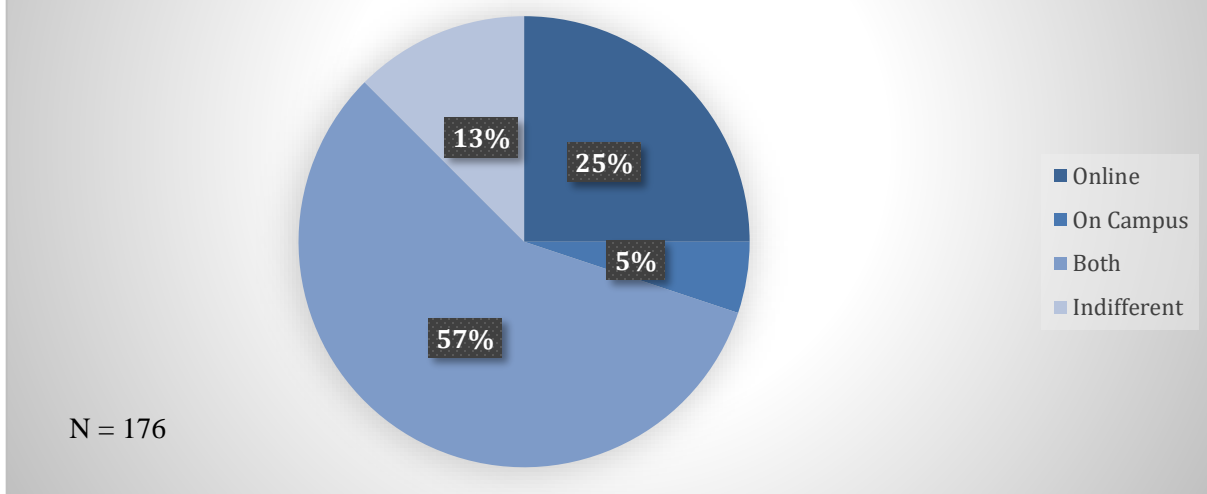
Figure 15: Energy monitoring dashboard location preference

In asking why or why not implement a dashboard the feedback was overwhelmingly positive. Here are a few samples of comments we received:

"Visualizing energy and resource consumption can be a persuasive way to convince others to reduce our overall consumption."

"This shows what is going on in the campus setting and makes users think about how they are using their resources."

"It'll put into perspective how sustainable we actually are instead of just talking about it."

"It seems like a good way to track whether or not WPI is being efficient and sustainable with its power use and could help us keep ourselves on track for our sustainability goals"

"It would be enlightening to see how our consumption varies depending on time of year, etc. and perhaps it would help us make better energy related choices"

Dashboard Qualities

The following results in Figure 16 depict the energy monitoring characteristics that are most important to the sample WPI community in this survey.
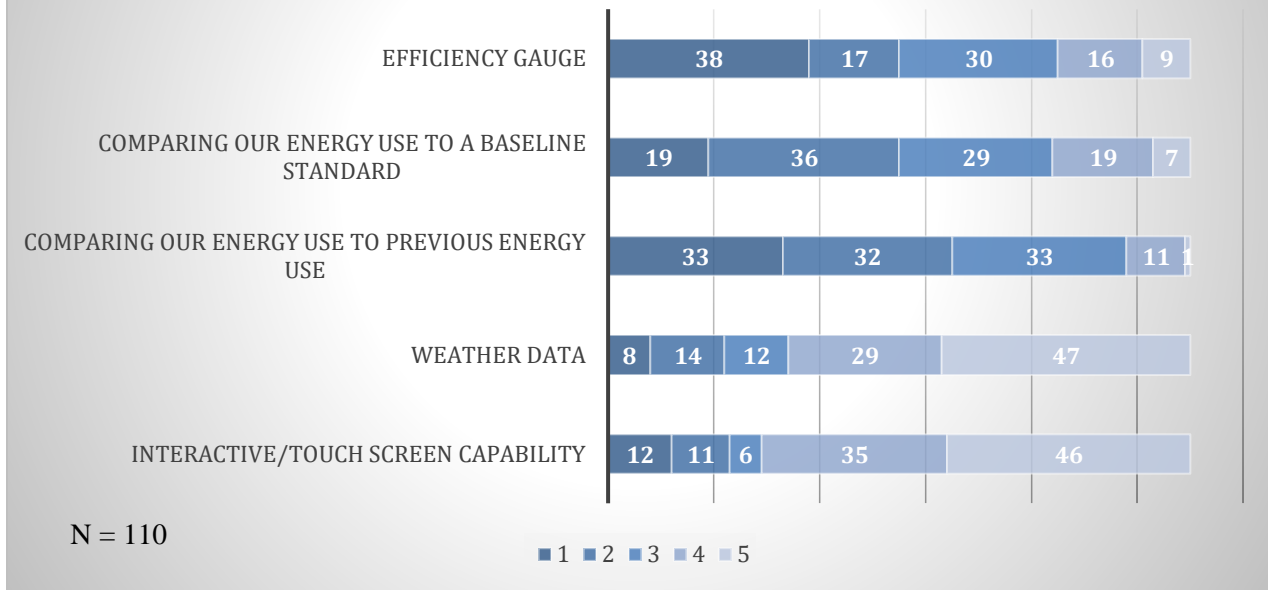
Figure 16: Rank of importance for features on an energy monitoring dashboard

The respondents ranked an efficiency gauge and a comparison of previous energy usage as the most important characteristic of an energy monitoring system at 35% and 30%, respectively. The weather data and the interactive feature were deemed less important, only receiving a combined 18% for ranking most important. Another important feature, that is comparable to the two ranked most important, is comparing our energy usage to a baseline standard, receiving only 6% of the least important votes. This feedback shows that the most appealing aspects to implement are the comparative analysis' to both a baseline standard as well as previous energy use. Incorporating a simple efficiency gauge displaying whether specific buildings are performing efficiently could offer a simple and easy-to-understand way to relay to the most viewers exactly how efficient WPI really is. Due to surveys being taken after our proof of concept dashboard had been created, the ranking of these characteristics is included in the recommendation section for future student groups who will design EMDs.

4.3   Dashboard Design

EMDs were created using Tableau and using trend data from WebCTRL, and were configured to display energy usage, energy demand, weather data, etc. Using Atwater Kent energy demand trends as well as outside temperature, we created a dashboard that attempted to juxtapose the two datasets (hourly data for past 24 hours) in hopes that a viewer would be able to compare their energy usage to the weather to see the story of whether energy is being used efficiently, seen in Figure 17. By seeing whether a building is being efficient with energy resources, a viewer would hopefully change their behaviors to encourage sustainable habits, helping energy resource sustainability. This concept of comparative or relative energy

