1-1-2019

Paving the Way for Multidisciplinary Smart Campus Infrastructure: Leveraging DU's Unique Campus for the Advancement of Smart Campus Culture

Camerron T. Mismash
University of Denver

Paving the Way for Multidisciplinary Smart Campus Infrastructure: Leveraging DU's Unique Campus for the Advancement of Smart Campus Culture

Abstract

Institutions are embracing smart technologies to reap their benefits while simultaneously innovating new uses. From localized renewable energy generation to health monitoring and everything in between, academic campuses globally are paving the way for smart technology application. Eight primary categories have been identified in which institutions are applying smart technologies. Energy development is on the forefront of these smart initiatives. The University of Denver has begun its Smart Campus Initiative by implementing a revolving fund to invest in campus improvements related to the offset of carbon. By comparing how institutions are investing in smart campus initiatives and analyzing costs associated with renewable energy development, recommendations are provided on how University of Denver can better apply its resources to become a leader in the global smart campus initiative. Recommendations are given on how the university should invest in additional energy related projects to catalyze its currently implemented projects. Additional recommendations are given on how to achieve an all-encompassing smart campus infrastructure realizing status in each of the eight categories.

Document Type

Thesis

Degree Name

M.S.

Department

Engineering

First Advisor

Amin Khodaei, Ph.D.

Keywords

Smart campus, University of Denver, Renewable energy

Subject Categories

Electrical and Computer Engineering | Engineering | Power and Energy

Paving the Way for Multidisciplinary Smart Campus Infrastructure: Leveraging DU's Unique Campus for the Advancement of Smart Campus Culture

---

A Thesis

Presented to

the Faculty of the Daniel Felix Ritchie School of Engineering and Computer Science

University of Denver

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Camerron T. Mismash

November 2019

Dr. Amin Khodaei

Author: Camerron T. Mismash
Title: Paving the Way for Multidisciplinary Smart Campus Infrastructure: Leveraging DU's Unique Campus for the Advancement of Smart Campus Culture
Advisor: Dr. Amin Khodaei
Degree Date: November 2019

Abstract

Institutions are embracing smart technologies to reap their benefits while simultaneously innovating new uses. From localized renewable energy generation to health monitoring and everything in between, academic campuses globally are paving the way for smart technology application. Eight primary categories have been identified in which institutions are applying smart technologies. Energy development is on the forefront of these smart initiatives. The University of Denver has begun its Smart Campus Initiative by implementing a revolving fund to invest in campus improvements related to the offset of carbon. By comparing how institutions are investing in smart campus initiatives and analyzing costs associated with renewable energy development, recommendations are provided on how University of Denver can better apply its resources to become a leader in the global smart campus initiative. Recommendations are given on how the university should invest in additional energy related projects to catalyze its currently implemented projects. Additional recommendations are given on how to achieve an all-encompassing smart campus infrastructure realizing status in each of the eight categories.

Acknowledgements

This work was made possible by the support of multiple departments within the University of Denver including: DU IEEE Student Chapter, Facilities, Sustainability Committee (SUSCOM), and Campus Life & Inclusive Excellence. External support comes from Tri-State Generation & Transmission Association Inc, eGauge, EnergyCAP, Pivot Energy, Canadian Solar, National Renewable Energy Laboratory, ComEd, and Xcel Energy. Special thanks to Dr. Amin Khodaei and Lynn Bailey PE.

Table of Contents

List of Figures

List of Tables

1 Background Research on Current Institutional Microgrids And Other Smart Campus Projects

1.1 Introduction of smart campus initiatives

Accelerating rapidly with technology previously unimagined, energy infrastructure within institutional campuses is becoming increasingly complex. Every institution - whether it be academic or not - is grasping every bit of innovation it can. Academic campuses everywhere are embracing many ‘smart’ technologies that enable them to accomplish various modernistic tasks.

Like many complex infrastructures, pieces of simple technological concepts are combined to create a larger system for solving larger problems. These *grand* problems are high-level challenges requiring large amounts of systematic solutions on a global scale. However, the problem is localized within a smaller footprint such as an academic campus. For example, the amount of carbon dioxide released into the atmosphere as a greenhouse gas is a global problem but can be localized and mitigated by a campus’ sustainable energy projects. Across the globe, many institutions are joining the movement of offsetting their carbon footprint and environmental impact.

Institutional projects across the globe have many focuses around implementing modern technology for the betterment of the campus and community in which it resides. Additional to carbon and environment, institutions are addressing several other global challenges. Across several sample countries, 33 academic institutions were studied for their involvement in implementing ‘smart campus’ projects. The main problem focus of the campus’ project was categorized into several global issues present in academic institutions including:

- Microgrid (Energy), CO2, Energy Storage
- Lighting
- Heating/Cooling
- Waste
- Water
- Transportation
- Health, Education
- Other Tech (IoT integration/open access

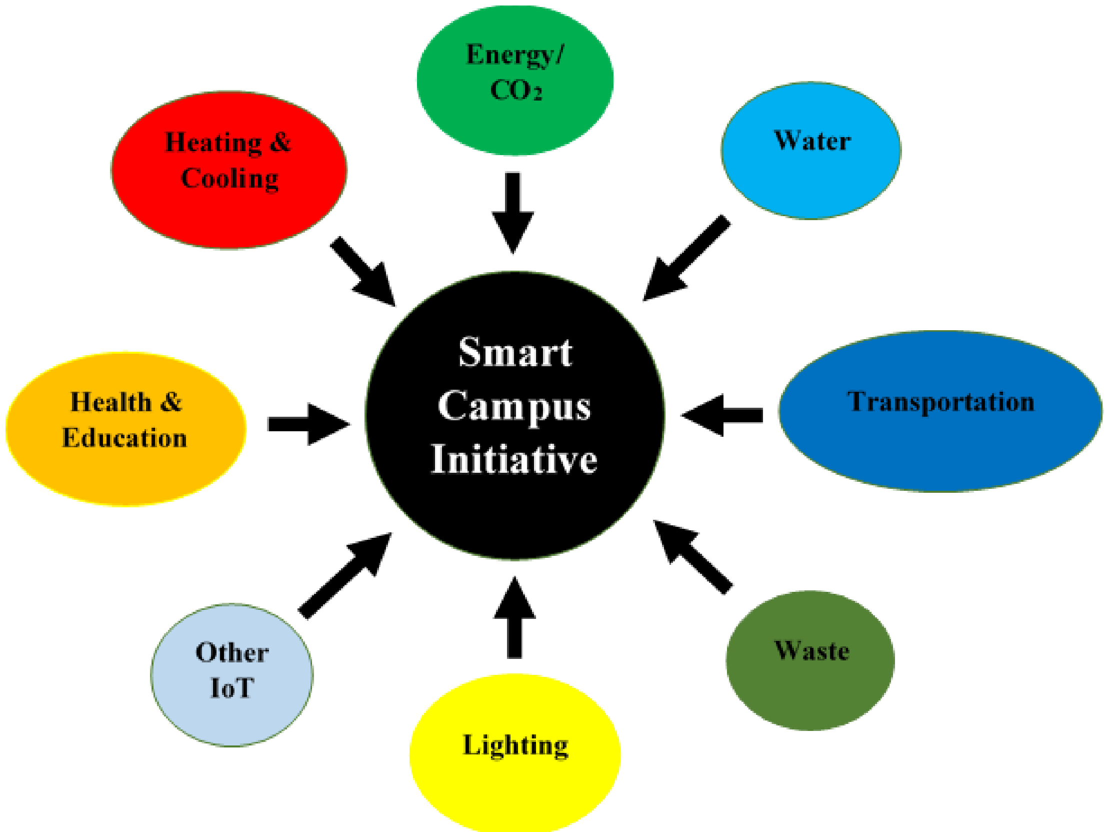

Figure 1: Smart Campus Initiative Components

Microgrid (Energy), CO2, or Energy Storage focused projects are centered around the development and installation of localized energy infrastructure or methods of sequestering CO2 related to energy consumption. Examples of this may include the instillation of rooftop photovoltaic arrays and batteries within campus buildings. Lighting focused projects are centered around the development and installation of smart lighting solutions. Examples of these projects may include installing efficient lights and control systems that reduce output during periods of ideal solar inclination. Heating/Cooling/HVAC centered projects are focused on the development and installation of systems that are efficient and offset energy usage related to heating/cooling. Examples of these types of projects include heat recovery systems and cold sequestration.

Projects centered around waste are focused on the reduction and prevention of landfill waste. Projects in this category may include zero-waste campaigns and overhaul of all disposable consumables within campus events to be sustainable and compostable.

Water is another major project focus. These projects look to reduce the overall consumption of freshwater and recycle rainwater where applicable.

Transportation is a very popular project focus among institutions. Transportation projects vary widely but may contain sustainable mobility solutions, parking monitoring, single occupancy vehicle (SOV) incentives.

Social improvements such as education and health are another focus for campus projects. Some of these include healthy activity incentives and rewards for healthy study habits. All these project focuses generally use some sort of modern technology such as cloud services or IoT networks to implement the general concept but some projects using these do not fall into one of the categories and are considered separately in a category alone.

Projects centered around these topics may encompass multiple aspects of a few different focuses. However, none of the academic institution's campus initiatives include integration of smart technologies in *all* topics. As the DU Campus Framework Plan is implemented, smart technologies can be integrated in each category putting DU at the forefront at an all-encompassing 'Smart Campus.'

1.2 Overview of researched smart campus projects

1.2.1 Pertaining to Microgrid/Energy/Storage/CO2:

The Illinois Institute of Technology is one of the premier academic campuses with full-scale ‘Smart Energy’ development. Their ‘Microgrid’ project includes: smart switching, metering, dynamic building control, localized gas, wind, and photovoltaic (PV) generation with an overall objective of a ‘Self-sustaining and technology-ready infrastructure.” The project is funded by IIT and the DOE with a total $12M investment. The projected savings include an annual savings of $1.3M with an initial savings of $5M resulting in a simple payback period of 5 years according to the project website. $3.5M of the total project funding will included research in advanced distribution automation and recovery systems, buried cable fault detection and mitigation, intelligent system controllers, and advanced wireless communication systems [1].

The University of Genoa in Italy incorporates a similar concept of a microgrid with localized generation in their ‘Smart Polygeneration Microgrid (SPM)’ project with the addition of absorption chillers for increased efficiency of cooling large buildings. The project analysis concluded to have significant annual savings in terms of operating costs, CO_2 emissions, and source of primary energy use [2].

The University of Minnesota Morris integrates simpler approach to the smart technology category in their campus sustainability projects. The majority of their energy, heating, and cooling is derived from renewable energy sources such as installations of wind and biomass generation. Additionally, the campus swimming pool is heated by a solar array installation on the fitness center [3].

Energy diversity and localized microgrids on campus are some of the most substantial ways universities are contributing to the global sustainable energy movement but also providing significant energy security for the campus

1.2.2 Pertaining to Transportation:

The University of Twente in The Netherlands is implementing the use of eBikes on campus to provide sustainable transportation and analyze the transportation used around campus. The bikes are charged via PV charging stations and equipped with GPS for analysis on how they are used [4]. Ohio State university is implementing a similar project on campus [5].

The University of British Columbia has implemented a project to collect data on the usage of parking. The project enables the university to better understand on how parking is used and to better serve the campus community. By using occupancy sensors in over 8000 parking spaces, the university can monitor and adjust parking availability in real time to alert and funnel drivers to other locations across campus [6].

Texas A&M has one of the largest transportation oriented smart campus initiatives that looks to optimize the campus transportation ecosystem, provide greater mobility, improve safety, enhance connectivity, and offer a broader range of services. Some of the project's implementations include: automated vehicles, smart parking, smart intersections, ride sharing incentives, data gathering and analytics [7].

