Project Report

Carbon Charge: Plug Load Pilot

Nusaybah Estes

nestes1@swarthmore.edu

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Summary of the Project

Carbon pricing has long been acknowledged by many climate activists as a market based solution that takes into consideration the social cost of carbon to signal to society a need to shift away from carbon based resources. In 2016, Swarthmore established an internal Carbon Charge with the goals of providing a platform to educate and engage the community with carbon pricing solutions, incentivize emission reduction, provide capital for projects that reduce emissions, and build momentum for carbon pricing outside of the college. Currently, Swarthmore has implemented a school-wide levy on departments which charges based on the size of the department compared to the school as a whole.

However, it has come to our attention that we are in need of more precise ways of understanding our energy use and the resulting emissions. This understanding would help in two veins. The first is with the carbon charge. By using said data, we would have a more informed estimate of a department's emissions. Secondly, the visualization of electricity expenditure will better help in the incentivizing of emission reduction amongst community members.

In recent times, sub-metering has emerged as a tool to address the information gap and provide real-time, granular visibility of energy use. A study on building energy use revealed 40% of a building's the total energy expenditure is through plug loads [1].

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1 - KEEWI. "Occupant Engagement Leads to Substantial Energy Savings for Plug Loads" Dec 2017

Aside from collecting usage, information from plug load meters could enable facility operations personnel the ability to monitor, measure and control plug load. With the integrated measurement capabilities, they could also potentially enable devices to alert the office when power levels exceed the thresholds in either extremes.

The plug load pilot is a collaboration of offices all across campus. The board consists of Climate Action Senior Fellow Nathan Graf (ngraf1@swarthmore.edu), Engineering Professor Art McGarity (amcgar1@swarthmore.edu), Heat Plant/Energy Supervisor Domenic Porrini (dporrin1@swarthmore.edu) , and Technology Outreach Team Lead Joel Price (jprice1@swarthmore.edu). Volunteers in the pilot were also diverse members of the campus including Sproul, the Lang Center for Civic and Social Responsibility, Advancement, Office of Sustainability, Human Resources, Communications Office, Finance Office, Facilities and the Theater Department. Volunteers played a huge role in providing input on the effects of the energy saving interventions based on their experiences with the Plug Load Meters.

There were three main goals with this project. The first was to better understand our day to day electricity use in offices through real time granular data. Current metering on campus loosely covers overall building energy use but does not break energy use into its specific veins. The second was to investigate the meter's ability to reduce overall electricity usage using the off-switch timers. With rising energy efficiency, it is expected that plug loads will have a greater share of the overall energy usage and thus have great potential to be reduced. Additionally, few places have tried this relatively new technology and the study was aimed to increase the larger community's

understanding of it. And lastly but most importantly, this project aimed to engage the campus community in a larger conversation of sustainability and the Carbon Charge. Many community members have expressed the distance they feel from the Carbon Charge as it is often a process that happens when budgeting without the voice of community members. This means any efforts members make to reduce their carbon footprint on campus does not have a system of appreciation or acknowledgement that affects the carbon charge. Additionally, this communication has great potential to foster increased community awareness that may hopefully be expanded beyond office spaces.

This report goes over the research conducted on other organizations who have used similar technology, a description of the meters themselves, the process of selecting a vendor, the outreach done to the community, the progress of the pilot program, next steps for the Fall 2019 semester, as well as final reflections and recommendations.

Background

Swarthmore's Carbon Pricing Culture

As mentioned above, in 2016 Swarthmore established Carbon Charge aimed to help address the college's goal of net zero by 2035. This Carbon Charge comprises three parts. The first is a school wide levy on departments for their college carbon emissions. As the school's submetering is not granular enough to differentiate between individual departments' energy use, the amount paid to the Carbon Charge is dependent on the department's budget size as well as voluntary additions [2]. The Carbon Charge also

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2. Voluntary contributions refer to additional allocation of a budget to the Green Fund done on top of the required contributions

established a fund that collected the levy payments as revenue that could be used to support renewables, efficiency metering and education projects. Lastly the Carbon Charge established a shadow price which adds the social cost of carbon to capital projects and is used as a tool for decision-making to motivate pursuing less carbon-intensive construction and renovation initiatives.