consumption display is vital in composing robust EMDs. This theme allows users to see patterns of high energy consumption and understand that certain behaviors, like air conditioner abuse, have consequences on energy resource usage and therefore spending.
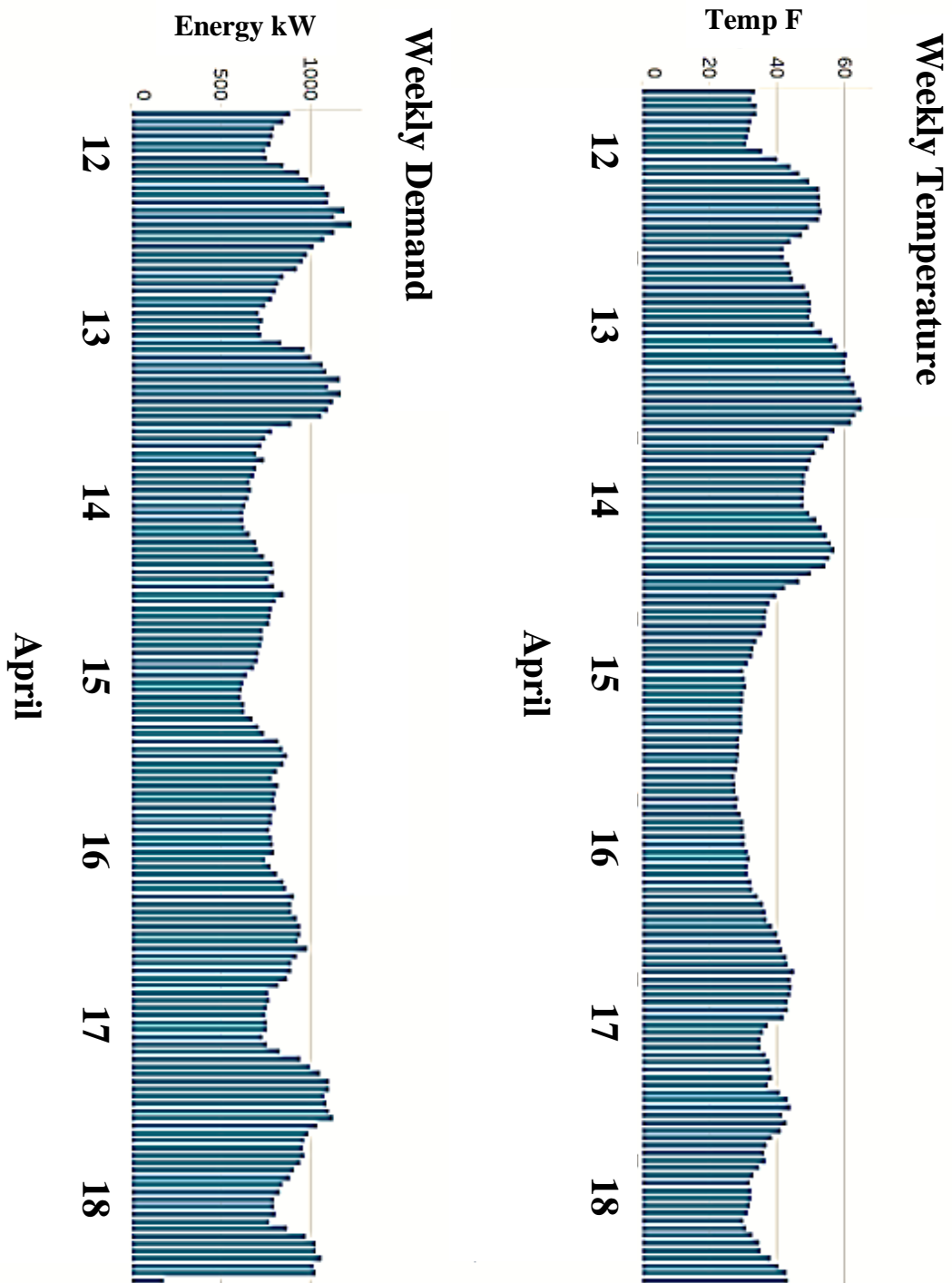

Figure 17: Hourly energy demand and outside temperature of Atwater Kent, April 17, 2018. See Appendix D for more dashboard mockups.

Due to time constraints and the aforementioned (section 3.3) technological barriers, we are limited to adding more features to be able to have the dashboard tell the story of comparative energy usage; adding cards to the dashboard that compare current energy usage to efficient energy usage would be ideal, a takeaway from the case studies. Unfortunately, it is difficult to create such a card and add to the dashboard, more data analysis and engineering need to be done to effectively show such comparisons.

Another struggle with creating these dashboards in Tableau is the inability to display live energy data. The current method for getting the data is by manually pulling trends of WebCTRL, giving Tableau only static data. The Trend Export add-on from ALC is a solution to this issue, allowing for live trend data be displayed. The setup process for the add-on includes setting up a server for WebCTRL to send data to, as well as connecting the Tableau software to this server to pull data from. The full instructions for setup are found in a confidential manual supplied by ALC and in possession of Will Grudzinski, mentioned in our instruction guide for future groups to continue.

4.4   Instruction Guide

An instructional guide (Appendix I) was developed to detail the methods to take to design EMDs in Tableau the way it was done in this project. The guide instructs how to get access to and retrieve energy trend data and use it to create dashboards in Tableau. The purpose of the guide is to have other groups on campus follow through the process outlined in this guide to ensure a streamlined process. The goal of this guide is to set the precedent for creating EMDs at WPI by outlining the process that students may follow to bring more dashboards to campus.

5 Conclusions and Recommendations

This section outlines the conclusions of our project and future recommendations to further this project. The following conclusions are based on the data presented in the Results and Analysis Section above, along with recommendations that define the potential ways to continue the implementation of energy monitoring dashboards at WPI. This section also includes the selection of a dashboard and the opportunities and suggestions for future development.

Recommendation 1

> The WPI administration and the facilities department, in conjunction with the Green Team, should pursue the continuation of this project by implementing energy monitoring dashboards at WPI to promote energy usage awareness and ultimately increase energy sustainability.

The results of this project show that an energy monitoring system would be beneficial to WPI, both in the interest of the WPI community and the long-term benefits that occur. These dashboards will visually display the sustainable growth in the new LEED certified buildings and energy saving practices being implemented within the WPI community. Aligning with the WPI Strategic Plan and WPI Sustainability Plan, these dashboards can help promote a culture of sustainability that incorporates the beliefs and behaviors supported by the WPI community's technical strengths and enhance the effort of data-driven decision making.

Through background research, the benefits of energy monitoring dashboards (EMDs) have been identified as something that would help WPI increase its sustainability. By increasing the general awareness about sustainability issues, people are more likely to practice sustainable habits. The energy monitoring dashboard will promote energy efficient habits by combining energy efficient infographics with visual representations of the impact the WPI community can make by following these tips. Based on the preference of students, faculty and staff, future EMDs should include comparative usage analysis to both baseline data as well as previous consumption. Additionally, an easy to read and understand efficiency gauge should also be included with the dashboard.

To implement these dashboards, the following steps need to be completed:

> Step 1: Contact William "Will" Grudzinski Jr in the IT department about creating a server that will store the exported WebCTRL live data.

> Step 2. Read the Tableau Instruction Manual on creating energy dashboards, in Appendix H, and investigate different functional EMDs that use both comparative data and an efficiency gauge.

> Step 3: Reach out to the Green Team for discussion of taking on the Tableau energy boards maintenance and content for the future.

> Step 4: Investigate locations for the implementation of physical dashboards on campus.

The only cost associated with implementing these dashboards is the annual fee for the WebCTRL export add-on.

Recommendation 2

> Future energy dashboard IQP teams should identify a Professor that would be willing to expand this project, either as a Graduate Research project, IQP or MQP, to ensure the dashboard is improved in the future.

There is potential for future projects to focus on investigating specific building inefficiencies on campus using the energy dashboards and investigate the possibility of correcting these inefficiencies. Other research opportunities include projects in data science involving user testing to ensure that appropriate data comparisons and supporting infographics portray a sustainable story of the WPI campus.

To implement this recommendation, the following steps need to be completed:

> Step 1: Determine the scope of the future project (either in inefficiency investigation or data visualization).
>
> Step 2: Identify a professor with background knowledge in the project scope
>
> Step 3: Pitch to the professor why they should continue this project utilizing the results provided within this paper

Recommendation 3

> Future energy dashboard IQP teams should identify secondary uses of the energy monitoring dashboards.

These secondary uses are defined as ways for the WPI community to encourage peers to utilize the energy monitoring dashboards in a competitive or educational manner. These uses will encourage constituents to use the energy monitoring dashboard to visualize the impact that can be made by practicing energy efficient habits. The secondary uses include, but are not limited to:

- Creating a sustainability presentation on energy monitoring dashboards to present in the Foisie Innovation Studio, utilizing the "Hive" screen.
- Implementing dorm competitions, using the energy monitoring dashboards, to increase energy efficiency in the dormitories, where first-year students and upperclassman will be housed. These competitions have shown to encourage efficient sustainability practices on campus, beginning with first-year students.
- Investigating locations for the implementation of physical dashboards on campus, as well as installing additional sub-metering areas to monitor more buildings and the specific areas within them.

Summary

Through extensive background research, a case study analysis, and campus survey, our team was able to produce a group of recommendations for WPI in furthering the implementation of energy monitoring dashboards. While initial recommendations pertain to the direct implementation tasks of creating the dashboard server and identifying someone to maintain the dashboard, future recommendations address possible research or project groups in expanding EMDs to increase their value to WPI. The potential effects that EMDs can have at WPI can only increase as future projects develop more uses of this

dashboard, such as energy savings competitions and sustainability presentations. In pursuing the continuation of this project, we hope that students in the future will look to these recommendations as a baseline for the realities that energy monitoring dashboards can bring about.