1.2.3 Pertaining to Waste:

The Technical University of Denmark has a few smart technology initiatives including one that focuses on waste service optimization. The project involves the installation of sensors within waste receptacles across campus to determine if collection is necessary earlier or later than normally scheduled [8].

Arizona State University is striving for net zero waste events at their Sun Devil stadium [9].

1.2.4 Pertaining to Heating/Cooling:

Stanford University has implemented a large-scale smart campus initiative. The Stanford Energy System Innovations (SESI) group incorporates several smart technologies with a focus on heating/cooling. Part of the project showcases a heat recovery system which collects waste heat from buildings via chilled water loop to be reused in a centralized energy facility. The project reduces campus heating/cooling emissions by 68% from peak levels [10].

1.2.5 Pertaining to Lighting/Light Pollution:

The Illinois Institute of Technology's smart campus initiative includes an Intelligent Off-grid Street Lighting system. The project utilizes solar powered streetlights connected to a network. The project dramatically reduces energy use related to lighting by the replacement of costly lighting methods with efficient LEDs. Additionally, the network integration allows for the lights to provide feedback to the controller and only illuminated when needed to reduce light pollution [11].

The University of California Davis established the Smart Lighting Initiative to improve the quality and efficiency of both indoor and outdoor lighting on campus. The project includes the installation of over 1500 adaptive network connected lights which reduce the campus energy consumption related to lighting by 60%. Oakland University has implemented a similar project with a focus on research of lighting effectiveness [12].

1.2.6 Pertaining to Water:

Western Kentucky University has implemented a smart initiative focusing on water. Water is collected from rooftops and collected in three large cisterns. The water is used for irrigation of several campus gardens [13].

The University of Minnesota Morris recycles water from their cogeneration project which reduces the overall water consumption by 2M gallons per year [3].

1.2.7 Pertaining to Health/Wellness/Social Justice/Education:

Curtin University in Australia advances their smart campus initiative by installing numerous sensors to gather information on how students travel to campus and how they utilize parking among other goals such as facial recognition for keyless housing and course attendance [14].

Shanghai International Studies University has implemented an exercise promotion/tracking app to promote the health of visitors on campus. Patrons can enroll in an incentive program for exercise tracking and utilization of campus fitness facilities. The facilities are integrated with sensors that participants can "check-in" with and analyze their performance [15].

1.2.8 Pertaining to IoT:

Cornell University Energy Management and Control System (EMCS) collects steam, electricity, and chilled water data from nearly 200 locations around campus. The information is fed into the Utility Data System in order to perform various energy analyses. In addition, operators can interactively adjust more than 8,500 motorized fans, pumps, dampers, and valves at buildings throughout the campus based on optimization [16].

Georgia Institute of Technology has implemented a similar project with a living laboratory to collect energy utility systems across campus. Additional sensor networks collect weather data at several points around campus for analysis on energy use affects [17].

1.3 Determining the value of indirect consequences

During periods of electrical disconnect from the energy utility, the DU campus suffers dramatically. Backup generators are needed to supply power to emergency lighting and fire suppression systems. Primary lighting and HVAC systems are reduced or unable to operate. Often class is canceled, and productivity suffers. The most recent occurrence of widespread outage on campus was during the bomb cyclone storm in the spring of 2019. It was estimated that 90% of the campus was experiencing electrical outage at the worst point. The estimated average load for the campus before the outage was approximately 10 MW. The outage lasted for about 4 hours before buildings were being restored. The value of lost load (VOLL) for small commercial customers is estimated to be $8,000/MWh [18]. Therefore, the estimated value of the loss from the storm is: 90% x 8MW x 4h x $8,000/MWH = $230,400. This is a high-level estimation based on indexes and estimated values but provides a good indication on the severity of widespread prolonged outage.

From previous research conducted the social cost of carbon (SCC) which refers to an estimated overall cost of the harmful effects of the emitted pollutant on society is estimated to be $42 per ton and the abatement cost of carbon (ACC) which refers to an estimate of the expected cost of reducing emissions of a pollutant is roughly $19 per ton. The average cost is then levelized to be (ACC + SCC) /2 = $30 per ton. This number is slightly higher of the widely accepted industry standard of $22 - $28 per ton. For purposes of this cost within this research, the best-case and worst-case-scenario will be considered in determining overall cost [19].

As the University enters a new era of modern IoT technology, it has the opportunity to apply this technology to monitor energy usage and dramatically reduce energy costs. By implementing a network that can monitor usage and potentially control the way energy is consumed, the university can reduce the overall cost by over 50% based on short-term and long-term net benefit internally and externally.

2 Current State of Energy Diversity on DU Campus

The University of Denver campus is substantially deficient in the way it self-produces energy as compared to other institutions of its size. The university does not have any localized generation and has only begun energy savings initiatives recently. The University Utility Reserve Fund was established in 2009 to reinvest remaining money from the annual utility budget into projects designed to save money on utility costs. The fund was initially seeded at $1.9M and has evolved into a broader program today. Between 2009 and 2015 the fund helped implement projects related to system control, lighting, mechanical system, and energy savings upgrades to reduce over 500,000 kWh annually. In 2017 the fund was reassigned and rebranded the “Green Fund” to expand the availability to projects designed to reduce carbon footprint such as waste mitigation. Today the fund’s projects are at an average of 2.33-year payback including a $1.69M contribution to LEED goals for capital projects. Recent projects have produced over $1M in incentive rebates by Xcel energy. The university has not been able to invest in renewable energy projects until just recently due to several challenges. The DU campus is unique in that most buildings are individually served by the utility and availability to secure funding for projects has been limited. Originally, the opportunities to build renewable generation on the campus involves purchasing the infrastructure outright which was costly. The board of trustees were reluctant to invest in projects with payback periods of less than 10 years. As renewable energy technologies are becoming increasingly more affordable and more diverse in structure, the university has decided to reconsider renewable energy production on campus. Additionally, student advocacy groups such as Divest DU, helped pressure university executives to consider implementing programs that would terminate the university's dependency on fossil fuels. In negotiation, the university agreed to set sustainability goals as part of the "commitment to pioneering sustainability" in the long-term strategic plan DU IMAPCT 2025.

The university currently receives 100% of its energy through a commercial energy purchase tariff from Xcel Energy – Public Service of Colorado (PSCO). The tariff is standardized and used for rate setting and service agreements. Annually, the university spends over $3M in electric service. In 2018 the university's electricity service bill was over $3.9M. The largest electric cost is the Ritchie Athletic complex ($650k+) which costs nearly three times the next largest load -- Ruffatto Hall ($240k+). The average annual increase in electricity service cost over the last 10 years was 3.2%. To alleviate energy costs and achieve its sustainability goals, the university is participating in a Solar Photovoltaic (PV) installation with vendor Pivot Energy. The DU campus solar project is an integral part of incorporating renewable energy within the university long term plan. The project was conceived in October 2017 during the request for proposal (RFP) process collaborated with Colorado State University. Much of 2018 was spent reviewing proposals and negotiating final product. In December 2018 the final contract was signed for a 20-year power purchase agreement (PPA). The project consists of installing active photovoltaic panels (PV panels) on existing and currently under construction buildings throughout campus. A total of over 7,000 panels resulting in approximately 2.2 MW of capacity will be installed on 18 rooftops owned by the university. Desirably, the university will have no up-front costs associated with the project[1] and will only be responsible for purchasing the produced output of the panels as described in the PPA. Pivot energy is the PPA provider and manages the ownership, financing, installation, and maintenance of the rooftop solar energy systems over the duration of the contract. It is estimated that the entire project will offset between 7% and 8% of the university's electricity use. Xcel Energy remains the utility service provider and continues to supply the remaining required electricity service. The agreement with Xcel energy does not include any net metering structure. Therefore, no excess energy will be 'sold' back to the utility grid. The university will then purchase the output of the panels, like the energy provided by Xcel. Additionally, the university will own 100% of the resulting renewable energy credits (RECs) generated by the solar system. The anticipated REC production will reduce the university carbon footprint by 3-4%. Producing and maintaining the university's own RECs was a key characteristic desired by the activist group Divest DU and will place the university at the forefront of such an achievement.

Only certain buildings owned and operated by the university were eligible candidates for rooftop solar based on location and engineering constraints. The eighteen buildings selected for the rooftop solar project include:

- Ritchie Athletic Center (Gates Field House & Joy Burns Arena)
- Anderson Academic Commons
- Driscoll South
- Shwayder Art Building

[1] DU Facilities made upgrades to several building roofs to accommodate solar installations

- Boettcher West
- Sturm Hall
- AOB Building
- Hampden Warehouse
- Knudson Hall
- Frontier Hall
- Ammi Hyde
- Central Receiving/Processing
- UTS Building
- Cherrington (SIE) Complex
- Seeley J Mudd Building
- Fisher Early Learning Center
- Diamond Family Residential Village[2]
- Pioneer Career Achievement Center[3]

As previously mentioned, the university is a major customer of Xcel Energy and consumes a significant amount of energy when compared to the overall size of the campus. To better monitor the energy usage of campus buildings, a pilot energy monitoring program was implemented which consisted of archiving energy bills in an online database to analyze energy use based on building and load pocket. Additionally, network connected meters were installed to monitor specific buildings' energy usage in

[2] Under construction to be completed 2020

[3] Under construction to be completed 2020

real-time. Unfortunately, the installed real-time meters were sporadic in producing accurate data collection and provided limited insight to the campus energy consumption though they provide a general idea of consumption trends for a few buildings. Four buildings across the spectrum of size and type were analyzed using the meters for energy consumption in real-time: Olin Hall, Nagel Hall, Seely Mudd Science Building, and Daniels College of Business. Only one of these buildings, Seeley J Mudd Hall, will be part of the DU rooftop solar project and was the center of analysis for this project. A campus map illustrating the buildings with rooftop solar installations can be found in Appendix B.

2.1 Calculating Average Monthly Load Profile

2.1.1 Seeley J. Mudd

Seeley Mudd Science Building, 64,770 sq-ft, was constructed in 1982 and consists of classrooms and laboratories for the natural science school. Several months in 2018 of energy use data were extracted from the eGauge meters and compiled. The monthly data was then heat-mapped and analyzed for weekday and weekend/holiday load profile. The data from September 2018 can be found in Appendix A. The peak according to the data was approximately 271kW during the 14:00 hour on a weekday. The cumulative energy usage for the month was approximately 147,228kWh. The average load profile for the month can be found in Figure 1.

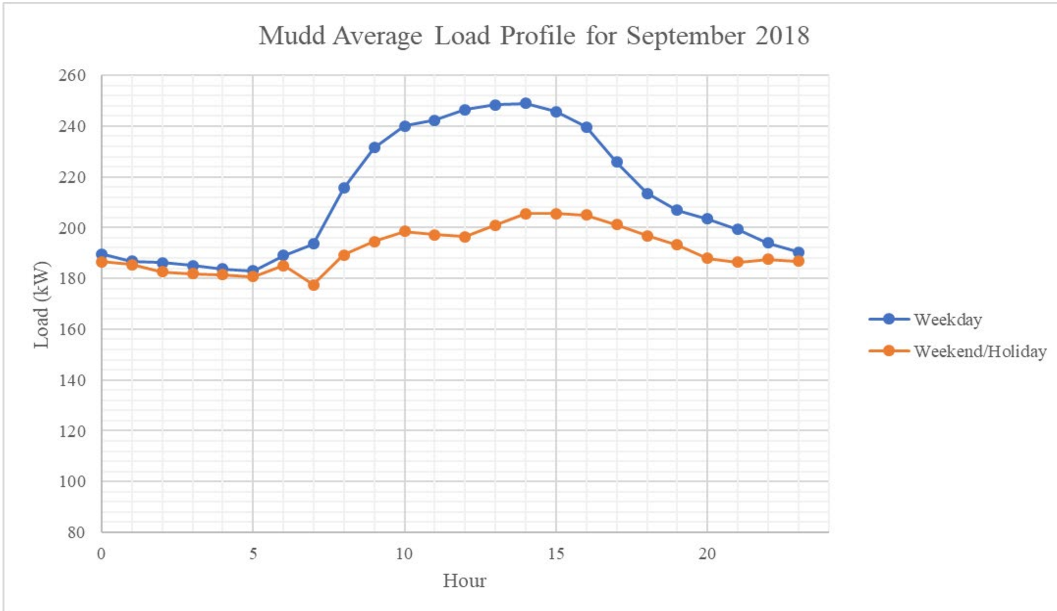

Figure 2: Mudd average load profile for September 2018

Average peak of weekday load is roughly 250kW and weekend load is roughly 205kW

2.1.2 Olin Hall

Olin Hall, 41,000 sq-ft, constructed in 1996 consists of classrooms and laboratories in the natural sciences school. Similarly, several months in 2018 of energy use data were extracted from the eGauge meters and compiled. The monthly data was then heat mapped and analyzed for weekday and weekend/holiday load profile. The data from September 2018 can be found in Appendix A. The peak according to the data was approximately 150kW during the 15:00 hour on a weekday. The cumulative energy usage for the month was approximately 48,320kWh. The average load profile for the month can be found in Figure 2.