Over the past few years, the college has been working to educate and engage the community in the college's carbon goals. However, a common question community members ask is how they can best partake in the initiative, as the largest components of the carbon charge take place among senior staff who allocate departmental and office budgets. With this project, we aimed to further delve into that question on engagement and how we can better ingrain the Carbon Charge's mission with the community.

Baselining with Other Colleges

During the Spring of 2018, Nathan Graf and I conducted research on other higher education institutions who have done studies on their plug load. We were able to contact University of Hawai'i, University of Michigan, University of Alberta, and Stanford University who different experiences with their studies.

Stanford University performed a comprehensive inventory of all of the plug load equipment on campus in 2014. This included counting the number of plugs on campus, seeing what each plug was being used for, placing the plug use into specific categories, and estimating the amount of electricity the device was drawing from the plug. From this study, Stanford concluded that campus wide metering would not be efficient, rather

the college should focus on areas where plug load use is high and schedulable. The inventory ended with an assessment of those areas where plug load metering would be most cost effective. This study was reported in their white paper [3].

While not a direct study of plug load meters, we spoke Stephen Kunselman from the University of Michigan's Office of Sustainability who briefly tested motion sensing power strips in 2008. This originally had a rapid return, however after revising the project in 2017, they found that the payback time had increased to 135 years. They decided this increase in turn back time was a result of the advent of more efficient appliances. As this device no longer met their payback requirements they decided to discontinue the project. The University of Michigan also looked into using BOSS devices (a brand of plug load metering) to decrease energy consumption however they found there was an unexpected amount of work in maintaining them especially because the building schedules varied so much across campus.

The University of Hawai'i was one of the first higher education institutions to test IBIS's plug load metering devices. Speaking to Matt Lynch from their Office of Sustainability, we found that they piloted 1500 meters across three of their campuses with the goal of evaluating campus appliances in order to update the college's purchasing policies. In general, Matt Lynch felt they had a good relationship with IBIS but, as they were testing the devices in the early stages of development, faced many bumps along the road. The University of Hawai'i concluded that they were good for data collection but did not feel they were efficient for electricity reduction.

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3. "Quantity and Electricity Consumption of Plug Load Equipment on a University Campus" Springer April 2017

On the flip side, the University of Alberta saw huge savings while using plug load metering. In 2016, they paired with Sustain Solutions to install 100 IBIS metering devices in their general services building. They reported great service from the company and have found the software to control the devices concise and easy to maneuver. Since installation, the building has already seen 40% savings and their Program Coordinator for Facilities and Operations, Lauren Hall, mentioned being excited to expand the program to more parts of the campus.

In general different colleges had different opinions on the success and usefulness of plug load meres. University of Michigan, University of Hawaii and Stanford have noted that plug load metering may not be efficient when it comes to reducing electrical consumption as most devices are advanced when it comes to efficiency and automated shutoffs. As University of Michigan and University of Hawaii already had building submetering in place, they were not interested in the data collection aspect of plug load meters. However the University of Hawaii and the University of Alberta both had overall positive reviews as their primary goals were not reduction. Similar to Swarthmore they face difficulty with regard to having faulty meters and were looking for alternatives to collect data. University of Hawaii experienced the beta version of IBIS and had difficulties with it, but it is clear after talking to the University of Alberta that the metering technology has significantly improved since. The largest hurdle amongst most higher education institutions was with regard to management and finding the most efficient spaces to target energy reduction.

Pilot Program - Product

Plug load meters are a relatively new spin to a long standing product. Meters have long existed for granular measurements of energy, however plug load meters have two main features which set it apart. One is that it measures energy and reports it to a server. Secondly, plug load meters have the ability to be programmed to control energy usage.