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Appendix A: Support Directory

William Grudzinski Sr. Chief Engineer. Facilities.

James Bedard. Director of Construction Svcs. Facilities.

Kevin McLellan. HVAC Technician. Facilities.

William Grudzinski Jr. Systems Engineer. Information Technology.

Professor Paul Mathisen - Director of Sustainability

Elizabeth Tomaszewski - Associate Director of Sustainability

Amy Morton – Vice President, Chief of Staff, Chief of Marketing

Eric Beattie – Facilities VP Campus Planning

Kyle Cory – President WPI Green Team

Appendix B: Meetings, Interviews, Discussions: Questions, Topics

Facilities Meeting 1 on 2-26-2018 at 4:00 PM at the Power Plant

Attendance:

Bill Grudzinski
Jim Bedard
Kevin McLellan
Energy Dashboard Team

Main Focuses of Meeting:

- Gain general knowledge about the current usage monitoring system on the utilities/faculty side
- Determine what future knowledge needs to be obtained to confirm the feasibility of energy monitoring dashboards

Questions for Grudzinski:

- What is your experience with dashboard systems?
    - EDSM, submetering, Automated Logic: how are they related/connected?

Questions for Jim Bedard:

- Is this project doable/feasible?
- Is Foisie LEED certified, or, what certifications are being sought?
    - Yes, the building is being built to achieve LEED Gold certification.

Questions for Both:

- What backend energy system is in place that would allow for us to analyze data?

Facilities Meeting 2 on 3-22-2018 at 9:00 AM at the Power Plant

Attendance:

Bill Grudzinski - Chief Engineer WPI
Jim Bedard - Director of Construction Services WPI
Rich Candage - Sr. Sales Representative ALC
Pete - Regional Sales Director ALC
Bill Grudzinski Jr. - Systems Engineer IT WPI
Kevin McLellan - Controls Engineer/HVAC Mechanic
Energy Dashboard Team

New Proposed Idea: sell dashboard based on helping other projects be able to analyze the data for their projects - push the continuation and benefits this will have in the future outside of primary monetary savings

For 4/2 meeting:

- Ask about costs of implementing ALC board
- Where to go from here if POC dashboard unfeasible
- Meeting with Amy Morton on Friday, any recommendations
- Getting us into the WebCTRL system

Meeting with Kyle Corry, President of WPI Green Team at 10:00 am 4-4-2018

Attendance:

Kyle Corry
Energy Dashboard Team

Main Focuses of Meeting

- Inform about the goal and objective of our project
- Introduction of project
  - Campuses across country have been installing these dashboards that allow the students access to certain energy and usage data
  - Started off with the idea of implementing only in Foisie, but have since moved more towards the idea of implementing as a view only dashboard that can be used in various spots on television screens all over campus
    - Places in mind- Bartlett Center, Foisie, Campus Center, Wedge, Library
- Current Status
  - Looking into Tableau dashboard creation as first option as it would be free but would require future maintenance and upkeep to stay updated.
  - If this doesn't seem to be a possibility, looking into the ALC dashboard which will cost some money
    - Is this something the Green Team would be able to pick up as a continuous project to make sure the dashboard stays afloat year to year?
      - If so, they could possibly just organize the board for a few terms a year and then dish the remaining terms out as potential IQPS
      - Maybe the possibility of the Green Team to regulate and then when inefficiencies are found, IQP groups could investigate finding solutions

Sustainability Directors Meeting on 4-13-2018 at 9:00 AM at Lee St.

Attendance:

Professor Paul Mathisen - Director of Sustainability
Elizabeth Tomaszewski - Associate Director of Sustainability

Main Focus of Meeting

- Update Liz and Paul about the current status of our project and take recommendations on moving this project into the future

Questions Asked

- What is the best content to include on the Dashboard?
- Which route is the best to go down? ALC or Tableau?
- What advice do you have for us moving forward?

Scope of Meeting

- Reintroduced the goals and objectives of this project
- Updated Liz and Paul on the results of previous meetings with faculty and staff members
- Updated on current status of being able to make dashboards via Tableau
- Discussed the survey we created in order to gain public understandings of sustainability and energy monitoring
- Discussed the future of this project moving forward and the continuation after completion

IQP Support Meetings

Meeting 1: 4-6-2018 at 10:00 AM at Lee St.

Members Present:
Eric Beattie, Vice President, Campus Planning Facilities

Meeting 2: 4-6-2018 at 4:00 PM

Members Present:
Amy Morton, Vice President, Chief of Staff Marketing and Communications
Dean Arthur Heinricher, Dean of Undergraduate Students

Main Focuses of Meetings

- Inform as well as gain support from Eric, Amy, and Arthur about the goals and objectives of our project
  - Gain information on the implementation aspect of this project from their perspective positions

Questions Asked

- Who do we need to pitch this project to in order to make it a reality?
- Where would you like to see this dashboard implemented if possible?

Scope of Meetings

- Introduction of project
  - Campuses across country have been installing these dashboards that allow the students access to certain energy and usage data
  - Started off with the idea of implementing only in Foisie, but have since moved more towards the idea of implementing as a view only dashboard that can be used in various spots on television screens all over campus
    - Places in mind- Bartlett Center, Foisie, Campus Center, Wedge, Library
- Current Status
  - Working with IT department to see if we can make a backend POC dashboard that will be low cost and offer multiple benefits
    - Allows WPI to more closely monitor and make changes to facilities to make campus more efficient
    - Spreads awareness of limiting energy usage to both students and faculty, something that down the road is a positive influence for all and helpful for the environment
    - Will allow for future students to update and design the dashboards which could in turn lead to future sustainability projects for IQP or MQP opportunities
    - Will allow for the opportunity to host dorm competitions and other competitive events that involve cutting energy/water/gas costs

- o If this dashboard infeasible, we are looking at the idea of pitching the ALC dashboard, which would require monthly and initial installation payment.
  - Still waiting back to hear what the cost of this dashboard system would be, but in previous years this has been the sole factor in preventing the dashboard from happening
- Moving forward
  - In talks with Bill Grudzinski, Jim Bedard, and Kevin McLellan, this dashboard has become more and more feasible over the years as we have installed more and more submetering systems on campus

Facilities Meeting 3 on 4-23-2018

Attendance:

William Grudzinski Sr.
Jim Bedard
Energy Dashboard Team

Conversation questions:

- Were you able to purchase the WebCTRL add-on that allows for the automatic exporting of energy data?
  - Yes:
    - With this technology now available, who's now responsible for maintaining the server that the data will get sent to? Is this something that IT can take care of? An MQP team?
  - No:
    - Will we ever be able to get this add-on? How do we move forward?
- We have made POCs using the data pulled from WebCTRL. We are developing solutions to continue the project when we are gone, including an instruction manual. Are we allowed to publicly display energy use data to the public? How about WPI? Is there any special paperwork that we have to fill because of this?
  - Are we allowed to distribute the instructional manual that we produced?

Appendix C: Meetings, Interviews, Discussions: Summaries

IQP Background Facilities Meeting 1 on 2-26-2018 at 4:00 PM

Summaries from Grudzinski:

- What is your experience with dashboard systems?
  - Worked with many energy monitoring systems but no actual implemented dashboards on campus
  - EDSM, submetering, Automated Logic: how are they related/connected?
    - E'mon-D'mons provide submetering connected to ALC which allows backend viewing and controlling of all HVAC, water, gas, etc.

Summaries from Jim Bedard:

- Is this project doable/feasible?
  - Depends on what IT has to say regarding tech feasibility, they have access to the data streams so if we get access we could build POC dashboards; if we get the privilege of showing private data publicly; if we can get access to put the dashboard on a screen somewhere; if the cost situation isn't a problem.
    - Is Foisie LEED certified, or, what certifications are being sought?
      - Yes, the building is being built to achieve LEED Gold certification.