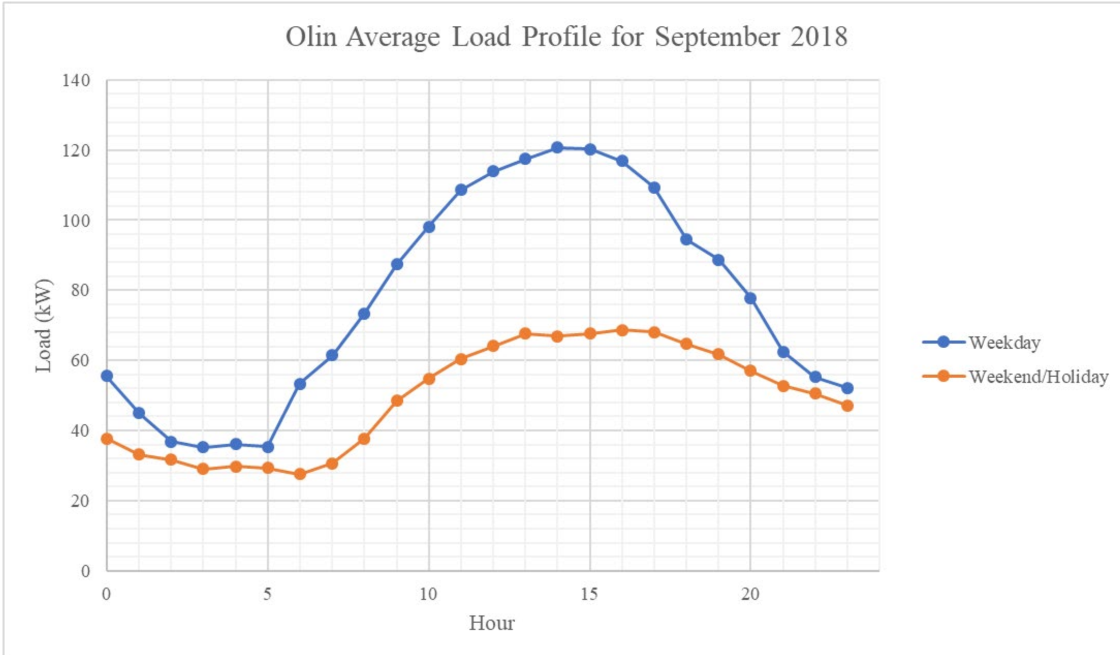

Figure 3: Olin average load profile for September 2018

Average peak of weekday load is roughly 120kW and weekend load is roughly 70kW.

2.1.3 Nagel Hall

Nagel Hall, 149,729 sq-ft, constructed in 2008 consists of housing for students and one of the major dining halls on campus. Nagel Hall is the university's only LEED Gold certified residence hall. Similarly, several months in 2018 of energy use data were extracted from the eGauge meters and compiled. The monthly data was then heat mapped and analyzed for weekday and weekend/holiday load profile. The data from September 2018 can be found in Appendix A. The peak according to the data was approximately 266kW during the 15:00 hour on a weekend. The cumulative energy usage for the month was approximately 172,500kWh. The average load profile for the month can be found in Figure 3.

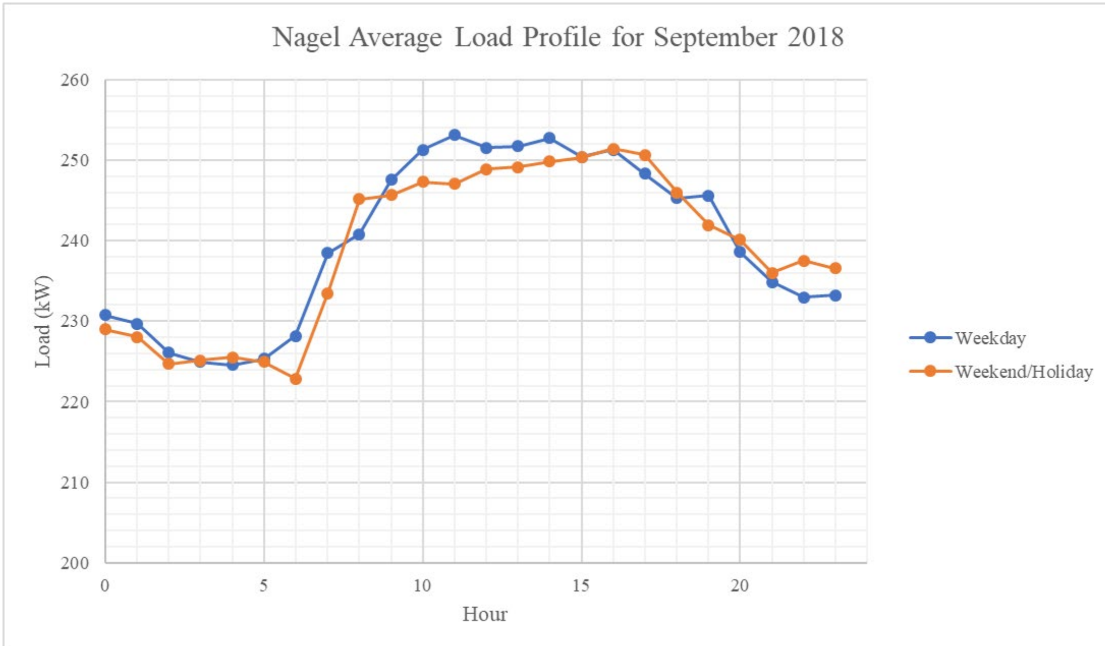

Figure 4: Nagel average load profile for September 2018

Average peak of weekday load is roughly 250kW and weekend load is also roughly 250kW.

2.1.4 Daniels College of Business

Finally, Daniels College of Business, 110,536 sq-ft, constructed in 1999 consists of classrooms and offices for the Daniels College of Business. Similarly, several months in 2018 of energy use data were extracted from the eGauge meters and compiled. The monthly data was then heat mapped and analyzed for weekday and weekend/holiday load profile. The data from September 2018 can be found in Appendix A. The peak according to the data was approximately 370kW during the 17:00 hour on a weekday. The cumulative energy usage for the month was approximately 145,379kWh. The average load profile for the month can be found in Figure 3.

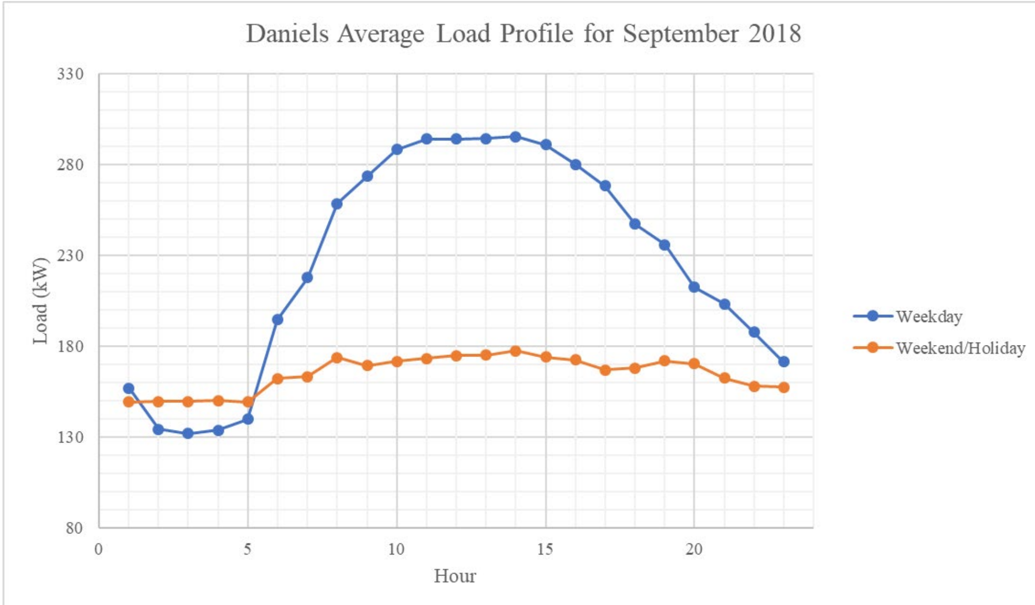

Figure 5: Daniels average load profile for September 2018

Average peak of weekday load is roughly 300kW and weekend load is roughly 175kW

2.1.5 Load Profile Discussion

Each building on campus possesses a unique load graph. Classroom oriented buildings such as Olin Hall have little to no load on weekends and peak in evening hours while others like Nagel Hall, which houses students, has almost the same weekend load as the week and may peak in morning hours. Each of these buildings studied for load profile was used to determine the effectiveness of the rooftop solar instillations on the selected buildings. Due to each building's unique load profile, the building's load profiles were analyzed and used to group the buildings in the solar project by load type.

First, each seasonal category (equinox, summer/winter solstice) load pattern was analyzed for midday load-peak offset and maximum-average load ratio. Midday load-peak offset is the number of standard deviations represented by hours that the peak load occurs offset from the maximum solar altitude. Maximum/average load ratio is the maximum load divided by the average load for the represented category. Each of these values for the studied buildings can be found in Table 1.

Table 1: Max/Average Ratio and Load-Peak Offset for each building

	Olin			Negal			Daniels			Mudd		
	Max/Min Ratio	Max/Avg Ratio	Load-Peak Offset	Max/Min Ratio	Max/Avg Ratio	Load-Peak Offset	Max/Min Ratio	Max/Avg Ratio	Load-Peak Offset	Max/Min Ratio	Max/Avg Ratio	Load-Peak Offset
June	5.304	1.578	1	1.233	1.034	0	3.170	1.303	0	1.680	1.177	1
Sept	6.584	1.562	2	1.214	1.055	-1	3.062	1.319	0	1.620	1.174	0
Dec	1.930	1.193	-1	1.057	1.011	-2	2.853	1.350	-1	1.447	1.129	-1

This data was then used in estimating load shape for the buildings involved in the rooftop solar project based on building characteristic similarities.

2.2 Determining Effectiveness of Demand Reduction

2.2.1 Discussion on demand reduction

Actual demand Reduction is difficult to determine without knowing the average load profile for each month of every building due to variability in building characteristics between the applied load profiles.

2.2.2 Seeley J Mudd

Starting with Seeley J. Mudd, Pivot designed a rooftop PV system DC nameplate rated for 91.41 kW and an estimated annual production of 101.6 MWh. Mudd had a June peak of 291 kW during the 14:00 hour on the 27th day. Xcel energy’s demand charge was $22.95 per kW for the month of June resulting in $6,678.45 of demand charge alone. The maximum PV system output for this hour is approximately 73.18 kW. For a best-case scenario analysis of PV demand reduction, the maximum PV system output is assumed to coincide with the month peak resulting in a theoretical new peak of 217 kW and a demand charge of $4,987.58. A savings of roughly $1,690.87 in demand charges alone. However, it is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand and the solar system would have to be outputting at maximum during the entire day to achieve total demand reduction. Therefore, analysis was conducted on the overall demand reduction by PV output based on load profile superimposed with anticipated solar output. The results can be found in Figure 5.