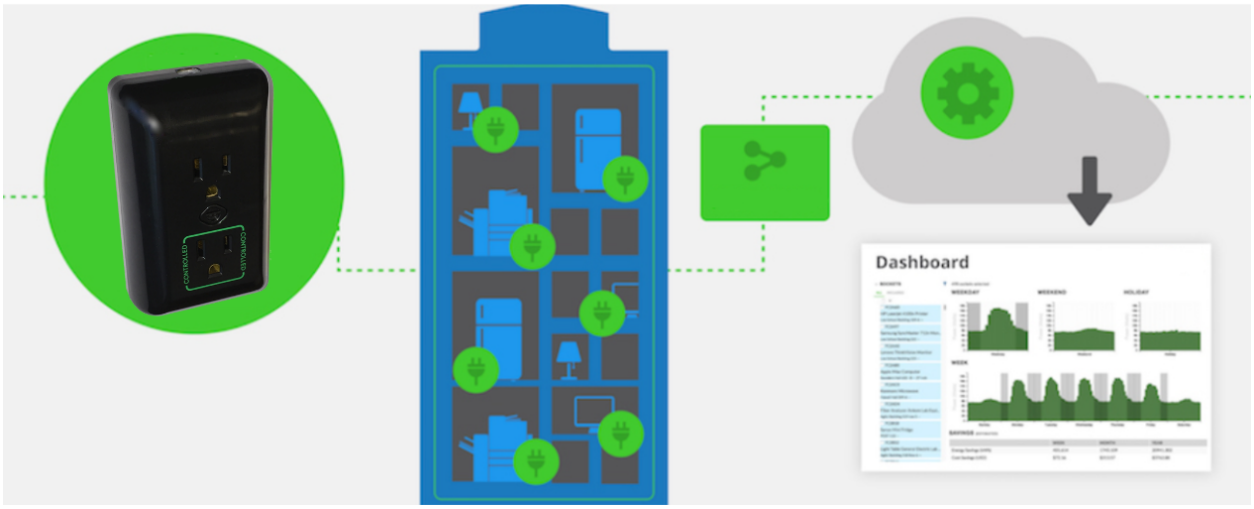

Image 1. Plug Load Meter System

This system works in three parts: the individual meter, gateways and the cloud. The meter is a small, fist sized device which can be plugged directly into wall outlets. These act as extension to normal outlets, as devices can be plugged into the meters as they normally would be into wall outlets. Once installed and activated, meters will report energy usage on device every 15 seconds.

The devices communicate wirelessly to gateways using several methods of wireless communication tools similar to that of bluetooth. The two most common are Zigbee and Z-Wave. By functioning separately from the internet, it avoids the problem

of bogging down the school's network and failing when the school's network fails. Both function similarly, but differ in the amount of plugs that can connect using it and the strength of the signal. Z-wave signals work better in areas with thick walls, however they don't have the same carrying capacity as Zigbee. As most of the walls in the volunteer spaces did not heavily impede the plug signals, Zigbee was used.

Meters and gateways are organized to form a mesh network. Each meter and gateway have ranges of around 50 ft. These act as spiderwebs of communication where each plug is a node that can pass on information to other nodes until it reaches the gateway. In a successful mesh network, nodes can pass information most efficiently by optimizing their paths and can reroute paths if a node is lost.

The gateway itself is a router esque device that is connected to the ethernet. This allows the gateway to send the collective data to a data server. Aside from sending data, gateways also pass commands to the meters and report when there are issues with devices.

Lastly the server is where all the data is fed into. This is a cloud based service that provides reporting, scheduling, data analytics and management tools. This information is organized in an easy to digest format and includes reports on the list of hardware, a visual of time vs Power (watts), data specific reports, and much more. This platform can be accessed through ibis.io, and can be programmed such that different people have access to the information collected from different devices.