Summaries from Both:

- What backend energy system is in place that would allow for us to analyze data?
  - Schneider is the old system they are replacing
  - Automated logic (WebCTRL) is everywhere on campus
    - We may get access to what we need
    - We can get 5-min interval data
    - 13th of march is when energy comes online
    - EDSMs on same network as AL
    - Graphics show heatmaps of temperatures
    - ALC Eco-Screen - WPI would to buy it - fully implemented dashboard system provided by Automated Logic

Other Points of Business/ Action Items:

- Talk to IT
  - ALC offers dashboard support and improves/updates anyone WPI
  - Created software system to pull data
- Rotating content so it doesn't get boring
  - Opportunity to sell WPI to new folks on campus
    - Sales pitch - put it in Bartlett to better sell WPI to prospective students, to better sell our idea of having a dashboard

- In terms of sales pitch, potentially have the idea of dorm competitions for energy savings
- TODO: Fill out IRB paperwork
    - 37 Lee street - facilities main desk - fill out NDA

Facilities Meeting 2 on 3-22-2018 at 9:00 AM at the Power Plant

- It was mentioned briefly that the ALC dashboard would cost somewhere in the ballpark of around $10,000 initially, and subscription fees afterwards, dissuading WPI from purchase.
- Making our own dashboards is possible – existing energy data may exist to be used on a live dashboard. ALC provides an add-on that allows for the automatic exporting of energy trend data, meaning that a dashboard software tool like Tableau could be used to create an EMD that contains the most recently measured energy data. This add-on would come with a small financial cost that Bill Sr. may be able to find room in his budget for. More information needed from Will Jr. on the possibility of this option.
- Retro-commissioning started a few years ago - putting old meters onto the ALC system
  - CC, and gateway first buildings to do so
- Originally E'mon D'mon's were on their own network and went unlooked at for a while.
- Amy Morton - who does she think should be at this future presentation? Who is our audience?

Meeting with Kyle Corry, President of WPI Green Team at 10:00 am 4/4/2018

- Yes, the green team is available to continue updating and maintaining the dashboards. The team is already involved in the upkeep of the online Bike system on campus, which was once an IQP; they are competent enough to perform dashboard maintenance if we supply methods on upkeep.

Sustainability Directors Meeting on 4-13-2018 at 9:00 AM at Lee St.

Summary of Meeting

In our discussion with Liz and Paul we began with a status update on our current progress and finally being able to create energy and resource dashboards through Tableau. We mentioned that the costs of the ALC Dashboard have made it truly infeasible to implement at WPI, and the benefits of the low-cost Tableau version make it much more accepted by the faculty and staff that are required to make it a reality. This directed us into the talks of what would potentially be displayed on these future dashboards, to which they recommended that alongside the relevant energy usage data trends there be inclusion of sustainability awareness side notes, such as current events on campus. Additionally, they mentioned that when this dashboard becomes implemented, displaying usage trends that result from increased campus sustainability awareness would be relevant. Our conversation was then directed into a discussion of what our next steps should be in moving this project forward. This included that we need to determine a finalized process of recommendation for future projects relating to this topic, as well as a protocol for future students that are going to be utilizing Tableau to create dashboards. In this protocol they recommended that we establish a clear constraint on what dashboards should be investigated and exactly what data can be withdrawn and publicized. They followed up with a recommendation to send them our Qualtrics Survey, so they could relay it to WPI faculty and staff in order to get more diverse responses.

IQP Support Meetings

Summary of Meetings

Meeting 1: Eric Beattie, Vice President, Campus Planning Facilities

Eric Beattie was interested in the concept of integrating the idea of the dashboard into the Foisie Innovation Studio and provided us with a few others to talk to as we moved this project forward. Overall, the discussion was more informational for him than anything, and did not offer a lot of results for us in terms of forwarding our implementation of the project. However, he showed us a few renditions of the future interior plans for the new building and offered the idea that if the dashboard was unable to happen on the large screen in the main passageway, that there could be the possibility of allowing it on the smaller screens distributed throughout Foisie.

Meeting 2: Amy Morton, Vice President, Chief of Staff Marketing and Communications;

 Professor Arthur Heinricher, Dean of Undergraduate Students

Our meeting with Amy and Arthur began as mostly an informative session presenting them with a handout of the objectives of our project and the current status of our progress. They were both intrigued by the idea of the dashboard and offered a few recommendations on potential locations and future ideas. At this point in time, we were still waiting for the IT department to deliver us the program that allowed us to pull the backend usage data from WebCtrl and had not yet produced any actual dashboards. At this late stage in the project, actually implementing one of these into a building seemed unlikely and the discussion moved into a variety of recommendations for moving forward with this idea. We discussed the potentiality for future student creation of a variety of dashboards specific for different buildings based on their efficiencies and inefficiencies, which could continue to provide future students with IQP and MQP projects as well as research opportunities for years to come. Though the idea of the dashboard being displayed on the Foisie main screen all the time was deemed unlikely, Amy recommended that other screens around the building could actually be feasible since currently their content is still being decided, and she pointed out to us that2 Maureen Deiana would be a good person to talk to in further implementing a dashboard on these screens. Arthur then brought up the potential idea for either an IQP/MQP project team or the Green Team to give scheduled sustainability presentations on the Foisie main screen, with the aim of increasing sustainability awareness to the WPI community.

Recommended Contacts:

- Maureen Deiana, Asst VP, CMO Marketing and Communications
  - Director of screen content for Foisie Building
- William Sprat, Dir of Facilities Operations

Facility Manager in charge of heating & cooling resources

Facilities Meeting 3 on 4-23-2018

- Bill Sr. was able to purchase the ALC automatic trend exporting add-on. The next steps are to talk to Will Jr. and IT about how to implement the add-on for automatic trend data usage by Tableau. A discussion with Paul Matheson needs to happen to determine if the public display of trend data is allowed, if our instructional guide is allowed, and if any future dashboards may be shown to the public.
    - In emails with Matheson, we are approved to present our poster, containing energy data, to the public. For the guide, we would need to get Paul's approval to make sure that no student may arbitrarily create dashboards for quality's sake. Additionally, any future dashboard would also need permission.
- In an informal meeting with Will Jr., more information on the trend exporting tool was revealed. Firstly, if that add-on were to be used, the energy trend data would be in the .csv file format, compatible with software like Microsoft Excel, and Tableau. Another key aspect of this data format is that it's the same format of the statically downloadable energy trend data from WebCTRL. With these pieces of information, Will Jr. suggested it would be possible to download the static data for use with Tableau, serving as a proof-of-concept for the possibility of any future dashboards that use the live data provided by the add-on. The conclusion of this meeting was to create Tableau dashboards

Appendix D: WPI Tableau EMDs

Hourly energy demand and outside temperature of Atwater Kent, April 17, 2018
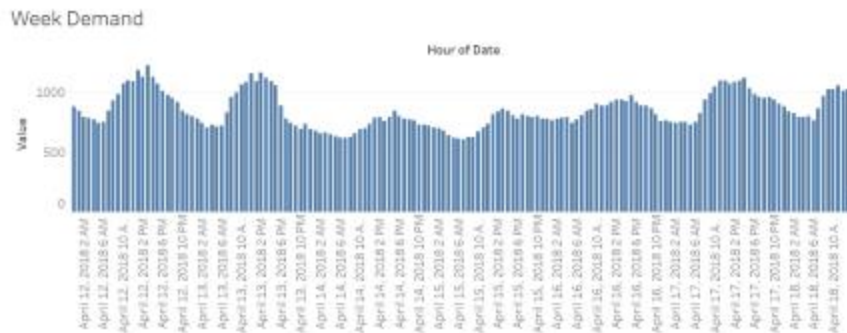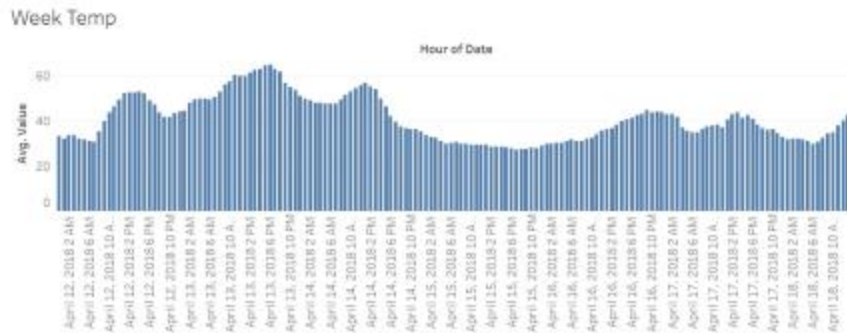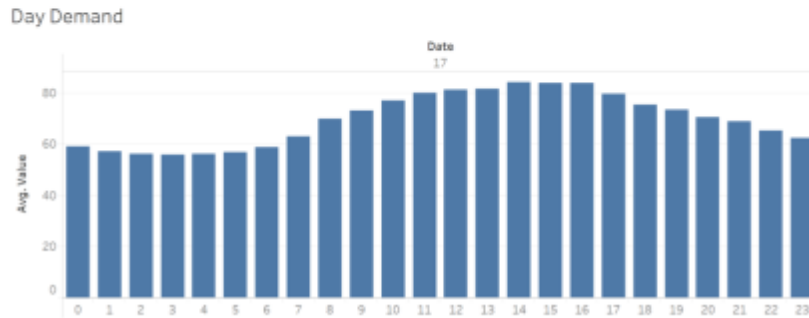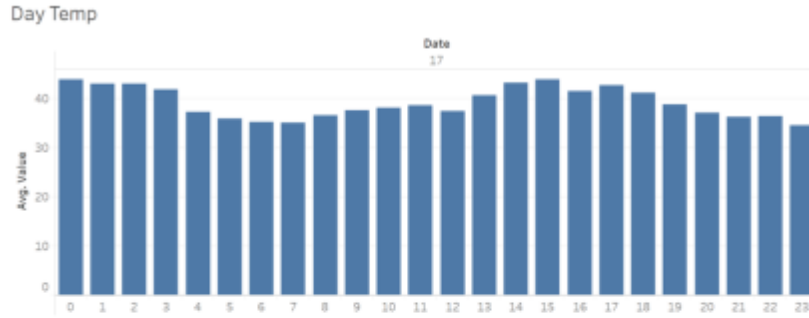
Appendix E: Qualtrics Survey Questions