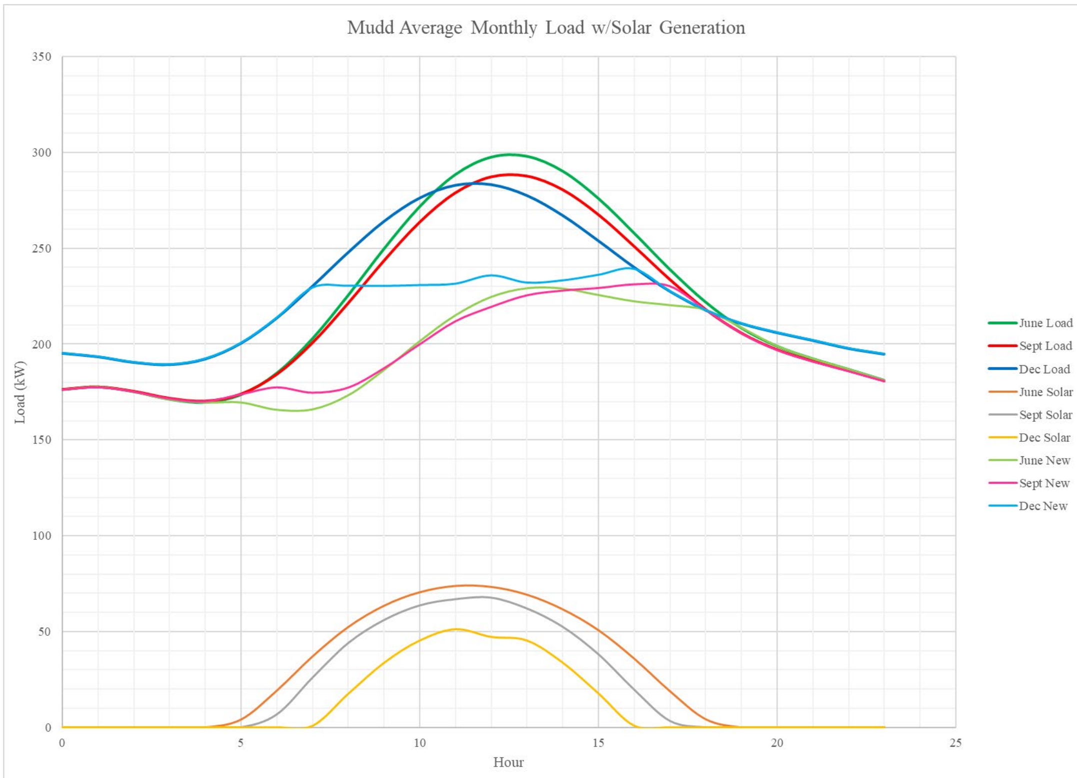

Figure 6: Seeley J. Mudd average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 229 kW. Assuming this will be the new monthly billed demand peak, the savings are only 62 kW instead of 73 kW. This results in a demand reduction ratio of 62/91 or roughly 68%. Demand reduction ratio is not to be confused by demand reduction divided by total billed demand. The same process was conducted for September and December months. In months other than the summer solstice such as September and December, the maximum solar output is reduced.

Therefore, the total demand reduction effectiveness is reduced also. Thus, the total derate was determined which represents the maximum expected solar output derated for the applied month superimposed on the billed demand for that month. The total derate ratio represents the determined demand savings divided by the absolute maximum solar output. The results can be found in Table 2.

Table 2: Seeley J. Mudd solar characteristics and demand reduction

Mudd		Load Shape	Mudd	Module DC Capacity (kW)	91.41	Performance Factor	80.6%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	291	173	0	228.991	62.009	84.16%	84.16%
September	281	173	0	231.247	49.753	73.59%	67.53%
December	278	192	-1	239.292	38.708	75.42%	52.54%

Using the load profile categories found in Table 2. Each rooftop solar building was analyzed using the same process as Mudd.

2.2.3 Ritchie Athletic Complex

Ritchie Athletic Complex has a designed rooftop solar system DC nameplate rated for 748.11 kW and an estimated annual production of 883.664 MWh. Ritchie had a June demand of 1,408 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Nagel to determine estimated demand reduction.

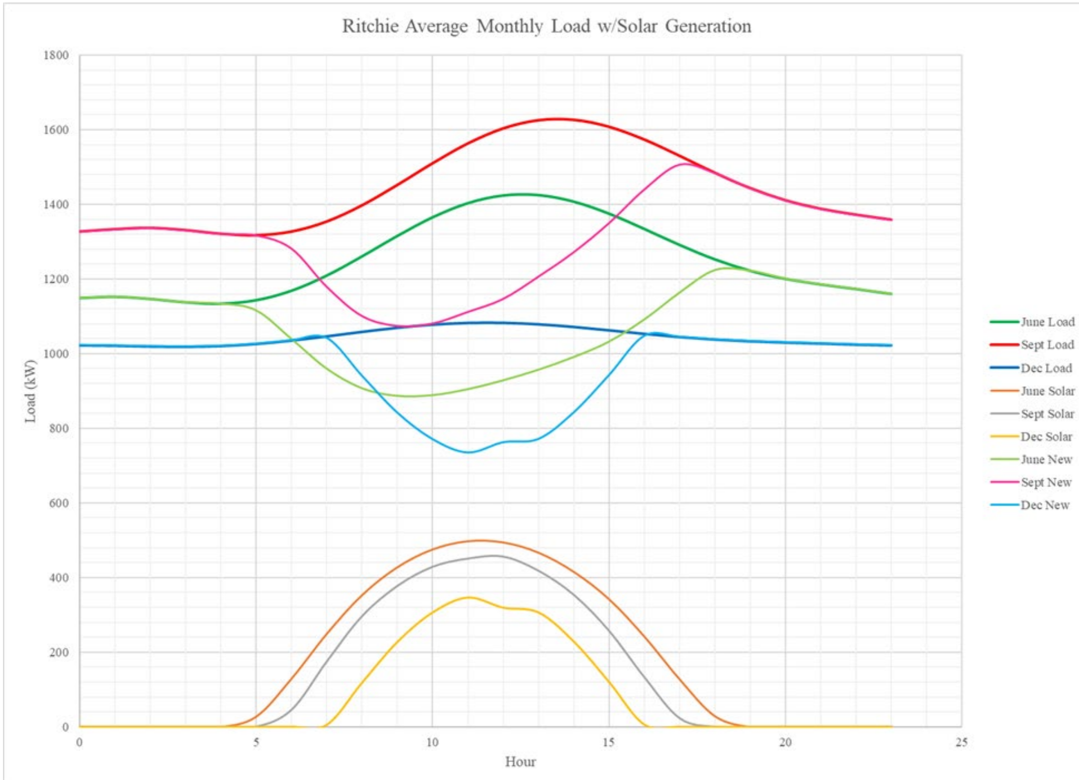

Figure 7: Ritchie average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 1,224 kW. Assuming this will be the new monthly billed demand peak, the savings are 1864 kW. This results in a demand reduction ratio of roughly 37.06%. The same process was conducted for September and December months. The results can be found in Table 3.

Table 3: Ritchie solar characteristics and demand reduction

Ritchie		Load Shape	Nagel	Module DC Capacity (kW)	748.11	Performance Factor	66.5%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	1408	1142	0	1223.639	184.361	37.06%	37.06%
September	1609	1326	1	1507.207	101.793	22.30%	20.46%
December	1079	1021	-1	1047.800	31.200	9.00%	6.27%

2.2.4 Anderson Academic Commons

Anderson Academic Commons has a designed rooftop solar system DC nameplate rated for 189.09 kW and an estimated annual production of 269.0 MWh. Anderson had a June demand of 213 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

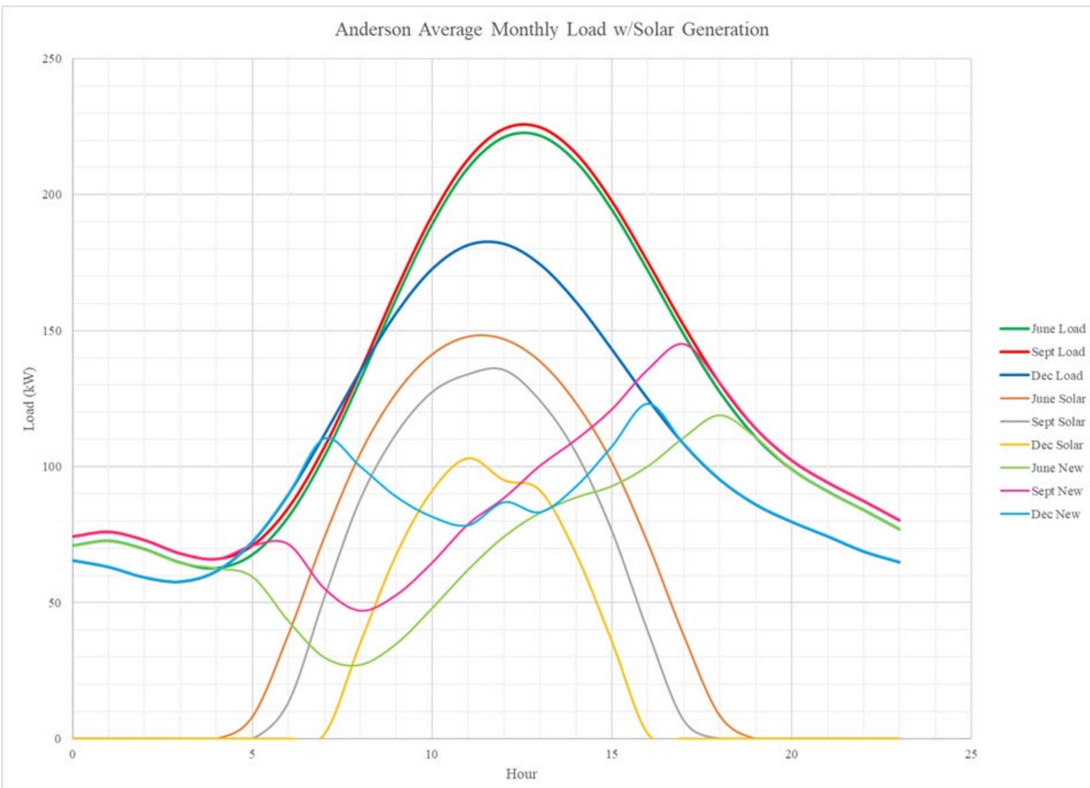

Figure 8: AAC average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 119 kW. Assuming this will be the new monthly billed demand peak, the savings are 94 kW. This results in a demand reduction

ratio of roughly 63.55%. The same process was conducted for September and December months. The results can be found in Table 4.