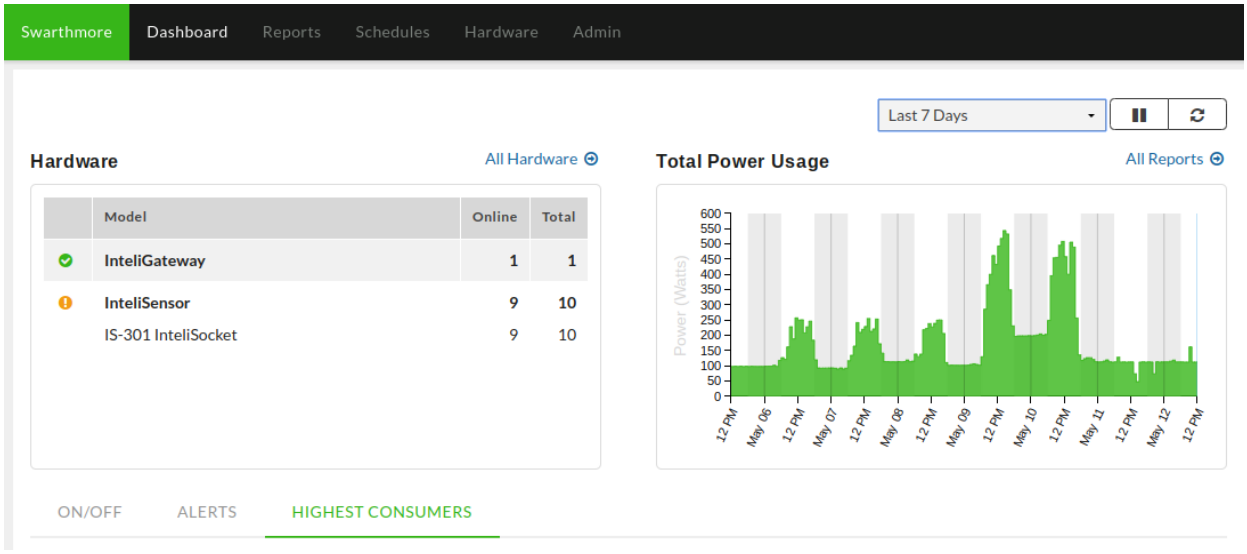

Image 2. Ibis Dashboard

On average, plug load meters cost $95-$150. Most vendors estimate a ROI of 2.5 years for the average device, but it can be as low as 4-6 months for energy intensive units such as vending machines. Through the pilot, we hoped to check the ROI with respect to Swarthmore's campus.

Pilot Program - Timeline

This project was divided into three main modes of action: outreach, contracting and the pilot itself. Outreach took place during the fall 2018 semester. Contracting began in the later half of the fall semester and went on till February 15, 2019. While the original timeline called for a three month pilot in the spring of 2019, there were some setbacks described later in this report postponed the pilot to the fall of 2019.

Pilot Program - Outreach

The process of outreach to the community began with the goal of getting as many volunteers we could and finalizing that list by the beginning of December. The amount of volunteers we had would play an important role in deciding on vendors as the two in mind, Sustain and KEEWI, had varying minimum meters for a pilot program. KEEWI had a lower number of 40 plugs while Sustain, the group the Office of Sustainability preferred, required a minimum of 150 meters.

The first group of people targeted were the Sustainability Advocate and Green Advisor pairs because of their established interest in environmental issues on campus. This was engaged by an initial email of interest to all of the members and followed by an invitation to come to a group meeting to learn more about the program. Multiple meetings were set up so that interested members were able to sign up for a time most convenient for them. The conversation started with introductions, followed by a brief presentation outlining what the devices were, how they worked and the goals of the project. Afterwards we opened the floor to questions. This was a great opportunity to understand what the main concerns and initial thoughts of community members were and better prepared me for conversations to come. Lastly, we ended with a conversation on their interests and how we could engage the rest of their offices. For the most part, only one group immediately committed but the others showed interest in continuing the conversation with their counterparts. The group that immediately committed comprised of a very tight nit office and was represented be a leader in the interest meeting while for

the other groups the individuals who attended were not in the position to make overarching decisions for their office spaces.