This is a survey relating to the topics of sustainability and the monitoring of campus energy use.

Disclaimer: All survey responses are anonymous. We do not intentionally collect any identifying data.

This survey takes approximately 5 minutes to complete.
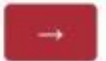
Which best describes your affiliation with WPI?

- ○ Student
- ○ Faculty
- ○ Staff

Do you think having a dashboard system in place would be helpful for faculty teaching, research, and student projects?

O Yes

O Maybe

O No

→


Do you feel that you participate in any activities aimed at making WPI more sustainable?

O Yes

O No

Before taking this survey, were you aware that WPI publishes an annual sustainability report?

O Yes

O No

→

An energy and resource monitoring dashboard is an interface that allows users to interact with usage data for energy and other resources such as gas, steam, and water.
Below is an example of one of these dashboards screens.

Would you be interested in having a dashboard similar to the one shown implemented at WPI?

- ○ Yes
- ○ Indifferent
- ○ No

Why or why not?

WPI

Would you prefer the dashboard be available online through the WPI website or displayed on various screens throughout the campus?

- ⭘ Online
- ⭘ On Campus
- ⭘ Both
- ⭘ Indifferent

→

WPI

Please rank the characteristics of what would be most important to you in an energy monitoring dashboard.

1 Interactivity/ Touch Screen Capability

2 Weather Data

3 Comparing our energy use to previous energy use

4 Comparing our energy use to a baseline standard

5 A gauge that tells us how efficient we are being

WPI

Lastly, what initiatives would you like to see in order to help make WPI a more sustainable campus? (Check all that apply)

- ☐ A dashboard displaying real time energy usage data on a WPI web page
- ☐ Physical dashboard screens around campus displaying real time usage trends
- ☐ Dormitory based sustainability competitions
- ☐ Sustainability seminars
- ☐ Other [   ]

→

Appendix F: Qualtrics Survey Response Data

Default Report

Energy Monitoring Dashboard at WPI
April 25, 2018 12:25 PM MDT

Which best describes your affiliation with WPI?

| 53% Student | 14% Faculty | 33% Staff |

■ Student (100) ■ Faculty (26) ■ Staff (61)
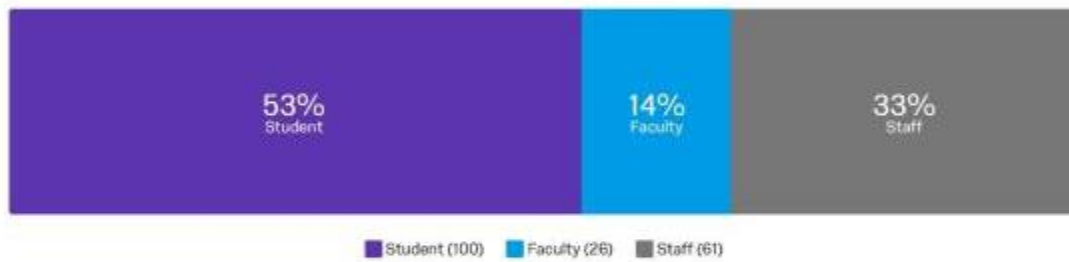
#	Field	Choice Count	
1	Student	53.48%	100
2	Faculty	13.90%	26
3	Staff	32.62%	61
			187

Showing Rows: 1 - 4 Of 4

End of Report

Default Report

Energy Monitoring Dashboard at WPI
April 25, 2018 12:29 PM MDT

Do you feel that you participate in any activities aimed at making WPI more sustainable?

| | 44% Yes | 56% No |

■ Yes ■ No
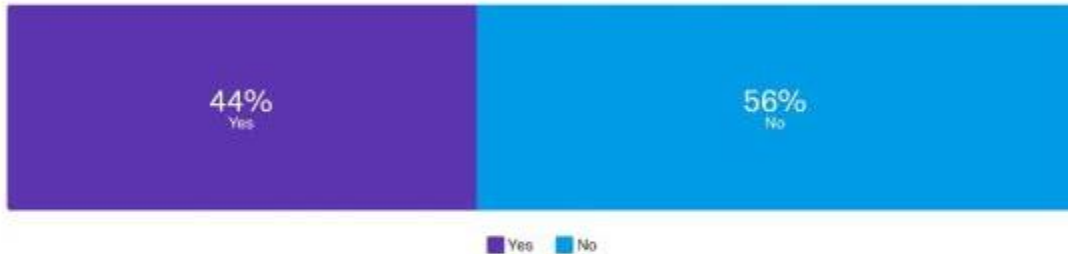
#	Field		Choice Count
1	Yes	43.88%	43
2	No	56.12%	55
			98

Showing Rows: 1 - 3 Of 3

End of Report

Default Report

Energy Monitoring Dashboard at WPI
April 25, 2018 12:30 PM MDT

Before taking this survey, were you aware that WPI publishes an annual sustainability

report?

| | 35% Yes | 65% No |

■ Yes ■ No

#	Field		Choice Count
1	Yes	35.11%	33
2	No	64.89%	61
			94

Showing Rows: 1 - 3 Of 3

End of Report

23

Default Report

Energy Monitoring Dashboard at WPI
April 25, 2018 12:34 PM MDT

Do you think having a dashboard system in place would be helpful for faculty teaching,

research, and student projects?
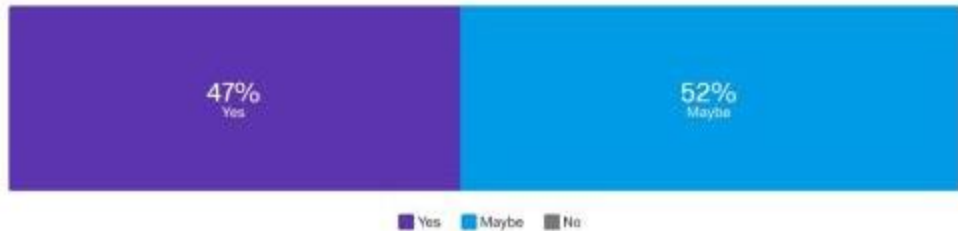
#	Field		Choice Count
1	Yes	46.84%	37
2	Maybe	51.90%	41
3	No	1.27%	1
			79