Table 4: AAC solar characteristics and demand reduction

Anderson		Load Shape	Daniels	Module DC Capacity (kW)	189.09	Performance Factor	78.2%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	213	67	0	119.029	93.971	63.55%	63.55%
September	216	71	0	145.169	70.831	52.20%	47.90%
December	175	61	-1	123.203	51.797	50.28%	35.03%

2.2.5 Driscoll South

Driscoll South has a designed rooftop solar system DC nameplate rated for 109.56 kW and an estimated annual production of 167.1 MWh. Driscoll had a June demand of 109 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

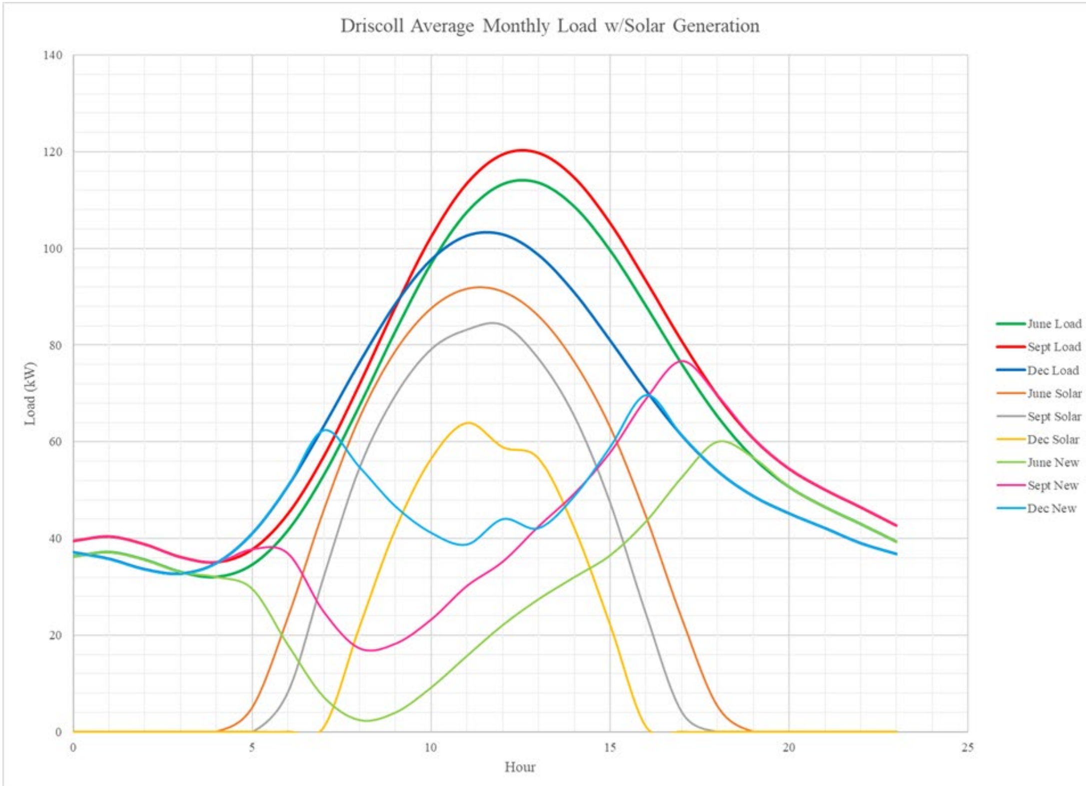

Figure 9: Driscoll average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 60 kW. Assuming this will be the new monthly billed demand peak, the savings are 49 kW. This results in a demand reduction ratio of roughly 53.44%. The same process was conducted for September and December months. The results can be found in Table 5.

Table 5: Driscoll solar characteristics and demand reduction

Driscoll		Load Shape	Daniels	Module DC Capacity (kW)	109.56	Performance Factor	83.7%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	109	34	0	59.991	49.009	53.44%	53.44%
September	115	38	0	76.703	38.297	45.51%	41.76%
December	99	35	-1	69.607	29.393	46.01%	32.05%

2.2.6 Shwayder Art Building

Shwayder Art Building has a designed rooftop solar system DC nameplate rated for 54.87 kW and an estimated annual production of 78.5 MWh. Shwayder had a June demand of 53 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine actual demand reduction.

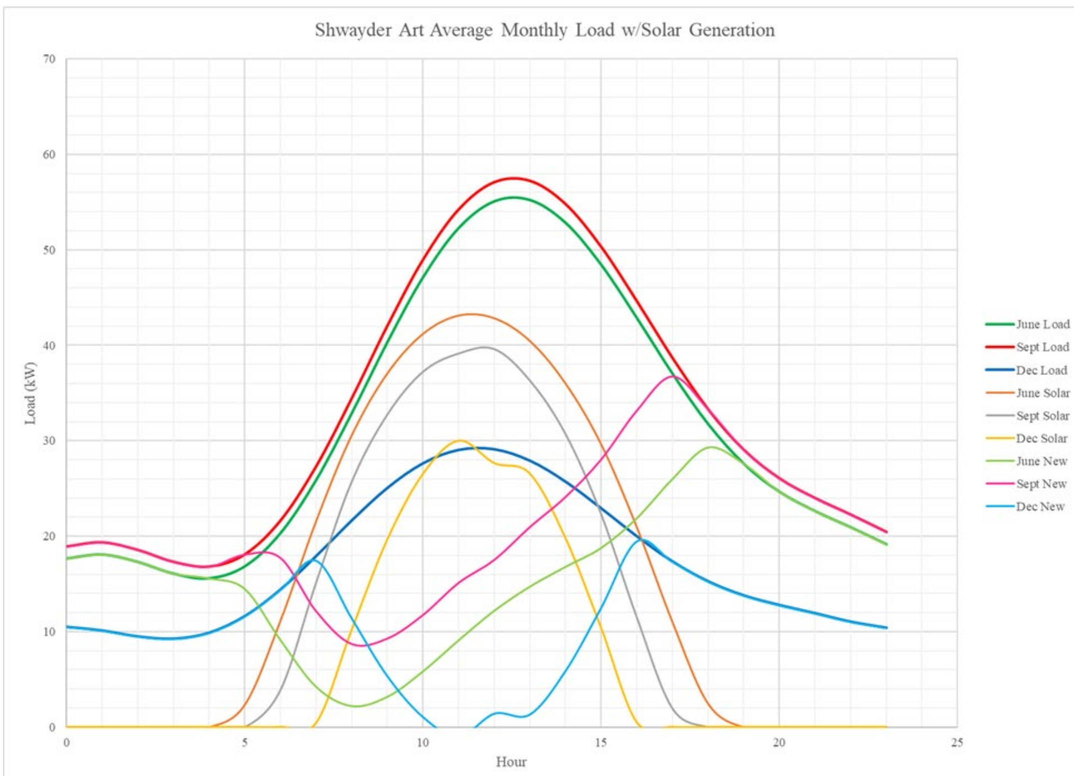

Figure 10: Shwayder average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 29 kW. Assuming this will be the new monthly billed demand peak, the savings are 24 kW. This results in a demand reduction

ratio of roughly 55.06%. The same process was conducted for September and December months. The results can be found in Table 6.

Table 6: Shwayder solar characteristics and demand reduction

Shwayder Art		Load Shape	Daniels	Module DC Capacity (kW)	54.87	Performance Factor	78.6%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	53	17	0	29.254	23.746	55.06%	55.06%
September	55	18	0	36.717	18.283	46.19%	42.39%
December	28	10	-1	19.493	8.507	28.31%	19.72%

2.2.7 Boettcher West

Boettcher West has a designed rooftop solar system DC nameplate rated for 154.77 kW and an estimated annual production of 234.1 MWh. Boettcher had a June demand of 130 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

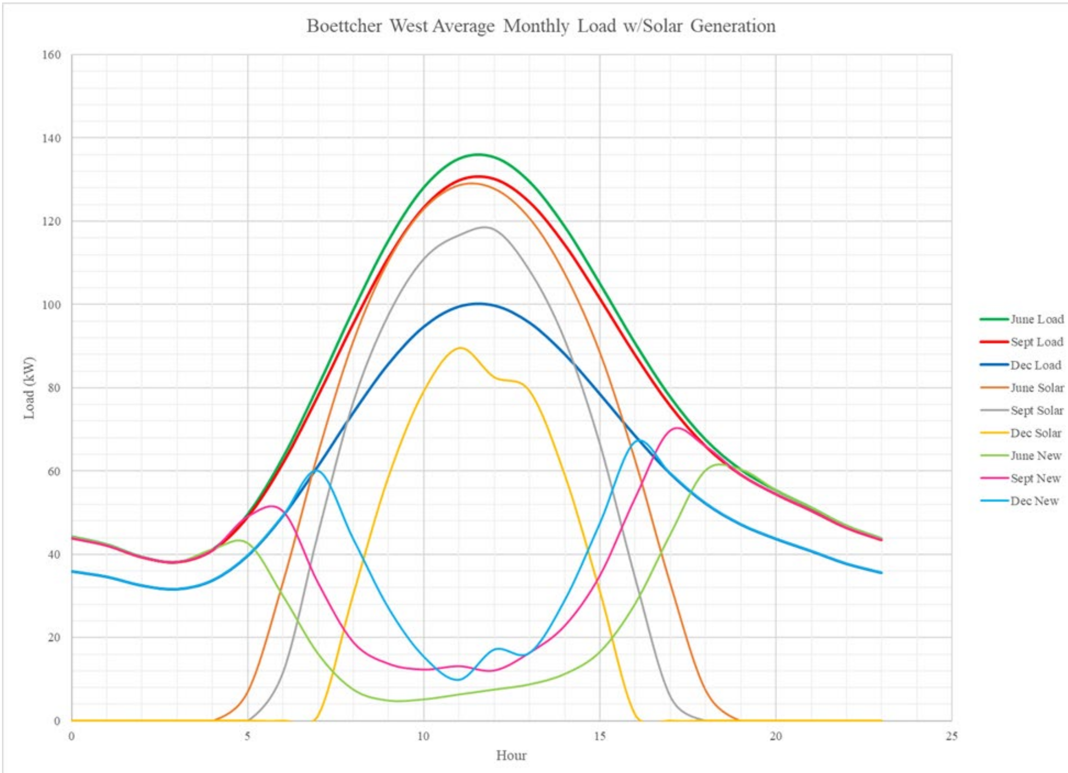

Figure 11: Boettcher average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 60 kW. Assuming this will be the new monthly billed demand peak, the savings are 70 kW. This results in a demand reduction ratio of roughly 54.09%. The same process was conducted for September and December months. The results can be found in Table 7.

Table 7: Boettcher solar characteristics and demand reduction

Boettcher West		Load Shape	Daniels	Module DC Capacity (kW)	154.77	Performance Factor	83.1%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	130	41	-1	60.427	69.573	54.09%	54.09%
September	125	41	-1	69.843	55.157	46.73%	42.89%
December	96	34	-1	67.051	28.949	32.31%	22.51%

2.2.8 Sturm Hall

Sturm Hall has a designed rooftop solar system DC nameplate rated for 116.16 kW and an estimated annual production of 172.2 MWh. Sturm had a June demand of 151 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

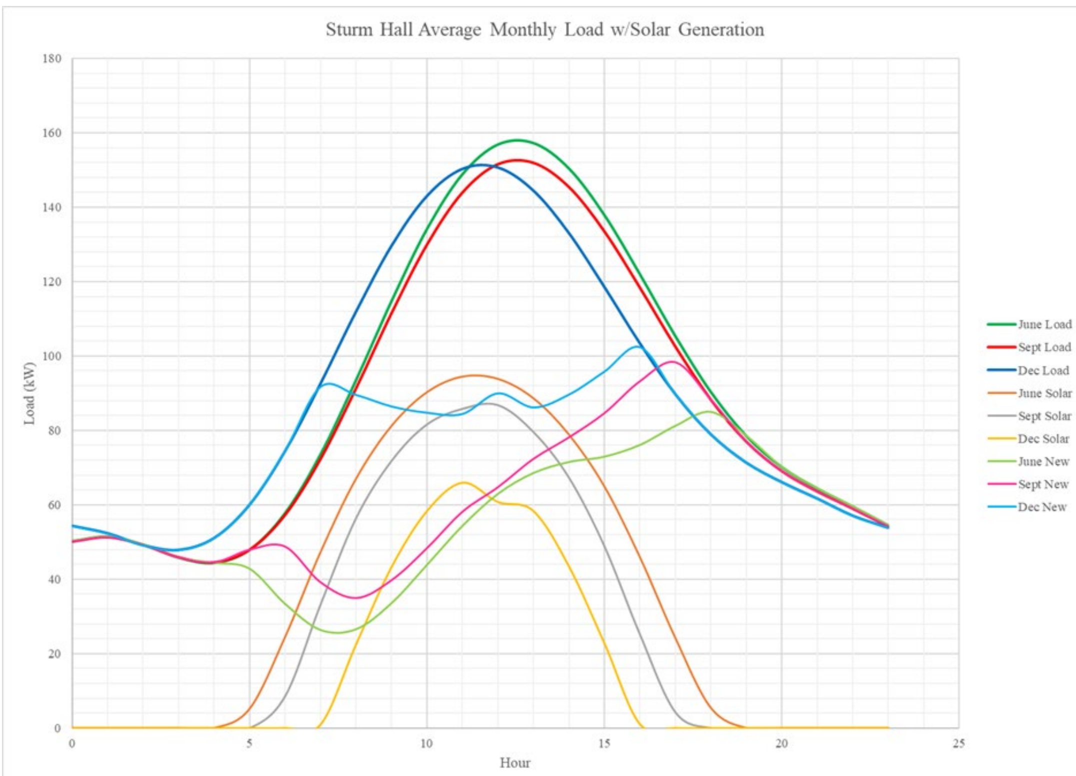

Figure 12: Sturm average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 85 kW. Assuming this will be the new monthly billed demand peak, the savings are 66 kW. This results in a demand reduction

ratio of roughly 69.83%. The same process was conducted for September and December months. The results can be found in Table 8.