The second round of outreach was directed towards individuals in Kohlberg, Science Center, and Trotter who took part in previous PSRF student, Chase William's, pilot. Unfortunately outreach on this end was more spread out, with few people agreeing in the same space. Wanting to avoid this, we ran into the tough question of how to reach these academic communities; be it a general email to all the offices in those spaces or a more top-down approach of emailing the departmental chairs residing in those spaces. This was stressed because of our perceived nature of the meters, in which they communicate more efficiently when there is a mesh of them (this was later found to be partially untrue, as we would be able to accomplish this by increasing the amount of gateways in the mesh). After consulting with Melissa Tier (mtier1@swarthmore.edu) and Aurora Winslade, we decided to instead focus on getting volunteers from Sproul, the Lang Center for Civic and Social Responsibility, LPAC, and offices in the 101 S Chester building. This was because it was determined that outreaching to all of those spaces would take a significant amount of time and the amount of individuals in the chosen spaces would be enough to reach our plug load meter goal discussed later. In addition, the 101 S Chester building was determined to be the most optimal for this study as the office spaces are standardized and allow for easy comparisons to be made.

To approach this outreach, we targeted the vice presidents of those spaces to set up meeting times to talk about participation. These meetings greatly mimicked the meetings we conducted for the Sustainable Advocate and Green Advisor groups.

However, because we were drawing closer to Thanksgiving there was a lul in availability amongst many of the busy staff members and it was increasingly difficult to find times that coincided. Because of this, we extended our goal of finalizing the volunteer list from early December to the end of the semester.

By the end of the fall semester we confirmed close to complete if not complete participation from the following offices: Sproul, the Lang Center for Civic and Social Responsibility, Advancement, Office of Sustainability, Human Resources, Communications Office, Finance Office, Facilities and the Theater Department.

Pilot Program - Choosing a Vendor

While simultaneously working on outreach, we worked on researching vendors and securing a contract. Before the beginning of the project, two vendors, Sustain Solutions and KEEWI, were identified as potential partners for the program and initial conversations between the companies and stakeholders at Swarthmore began. Once the fall semester began, the conversations were transferred to me. From each vendor we collected information with regards to the hardware and software for the Plug Load Meter pilot. Both companies planned to provide 150 meters, 100 user accounts, data access, installation services, volunteer training and technical support. Below lists the main differences between the two vendors.

KEEWI

- Required a minimum of 40 meters for a pilot.
- The quote was listed at $19,550 for a 12 month lease. An additional $13,050 annual fee would incur after the first year for maintenance and access to web features.
- In addition to the web dashboard, gamification activities for engagement and education are included. Examples of this include earning points and rewards through daily questions, personalized goals or friendly competition with peers.
- Analysis and reporting (including the deployment summary, a deep dive into device types, deep dive into engagement metrics)is *optional* and an additional $4,000.

Sustain Solutions

- Required a minimum of 200 meters for a pilot.
- The quote was listed at $16,250 for a 12 month lease with a $600 annual maintenance fee after the first year.
- Includes the reports on energy consumption metrics (device level consumption report, building level energy savings, device type consumption report, etc) which can be pulled at any time from the portal with no additional cost.
- Longer standing company that has previously worked with Higher Education organizations.

At this point a short proposal was presented to the Carbon Charge Committee (CCC) via email (December 5th) asking for their input on the vendors and requesting approval for funding from the Carbon Charge fund. Because the email was accidentally sent to both current and previous members of the CCC there were slightly tangential responses with regards to the proposal. However they allowed us gain a deeper understanding of the goals of the project. In general the consensus was for Sustain Solutions. Additionally the CCC was able to point us in the direction of important resources for contract approval.

The first was Swarthmore's Contract and Purchasing Manager, Cindy Urick (curick1@swarthmore.edu). She was able to look through the contracts from both companies and add the clauses typically seen in standard contracts and give feedback on if the terms we agreed with followed Swarthmore's guidelines.

In addition, a general accessibility review was completed by Swarthmore's Technology Accessibility Coordinator, Corrine Schoeb (kschoeb1@swarthmore.edu). This was something the PLM board had not expected, but were happy to be reminded of this important aspect of campus standards. Both vendors had several critical issues in which Swarthmore College would need a firm roadmap of when fixes would be made if we were to consider the vendor for a long term contract. A few of the issues include low contrast, missing labels, links without text and lack of functionality using keyboard controls. (The deeper review can be found linked here: KEEWI)Both vendors expressed their shared concern with accessibility and were willing to commit to developing the goals outlined in Swarthmore's accessibility guidelines. Because this was for a short

term pilot, we came to the agreement that this written agreement sufficed to move forward with either vendor for the time being.