Showing Rows: 1 - 4 Of 4

End of Report

Would you like to see a monitoring dashboard implemented at WPI?
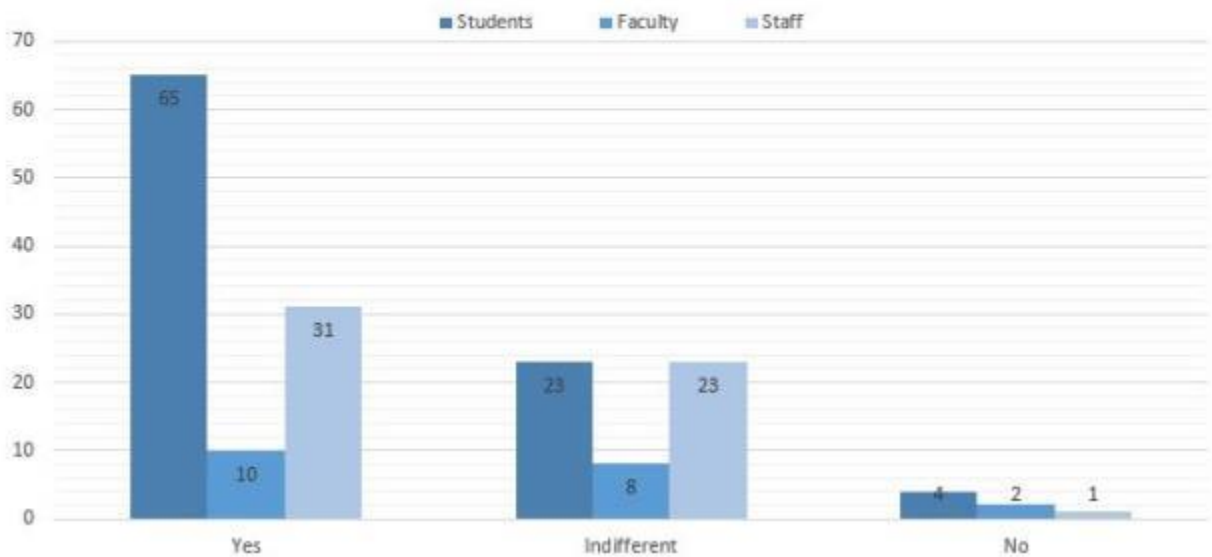
Default Report

Energy Monitoring Dashboard at WPI
April 25, 2018 12:33 PM MDT

Would you prefer the dashboard be available online through the WPI website or displayed

on various screens throughout the campus?

12.50%

5.11%

25.00%

57.39%

■ Both   ■ Online   ■ On Campus   ■ Indifferent
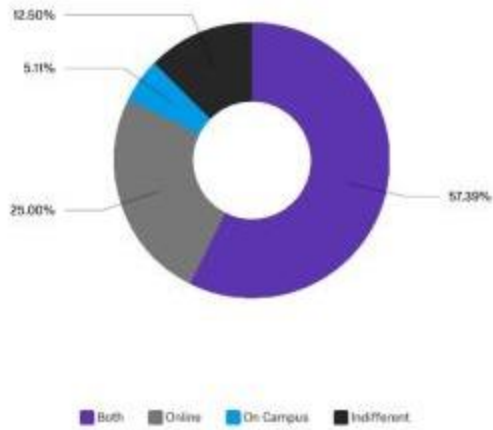
#	Field		Choice Count
1	Online	25.00%	44
2	On Campus	5.11%	9
3	Both	57.39%	101
4	Indifferent	12.50%	22
			176

Showing Rows: 1 - 5 Of 5

End of Report

Default Report

Please rank the characteristics of what would be most important to you in an energy

monitoring dashboard.
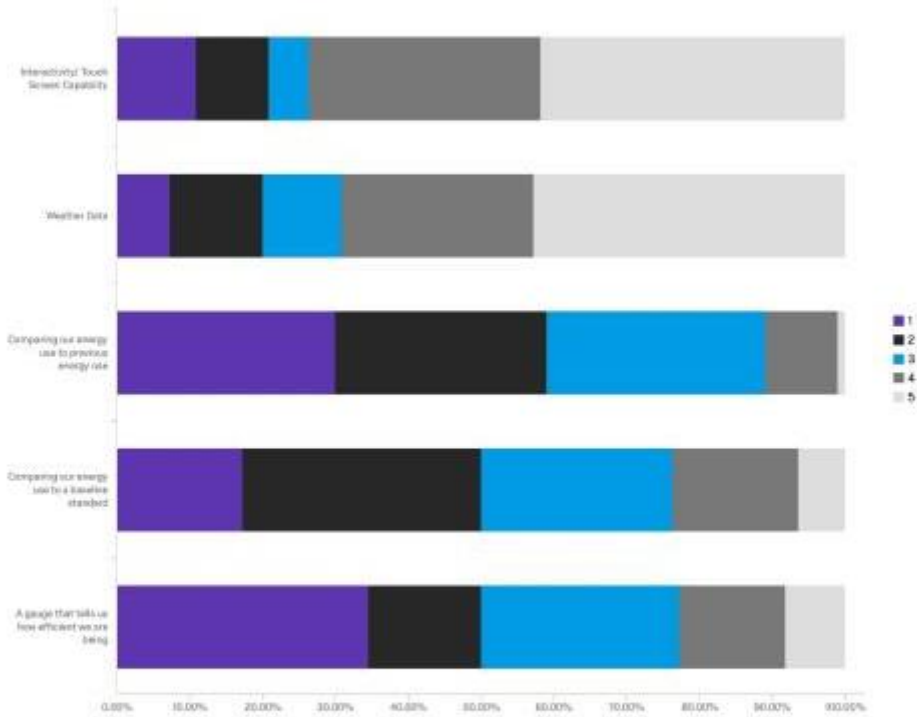
#	Field	1		2		3		4		5		Total
1	Interactivity/ Touch Screen Capability	10.91%	12	10.00%	11	5.45%	6	31.82%	35	41.82%	46	110
2	Weather Data	7.27%	8	12.73%	14	10.91%	12	26.36%	29	42.73%	47	110
3	Comparing our energy use to previous energy use	30.00%	33	29.09%	32	30.00%	33	10.00%	11	0.91%	1	110
4	Comparing our energy use to a baseline standard	17.27%	19	32.73%	36	26.36%	29	17.27%	19	6.36%	7	110
5	A gauge that tells us how efficient we are being	34.55%	38	15.45%	17	27.27%	30	14.55%	16	8.18%	9	110

Showing Rows: 1 - 5 Of 5

End of Report

Default Report

Lastly, what initiatives would you like to see in order to help make WPI a more sustainable

campus? (Check all that apply)

A dashboard displaying real time energy usage data on a WPI web page
Physical dashboard screens around campus displaying real time usage trends
Dormitory based sustainability competitions
Sustainability seminars
Other
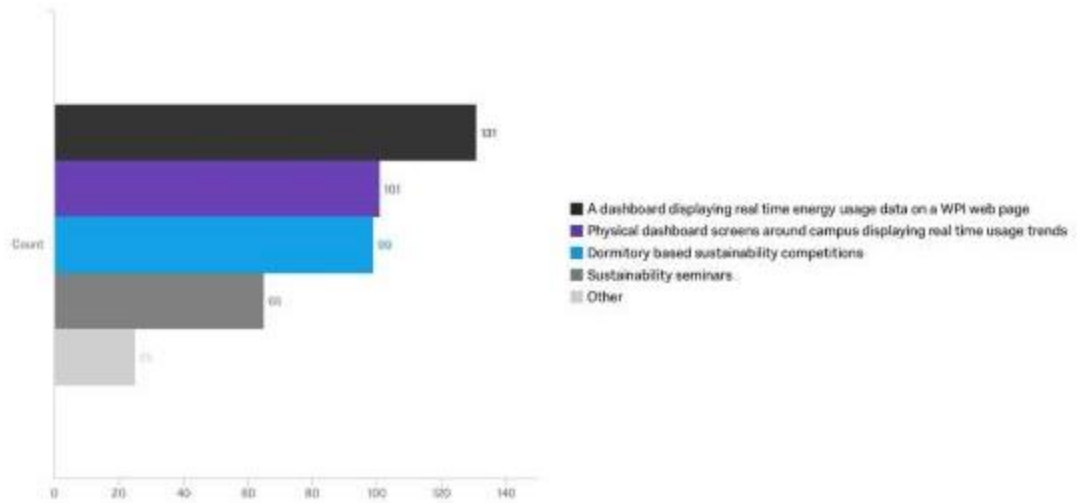
#	Field		Choice Count
4	Sustainability seminars	15.44%	65
2	Physical dashboard screens around campus displaying real time usage trends	23.99%	101
5	Other	5.94%	25
3	Dormitory based sustainability competitions	23.52%	99
1	A dashboard displaying real time energy usage data on a WPI web page	31.12%	131
			421

Appendix G: IQP Support Handout

Energy Monitoring Dashboard IQP Group

Nick Batchelder   Lucas Mancinelli   Paul Shingleton   Daniel Vega

Group Contact: sustainability-energy@wpi.edu

Goal: Have an energy monitoring dashboard in the Hive area in the Foisie Innovation Studio.