Table 8: Sturm solar characteristics and demand reduction

Sturm Hall		Load Shape	Daniels	Module DC Capacity (kW)	116.16	Performance Factor	81.4%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	151	48	0	84.971	66.029	69.83%	69.83%
September	146	48	0	98.367	47.633	54.90%	50.38%
December	145	51	-1	102.397	42.603	64.68%	45.06%

2.2.9 Knudson Hall

Knudson Hall has a designed rooftop solar system DC nameplate rated for 26.4 kW and an estimated annual production of 40.1 MWh. Knudson had a June demand of 48 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Mudd to determine estimated demand reduction.

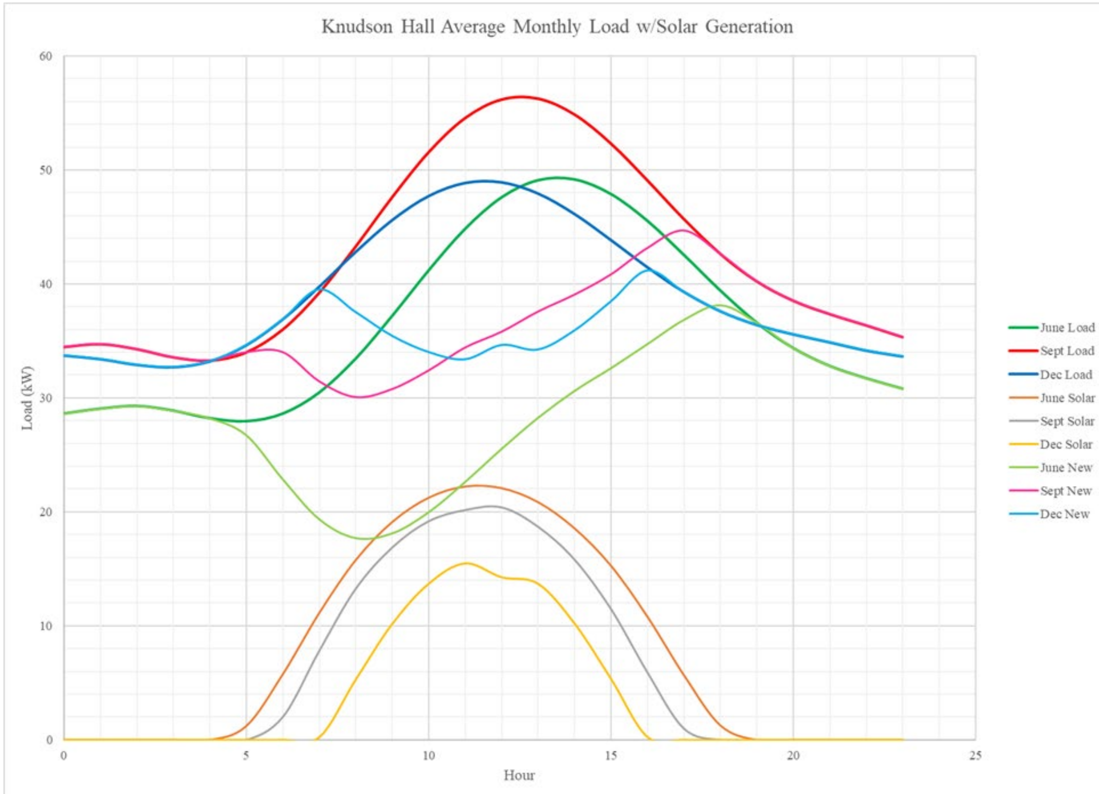

Figure 13: Knudson average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 38 kW. Assuming this will be the new monthly billed demand peak, the savings are 10 kW. This results in a demand reduction ratio of roughly 44.34%. The same process was conducted for September and December months. The results can be found in Table 9.

Table 9: Knudson solar characteristics and demand reduction

Knudson Hall		Load Shape	Mudd	Module DC Capacity (kW)	26.4	Performance Factor	84.1%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	48	29	1	38.156	9.844	44.34%	44.34%
September	55	34	0	44.717	10.283	50.47%	46.31%
December	48	33	-1	41.210	6.790	43.90%	30.58%

2.2.10 Frontier Hall

Frontier Hall has a designed rooftop solar system DC nameplate rated for 56.76 kW and an estimated annual production of 76.4 MWh. Frontier had a June demand of 115 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

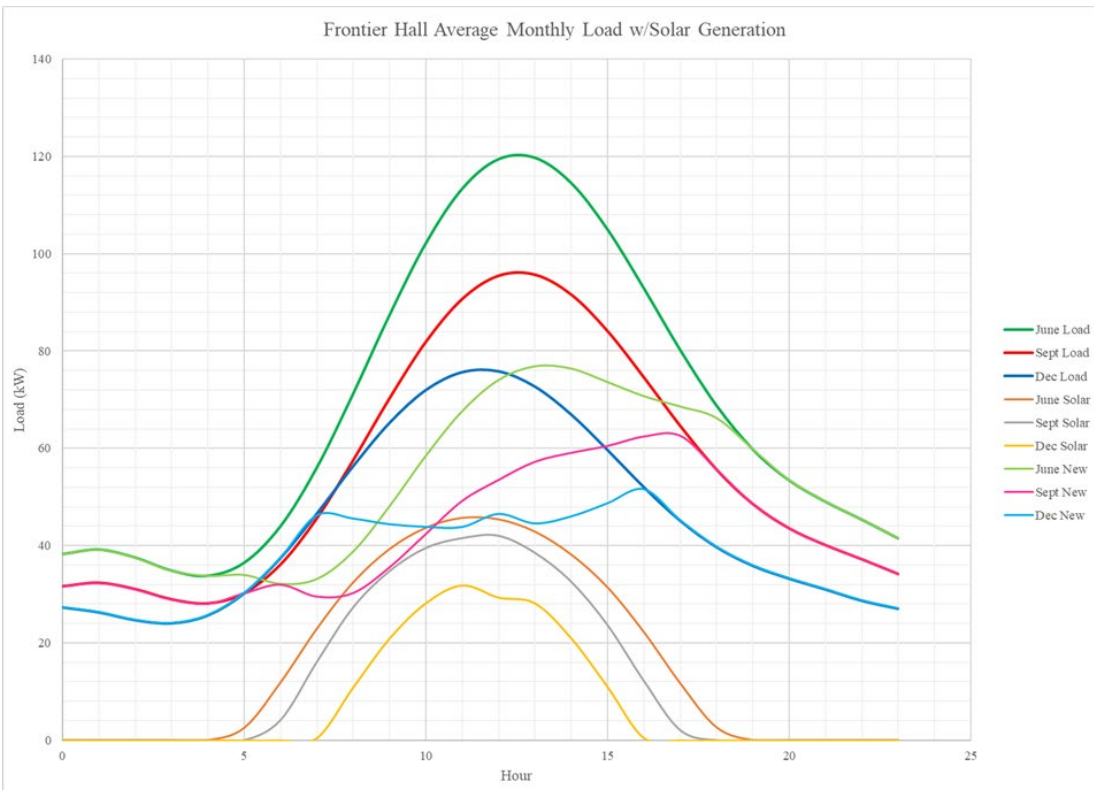

Figure 14: Frontier average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 77 kW. Assuming this will be the new monthly billed demand peak, the savings are 38 kW. This results in a demand reduction

ratio of roughly 83.43%. The same process was conducted for September and December months. The results can be found below.

Table 10: Frontier solar characteristics and demand reduction

Frontier Hall		Load Shape	Daniels	Module DC Capacity (kW)	56.76	Performance Factor	80.6%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	115	36	0	76.834	38.166	83.43%	83.43%
September	92	30	0	62.609	29.391	70.01%	64.24%
December	73	26	-1	51.572	21.428	67.23%	46.84%

2.2.11 Ammi Hyde

Ammi Hyde has a designed rooftop solar system DC nameplate rated for 33 kW and an estimated annual production of 49.4 MWh. Ammi had a June demand of 93 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Mudd to determine estimated demand reduction.

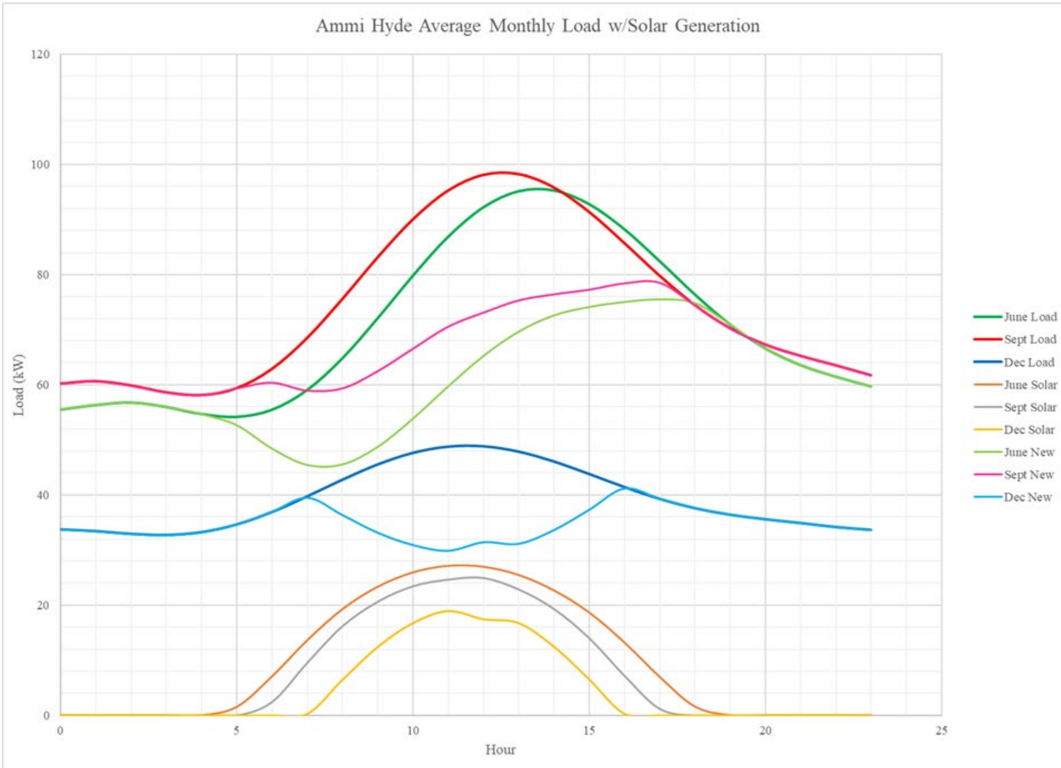

Figure 15: Ammi Hyde average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 76 kW. Assuming this will be the new monthly billed demand peak, the savings are 17 kW. This results in a demand reduction ratio of roughly 64.42%. The same process was conducted for September and December months. The results can be found in Table 11.