Unfortunately, the process of getting clearances on contracts and accessibility set us back in the timeline; pushing the decision to mid February. However we were collectively able to decide on signing on with Sustain Solutions for a one year lease. This decision was largely based on the cheaper price and the larger amount of experience the company had with clients. While gamification of the data was an idea to incorporate more community engagement, it did not appeal to the CCC board. Rather, the board hoped we would be able to form our own degrees of community engagement and focus more on the testing the devices functionality. The contract was signed by both Swarthmore's Sustainability Director, Aurora Winslade and Sustain Solution's representative, Andrew Williams (andrew@sustainsolutions.com). The information was sent to Patti Braun (pbraun1@swarthmore.edu) in Facilities Purchasing, to help with formalizing the payments.

Pilot Program - Pilot

Before finalizing signatures for the contract with Sustain Solutions, it was requested that Swarthmore took care of plug load meter installation rather than Sustain Solutions. Typically, Sustain Solutions sends out a crew along with the material to go through installations, network programming as well as minimal volunteer training. However, the company recently shifted the focus of its services so that they provide software for broader sustainable employee initiatives and no longer provide plug load

meter packages. By making an exception for Swarthmore because we were contracting during that transition, they asked that we would be able to take care of the onsite installation and they would help with software remotely.

While a change in plans, we were assured the process would be relatively straightforward and we would be given 24 hour service in case we needed to contact Sustain for help. Additionally, Facilities was comfortable with this change as this would allow them to be familiar with the technology and process in case minor debugging was needed throughout the pilot or we decided to expand the pilot in the future. With the installation process beginning, we reached out to ITS for support in the software and networking side of the installation process as the gateways would need to be scanned and connected to the ethernet. We were grateful to have a positive reaction from ITS for support with installation and Denny Moore (amoore2@swarthmore.edu), Network Engineer, was assigned to the task.

Unfortunately there were major setbacks in the the installation process that largely centered around poor communication from both Swarthmore parties and Sustain Solutions parties. The installation process was meant to begin with a conference call between Domenic Porrini, Denny Moore , and Jeff Ackley (jeff@sustain.ai) from Sustain Solutions. However, we were unable to get a hold of Jeff via email or phone till much later in the process. Beyond this initial call, general communications with Jeff Ackley were slow and took persistence. In addition to this, the provided installation manual did not cover the process in depth, making the need for communication between

both parties imperative. Lastly, there were minor tensions between the college and Sustain Solutions with information being held back until payments were finalized.

On Swarthmore's side there was some miscommunication between ITS and us on where in the process we were at several points of the installation and who to best contact when roadblocks arose. Additionally, because there were several other meter initiatives being assisted by similar parties they were confused with the plug load meters.

While waiting for installation, we used the down time to get ahead on processes that we would implement after the installation. This included

- Working with Professor McGarity to run statistical significance tests on the results
- Talking with Ella Foster-Molina (mfoster1@swarthmore.edu), Swarthmore's Social Sciences Quantitative Laboratory Associate, on best practices for gathering volunteer feedback (she recommended selecting a pool of volunteers after the study to interview and based off of the interviews create a short survey to send out to the entire volunteer pool)
- Gathering the floor plans for the volunteer spaces and mapping out where gateways should be placed with respect to the meters.

With time running out, we continuously reworked our timeline to fit shorter periods. One month till the end of the semester, we decided the best way to run the pilot was such that two weeks would be spent on baselining and afterwards half of the group switches to scheduled metering so that a proper baseline could be taken and the scheduled feature could be played with. However, because the installation process was

continually delayed we consulted one another and decided to postpone the pilot to the Fall 2019 semester.