Raise Awareness:	Cost Savings:
Allows for the WPI Community to see live time energy use trends with infographics to depict a sustainability story per building Dashboard shows past energy data that allows for the WPI community to visually witness sustainability growth in new LEED certified buildings and energy saving practices	5% energy savings reported in a study done on small businesses Can be used to find efficiencies and reduce over-consumption by facilities and student projects
Strategic Plan:	**Future Use:**
Enhance Reputation and Visibility - Foisie Innovation Studio Promotes a culture of sustainability that incorporates the beliefs and behaviors supported by the WPI communities technical strengths Enhance the effort of data-driven decision making Leverages optimal technology to support the technology and systems key to success in the strategic plan	Energy Saving competitions (i.e. Dorm Competitions) Potential for use in academic learning Allows for future students to further analyze data to correct campus inefficiencies - Project Based Learning Easy to maintain and grow utilizing existing technology

Appendix H: Instruction Manual

Energy Monitoring Dashboards at WPI

An instructional guide to creating energy monitoring dashboards using Tableau at WPI

Written by the Energy Monitoring Dashboard Interactive Qualifying Project team at the Sustaining WPI Project Center

D Term, 30 April 2018

Paul Shingleton, Nicholas Batchelder, Daniel Vega, Lucas Mancinelli

Advisors: Fred J. Looft, Derren Rosbach, Suzanne Lepage
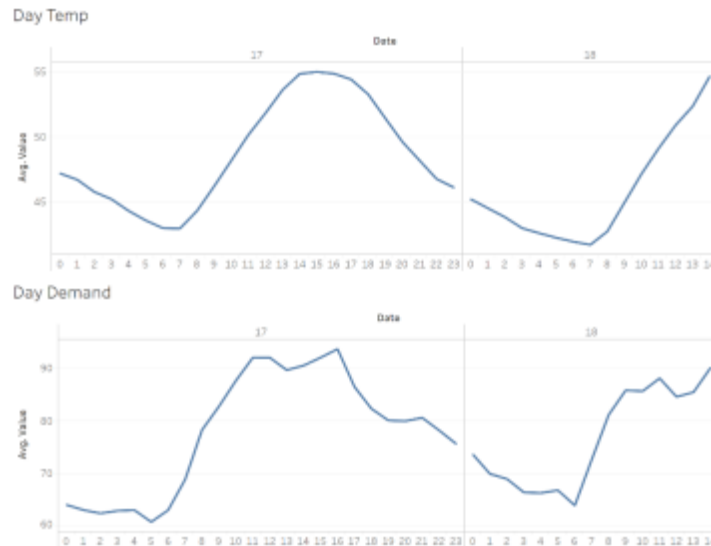
Figure 1: Energy monitoring dashboard in Tableau.

Worcester Polytechnic Institute

Introduction

       This instructional guide informs the process students can take to create EMDs for use on campus using Tableau, a WPI licensed dashboard creation tool.

Source: https://cdns.tblsft.com/sites/all/themes/tabwow/logo.png

Access to the Energy Data

The first step is obtaining the energy data, requiring the signing of a non-disclosure agreement (NDA), and access to ALC's backend web monitoring controls system, WebCTRL (shown in Figure 2 below). To get approval for these items, conversation with WPI facilities needs to occur. Facilities HVAC Technician Kevin McLellan and Chief Engineer of WPI William (Bill) Grudzinski Sr. are the main points of contact for this process. Kevin has authority over who has access to WebCTRL; an email to him at mclellan@wpi.edu and facilities@wpi.edu regarding the NDA are the first steps in getting the energy data.
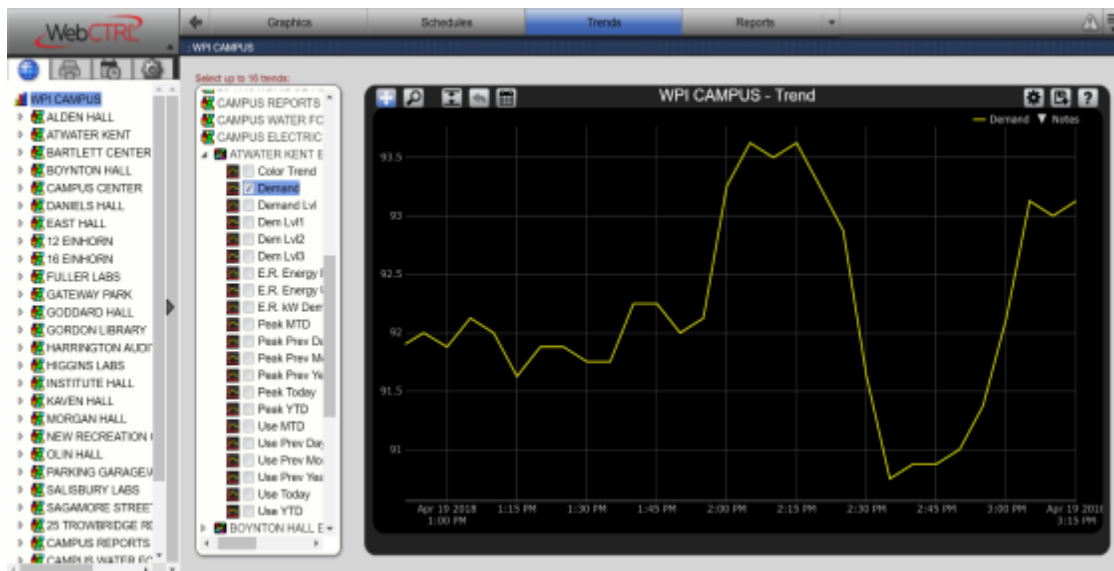
Figure 2: WebCTRL. All available energy data available is on this site,
https://WebCTRL.wpi.edu

Getting the Energy Data

The next step is getting the energy data. This data can be retrieved by using WebCTRL. Figure 3 shows how to export the data to a .csv format: Log in to WebCTRL, go to trends, select "CAMPUS ELECTRIC METERS" and select the desired building for its energy data.

There is currently an add-on that allows for automatic exporting of trend data, a necessity for a live energy monitoring dashboard. Appendix 1 has an info sheet describing the capabilities. To approach creating a live dashboard, a talk with William Grudzinski Sr. and Jr. (IT Systems Engineer, wgrudzinski@wpi.edu) need to be had to get the "Trend Export v2.1 User Guide" that describes the process of setting it up.
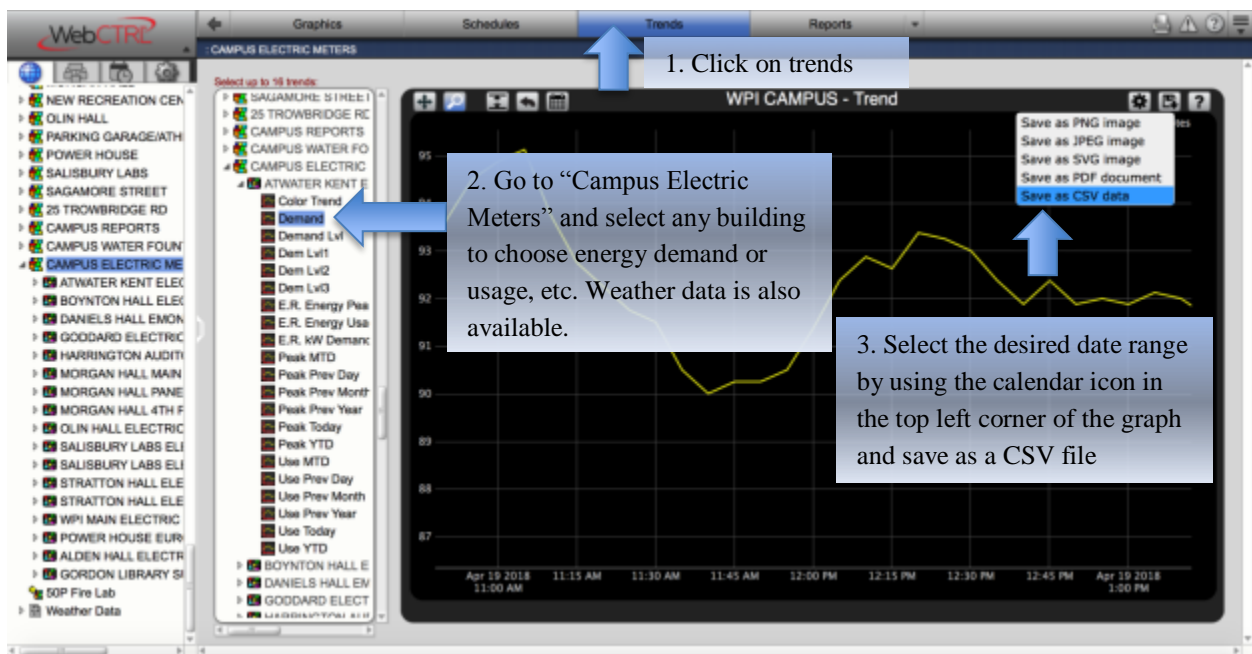
Figure 3: Pulling data from WebCTRL.