Table 11: Ammi Hyde solar characteristics and demand reduction

Ammi Hyde		Load Shape	Mudd	Module DC Capacity (kW)	33	Performance Factor	82.3%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	93	55	1	75.504	17.496	64.42%	64.42%
September	96	59	0	78.575	17.425	69.91%	64.16%
December	48	33	-1	41.154	6.846	36.18%	25.21%

2.2.12 Central Receiving & Purchasing

Central Receiving & Purchasing has a designed rooftop solar system DC nameplate rated for 26.4 kW and an estimated annual production of 26.4 MWh. Central R/P had a June demand of 24 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Mudd to determine estimated demand reduction.

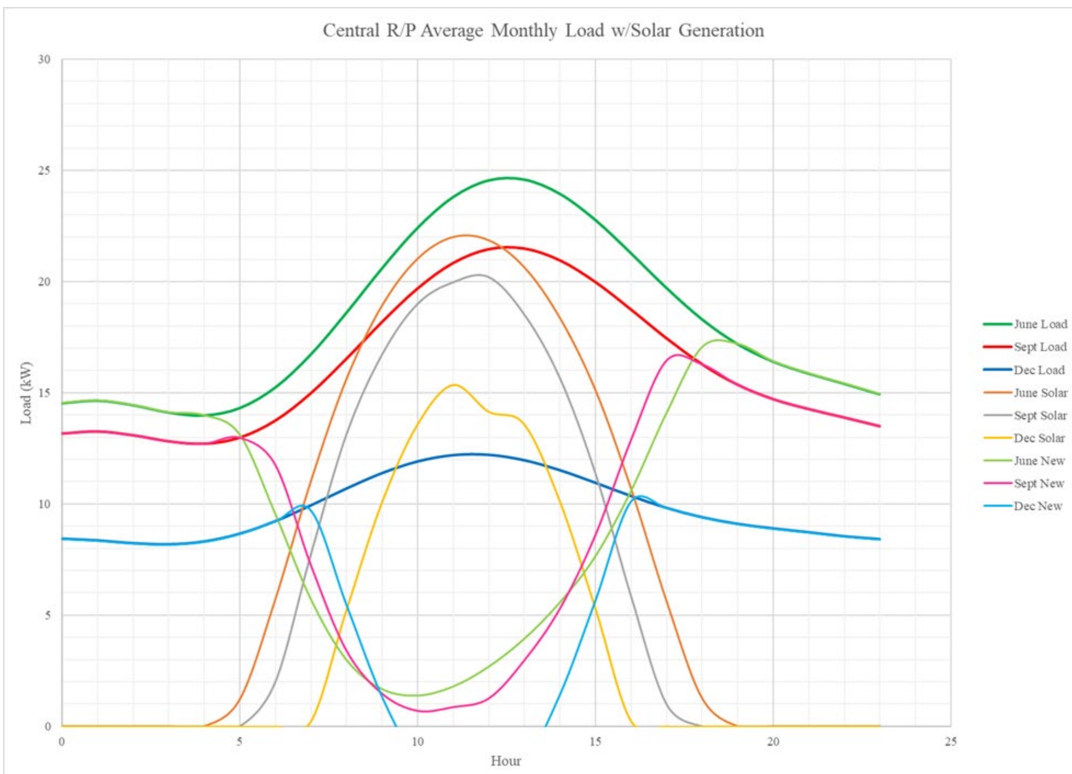

Figure 16: C R/P average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 17 kW. Assuming this will be the new monthly billed demand peak, the savings are 7 kW. This results in a demand reduction ratio of roughly 30.93%. The same process was conducted for September and December months. The results can be found below.

Table 12: Central R/P solar characteristics and demand reduction

Central R/P		Load Shape	Mudd	Module DC Capacity (kW)	26.4	Performance Factor	83.4%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	24	14	0	17.191	6.809	30.93%	30.93%
September	21	13	0	16.463	4.537	22.46%	20.61%
December	12	8	-1	10.117	1.883	12.28%	8.55%

2.2.13 University Technology Services

University Technology Services has a designed rooftop solar system DC nameplate rated for 26.4 kW and an estimated annual production of 40.2 MWh. UTS had a June demand of 200 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Nagel to determine estimated demand reduction.

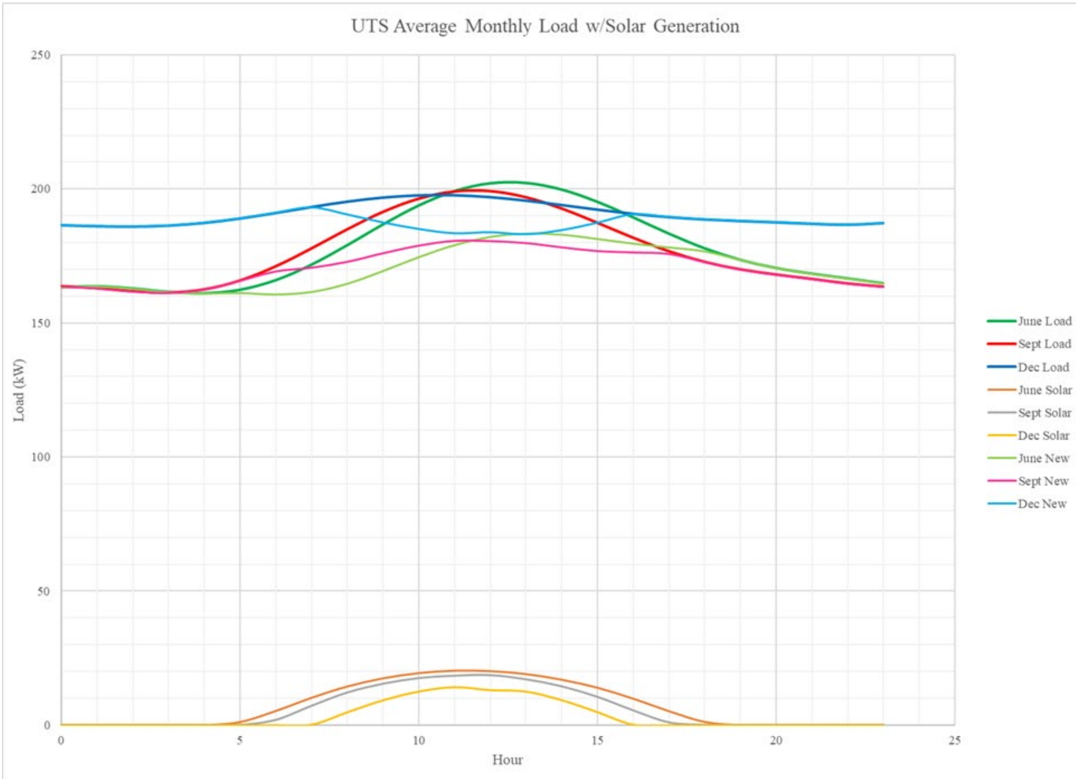

Figure 17: UTS average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 183 kW. Assuming this will be the new monthly billed demand peak, the savings are 17 kW. This results in a demand reduction ratio of roughly 68.77%. The same process was conducted for September and December months. The results can be found below.

Table 13: UTS solar characteristics and demand reduction

UTS		Load Shape	Nagel	Module DC Capacity (kW)	26.4	Performance Factor	76.5%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	200	162	0	183.332	16.668	82.53%	82.53%
September	197	162	-1	180.644	16.356	88.25%	80.99%
December	197	186	-2	193.086	3.914	27.82%	19.38%

2.2.14 Cherrington (SIE) Complex

Cherrington (SIE) Complex has a designed rooftop solar system DC nameplate rated for 41.25 kW and an estimated annual production of 61.0 MWh. SIE had a June demand of 177 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Mudd to determine estimated demand reduction.

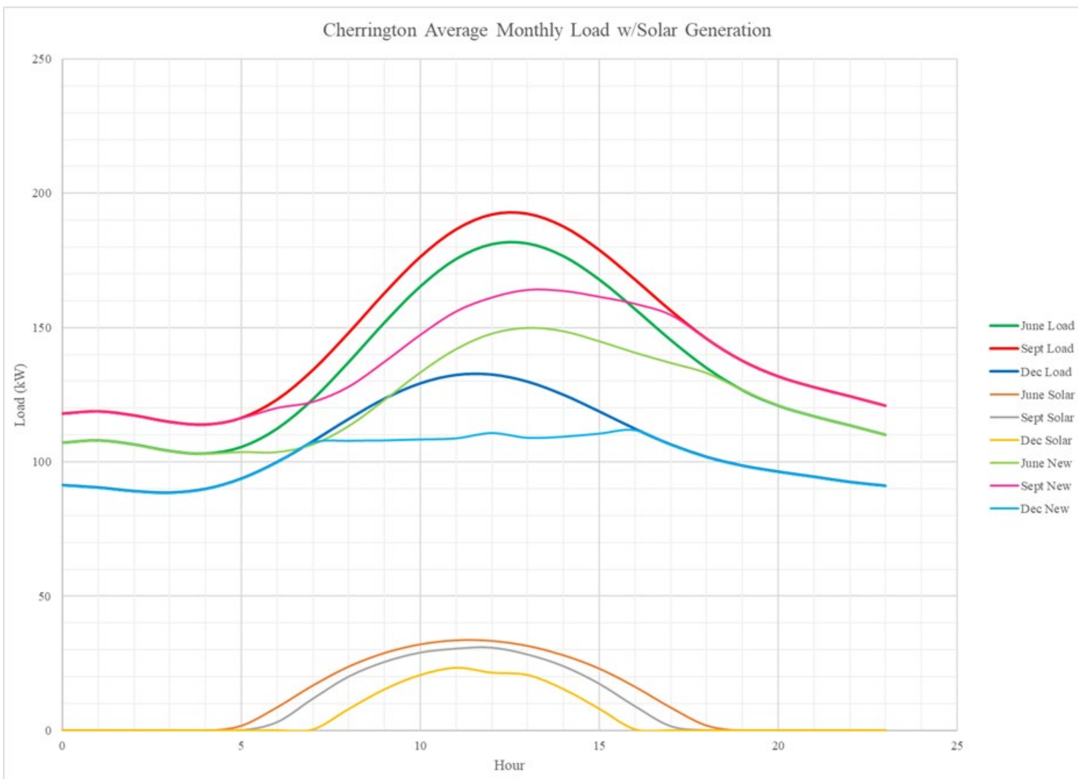

Figure 18: Cherrington average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 150 kW. Assuming this will be the new monthly billed demand peak, the savings are 27 kW. This results in a demand reduction

ratio of roughly 80.93%. The same process was conducted for September and December months. The results can be found below.

Table 14: Cherrington solar characteristics and demand reduction

Cherrington		Load Shape	Mudd	Module DC Capacity (kW)	41.25	Performance Factor	81.4%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	177	105	0	149.826	27.174	80.93%	80.93%
September	188	116	0	164.100	23.900	77.56%	71.18%
December	130	90	-1	111.909	18.091	77.34%	53.88%

2.2.15 Fisher Early Learning Center

Fisher Early Learning Center has a designed rooftop solar system DC nameplate rated for 19.8 kW and an estimated annual production of 28.6 MWh. Fisher had a June demand of 78 kW. It is unlikely that the PV system will be operating at maximum output during the billed peak monthly demand. Therefore, similar analysis was conducted on the overall demand reduction by superimposing anticipated PV output with estimated load profile shape categorized like Daniels to determine estimated demand reduction.