While we came upon this decision, the effort to install the plug load meters did not falter. Upon receiving the dongle which gave us legal access to the plug load meter's capabilities, we were able to begin installation. We began with the Facilities office as Dominic Porrini was familiar with the space and it would allow us to check for any bugs before rolling all of the devices out. The main bug that arose was plugs were not being recognized as installed once plugged in and added to the system. Following Facilities, the effort to install continues. Denny Moore plans to install the gateways and Domenic Porrini plans follow behind to install the plug load meters. Appendix A shows the projected distribution of plugs in each of the spaces. In total, this will sum to 250 plugs installed on campus. Appendix B shows the physical distribution of the plugs in the volunteer spaces where they have been installed.

Pilot Program - Future Plans

With the failure to complete the pilot during the Spring 2019 semester, we decided to extend the pilot over the summer and the fall semester. This is possible as we have a one year contract with Sustain Solutions that extends to February 15, 2020. Over the summer and early fall semester, the plugs will run untouched to capture baseline data. The time is extended past the summer to ensure summer schedules does not affect our understanding of general energy use and to give us time to set up interventions.

Once the baseline is complete, we hope to setup user accounts so that each volunteer will have access to the dashboard with their assigned plug load meter's data. This initial intervention would allow users to familiarize themselves with the ibis.io dashboard and give us a sense of volunteer reaction to simply knowing the amount of electricity one is using. The second intervention involves the scheduling feature. Here we plan to train the volunteers to use their account to set up timed schedules for their spaces to reduce overall electricity use. Both of these interventions will be compared with the baseline to see if there are significant difference between the two.

I hope as a senior PSRF I can continue to manage the pilot program. I am excited to continue to push for the completion of this initiative and to see the results we pull from the project.

Final Reflections

While we were unable to complete the project within the year, there were valuable takeaways I had from this year's efforts. The first is how Swarthmore can often operate as a complex web, even being a small college. Steps such as approval for certain parts of the project took an absorbent amount of time to complete. Because of issues like this, I found it was extremely important to stress communication, and sometimes over communication. It is extremely beneficial to approach communication aggressively especially considering the busy schedules of many on this campus. On a base level, this involves bouncing back emails, calling, or visiting an office in person. However in acknowledgement of busy schedules it has also been incredibly important to find ways

to cut down on used time, such as canceling a meeting and sending a memo instead when possible.

Specific to this project were three main reflections. The first was perhaps the red flag at the beginning when we were told by Sustain Solutions that they would not be doing the installations for the plugs. Swarthmore being the first client to handle this, Sustain Solutions was extremely underprepared to hand that responsibility off to us. They did not have detailed manuals to describe the entirety of the process and their tech specialist was often slow or unreachable via email or phone.

Secondly, for tech based projects such as the Plug Load pilot it is extremely important to have knowledgeable networkers from day one. In our case we had the wonderful support of Joel Price on the board from the beginning. However Denny Moore, ITS's networking specialist, was only onboarded near the end when we began with installation. This meant there was a large learning curve when it came to getting him up to speed on where the project stood, who to best contact when in need of certain pieces of information, and gaining a sense of urgency to finish installation. Additionally, there was a minor mixup in clarity of what was expected from Denny Moore as several energy based tech projects under similar managers were being confused for one another.

Lastly, working to bring this pilot program to Swarthmore reminded me of the importance of accessibility in conjunction with sustainability; that our sustainable solutions must include all of our community members. While perhaps on the lower end of the spectrum, with the Plug Load Pilot this affected us with regards to the website's accessibility. As described earlier in this project report, there were issues when it came

to the dashboard's color contrast and keyboard navigation among many other things with regards to Swarthmore's ADA accessibility standards. Since we are only working with Sustain Solutions on a short one year contract, there was no effort made to correct any of the issues. However it was made clear that if a longer term contract were to be established we would want to work on improving the website. We hope that by bringing this up with the vendor it will be at the forefronts of their minds when it comes to updates in the future with other clients. Additionally it sounded like Sustain Solutions had accessibility as something they were already planning on working on already, they simply hadn't gotten there yet as a small start up.

Appendix A : Plug Load Meter Distribution

Sproul: 16

Office of Sustainability/Lang Center for Civic and Social Responsibility: 32

Facilities: 28

Human Resources: 30

Business Office: 19

Communications Office: 17

Finance Office: 29

Advancement: 41

LPAC Theater Department: 38

TOTAL: 250