Tableau Dashboard Creation

Tableau allows for the direct connection to csv data. Download Tableau from https://www.tableau.com/academic/students and follow the steps to installation. You must use your WPI email to sign-up to get the full software at no cost.

After receiving the data, there may be an extra row in the csv file that could make the data unreadable by Tableau, so the first row of the sheet must be removed before moving forward. Make sure to save the file as a Microsoft Excel Worksheet to ensure the rows don't get combined. After these steps are completed, open Tableau and add a data source as shown in Figure 4.
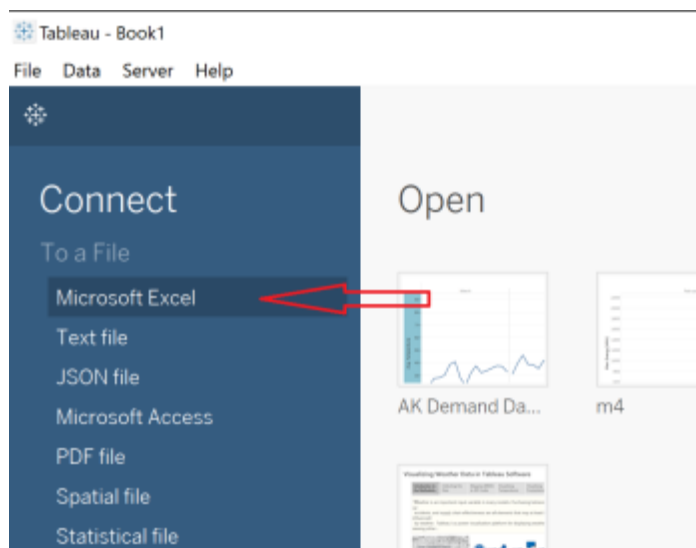
Figure 4: Open the csv data in Tableau.

Once this step is completed, you can now start developing worksheets that contain the data visualizations. You can then put multiple worksheets in a single dashboard as a final product. This is described in the next section. It is recommended to have a basic knowledge of Tableau, for beginner tutorials go to https://www.tableau.com/learn/training.

Dashboard Development

Designing an efficient and user-friendly dashboard is not an easy task. One must create readable axis-labels, format dates, portray the data in a useful manner, and test the design to ensure effectiveness. You are now ready to create any visuals using Tableau. Below is an example of creating a simple

The first steps to create a graph are to drag the data fields (i.e. date, energy measurements) into either the columns and rows, as shown in Figure 5. Right-click on the Date dimension and change the data type to "Date and Time" to tell Tableau that this is a date field and needs to be formatted as such. After this, a graph will appear but not look that useful. To change this, add more dates to the column and set them to break down by year, month, day, hour, etc. as needed. After this is completed, the graph will look more useful.

Tableau needs to make calculations on the values of the data to show the date aggregated values. When showing the energy usage over a month, Tableau will automatically calculate the sum of all those values for that month, which may not be good because the data is taken in 5-15-minute intervals. To change this, you can have Tableau show the average, min, max, etc. of all these values. When using Energy Demand data and trying to show total energy consumption, consider making a new calculated measurement in the data source tab that integrates the energy demand hourly to show total consumption in kWh.
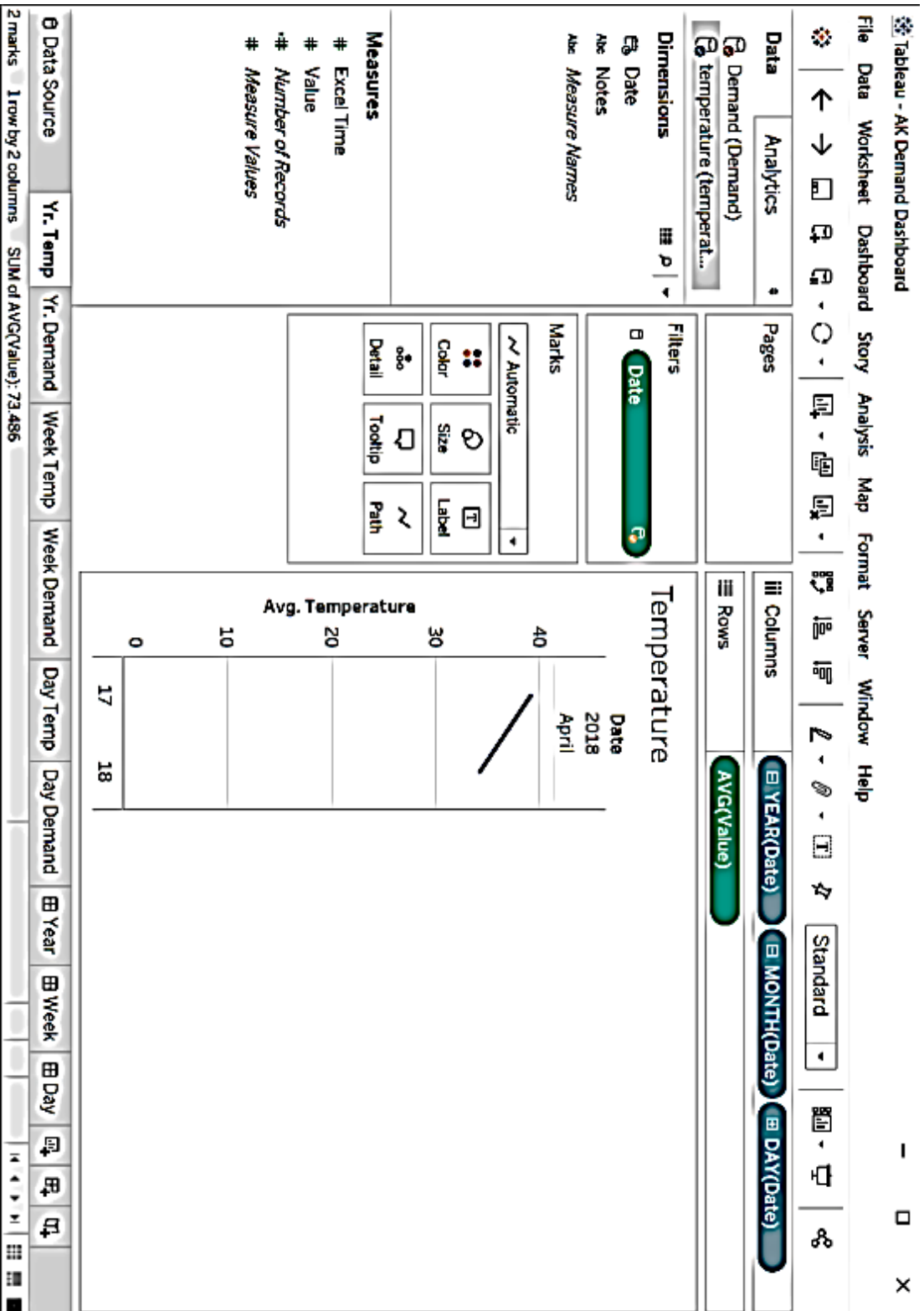
Figure 5: Designing a dashboard.

Appendix I: WebCTRL Add-on

This add-on allows automatic exporting of trend data to a server. Source:
http://www.automatedlogic.com/SpecSheets/ADD-Trend_Export__CS.pdf