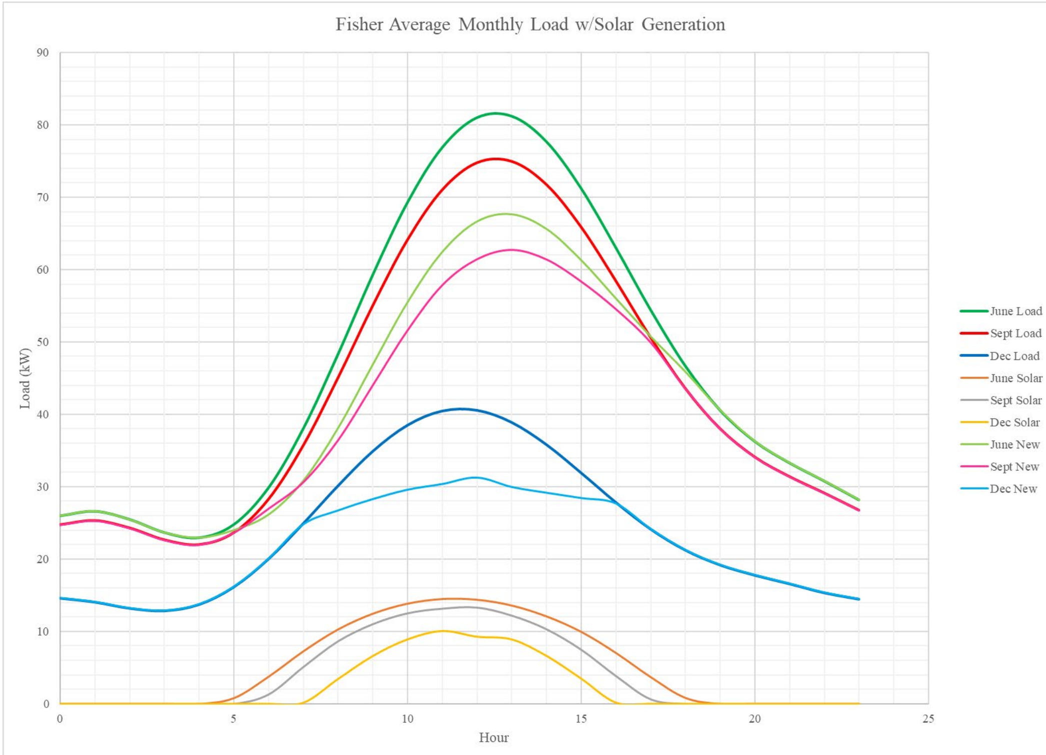

Figure 19: Fisher average monthly load with applied solar generation

Based on the load peak not occurring simultaneously with maximum solar output, the new anticipated peak billed demand is roughly 68 kW. Assuming this will be the new monthly billed demand peak, the savings are 10 kW. This results in a demand reduction ratio of roughly 71.52%. The same process was conducted for September and December months. The results can be found below.

Table 15: Fisher solar characteristics and demand reduction

Fisher		Load Shape	Daniels	Module DC Capacity (kW)	19.8	Performance Factor	73.1%
	Peak Demand (kW)	Minimum Demand (kW)	Load-Offset (Hours)	Peak Load with Solar (kW)	Demand Savings (kW)	Load-Offset Ratio	Total Derate
June	78	25	0	67.648	10.352	71.52%	71.52%
September	72	24	0	62.755	9.245	69.60%	63.87%
December	39	14	-1	31.238	7.762	76.98%	53.63%

2.3 Determining Economic Viability of Solar Installations

To analyze the economic benefit of each rooftop solar project. The annual electricity costs were compiled then compared to the cost analysis with the solar instillation.

2.3.1 Discussion on energy rates

The energy produced by the solar project for each building is purchased at $84.50 per MWh or $0.0845 per kWh. The energy cost per Xcel Energy's tariff is approximately $0.03542 per kWh depending on rider charges and quarterly changes. The energy cost for the solar output is thus double the cost of purchasing it from Xcel. However, the tariff also charges for demand where the rate is dependent on summer/wintertime timing and also rider charges and quarterly changes. The summertime demand charge is roughly $22.95 per kW and occurs June thru September. The wintertime demand charge is roughly $18.75 and occurs October thru May. In order for the rooftop solar to be economically beneficial, the demand savings must be greater than the increase in usage cost.

First, each PV eligible building's electric service bill of 2018 was compiled to determine monthly cost based on demand and usage. Next, the estimated daily load profile determined by the buildings analyzed with real-time eGauge meters was superimposed with the estimated solar output for each month.

2.3.2 Seeley J. Mudd

Table 16: Mudd Monthly Usage and Demand with Respective Costs

Seeley J Mudd Hall								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	147,262	227	$5,216.02	$4,256.25	$10,052.29	$0.035420	$18.75	$0.06826
Feb-18	151,306	274	$5,359.26	$5,137.50	$10,197.10	$0.035420	$18.75	$0.06739
Mar-18	147,764	261	$5,233.80	$4,893.75	$9,856.36	$0.035420	$18.75	$0.06670
Apr-18	136,586	266	$4,837.88	$4,987.50	$9,789.39	$0.035420	$18.75	$0.07167
May-18	147,488	268	$5,224.02	$5,025.00	$10,427.61	$0.035420	$18.75	$0.07070
Jun-18	160,216	291	$5,674.85	$6,678.45	$12,062.63	$0.035420	$22.95	$0.07529
Jul-18	152,163	307	$5,389.61	$7,045.65	$11,796.09	$0.035420	$22.95	$0.07752
Aug-18	149,297	273	$5,288.10	$6,265.35	$10,867.39	$0.035420	$22.95	$0.07279
Sep-18	147,227	281	$5,214.78	$6,448.95	$11,061.44	$0.035420	$22.95	$0.07513
Oct-18	152,122	284	$5,388.16	$5,325.00	$11,067.02	$0.035420	$18.75	$0.07275
Nov-18	151,262	269	$5,357.70	$5,043.75	$10,889.04	$0.035420	$18.75	$0.07199
Dec-18	167,998	278	$5,950.49	$5,212.50	$11,835.31	$0.035420	$18.75	$0.07045
Total	1,810,691	307	$64,134.68	$66,319.65	$129,901.67			$0.07174

Seeley J. Mudd had an annual average electricity cost of $0.07174 per kWh. Though this is lower than the cost of the solar energy, the demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 17: Mudd Monthly Costs with Applied Solar

Seeley J Mudd Hall with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	7,926	28.16%	20.75	52.54%	38.71	139,336	188	$669.72	$4,935.29	$5,605.01	$388.99	$3,530.47	$725.78	$336.78
Feb-18	8,586	30.51%	22.48	67.53%	49.75	142,720	224	$725.53	$5,055.14	$5,780.67	$421.41	$4,204.64	$932.86	$511.45
Mar-18	12,549	44.58%	32.85	67.53%	49.75	135,215	211	$1,060.40	$4,789.31	$5,849.71	$615.91	$3,960.89	$932.86	$316.96
Apr-18	11,889	42.24%	31.12	67.53%	49.75	124,697	216	$1,004.59	$4,416.78	$5,421.37	$583.49	$4,054.64	$932.86	$349.37
May-18	14,993	53.27%	39.25	84.16%	62.01	132,495	206	$1,266.89	$4,692.98	$5,959.87	$735.85	$3,862.33	$1,162.67	$426.83
Jun-18	15,191	44.09%	32.49	84.16%	62.01	145,025	229	$1,283.64	$5,136.79	$6,420.42	$745.57	$5,255.34	$1,423.11	$677.54
Jul-18	14,530	42.18%	31.07	84.16%	62.01	137,633	245	$1,227.83	$4,874.94	$6,102.77	$713.16	$5,622.54	$1,423.11	$709.96
Aug-18	13,540	39.30%	28.96	67.53%	49.75	135,757	223	$1,144.11	$4,808.52	$5,952.63	$664.53	$5,123.52	$1,141.83	$477.29
Sep-18	11,889	34.51%	25.42	67.53%	49.75	135,338	231	$1,004.59	$4,793.69	$5,798.27	$583.49	$5,307.12	$1,141.83	$558.33
Oct-18	9,907	35.20%	25.93	67.53%	49.75	142,215	234	$837.15	$5,037.25	$5,874.40	$486.24	$4,392.14	$932.86	$446.62
Nov-18	6,737	23.93%	17.63	52.54%	38.71	144,525	230	$569.27	$5,119.08	$5,688.35	$330.65	$4,317.97	$725.78	$395.13
Dec-18	6,473	23.00%	16.94	52.54%	38.71	161,525	239	$546.94	$5,721.23	$6,268.17	$317.68	$4,486.72	$725.78	$408.10
Total	134,209		39		62	1,676,482	245	$11,340.65	$59,381.00	$70,721.65	$6,586.97	$54,118.31	$12,201.34	$5,614.37

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 32.49 kW to save enough money to offset the $745.57 increase in usage charges for the month of June. Due to the primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $5,614.37.

2.3.3 Ritchie Athletic Complex

Table 18: Ritchie Monthly Usage and Demand with Respective Costs

Ritchie								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	634,606	1,511	$22,477.74	$28,331.25	$51,891.66	$0.035420	$18.75	$0.08177
Feb-18	658,409	1,508	$23,320.85	$28,275.00	$52,646.22	$0.035420	$18.75	$0.07996
Mar-18	710,315	1,528	$25,159.36	$28,650.00	$55,188.91	$0.035420	$18.75	$0.07770
Apr-18	633,271	1,293	$22,430.46	$24,243.75	$48,695.61	$0.035420	$18.75	$0.07690
May-18	705,489	1,499	$24,988.42	$28,106.25	$56,182.82	$0.035420	$18.75	$0.07964
Jun-18	813,938	1,408	$28,829.68	$32,313.60	$61,401.22	$0.035420	$22.95	$0.07544
Jul-18	719,060	1,689	$25,469.11	$38,762.55	$62,721.96	$0.035420	$22.95	$0.08723
Aug-18	694,949	1,577	$24,615.09	$36,192.15	$59,280.56	$0.035420	$22.95	$0.08530
Sep-18	678,499	1,609	$24,032.43	$36,926.55	$59,477.25	$0.035420	$22.95	$0.08766
Oct-18	669,384	1,452	$23,709.58	$27,225.00	$56,002.27	$0.035420	$18.75	$0.08366
Nov-18	622,762	1,426	$22,058.23	$26,737.50	$53,536.35	$0.035420	$18.75	$0.08597
Dec-18	630,545	1,079	$22,333.90	$20,231.25	$47,240.22	$0.035420	$18.75	$0.07492
Total	8,171,227	1,689	$289,424.86	$355,994.85	$664,265.05			$0.08129

The Ritchie Athletic Complex had an annual average electricity cost of $0.08129 per kWh. The demand reduction savings do not exceed the increase in usage costs resulting in an anticipated increase in electricity costs.

Table 19: Ritchie Monthly Costs with Applied Solar

Ritchie with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	53,020	27.90%	138.78	6.27%	31.20	581,586	1,480	$4,480.18	$20,599.78	$25,079.96	$2,602.21	$27,746.26	$584.99	-$2,017.22
Feb-18	55,671	29.29%	145.72	20.46%	101.79	602,738	1,406	$4,704.19	$21,348.99	$26,053.17	$2,732.32	$26,366.39	$1,908.61	-$823.71
Mar-18	79,530	41.85%	208.18	20.46%	101.79	630,785	1,426	$6,720.27	$22,342.41	$29,062.68	$3,903.32	$26,741.39	$1,908.61	-$1,994.71
Apr-18	70,693	37.20%	185.05	20.46%	101.79	562,578	1,191	$5,973.57	$19,926.51	$25,900.08	$3,469.62	$22,335.14	$1,908.61	-$1,561.01
May-18	94,552	49.75%	247.50	37.06%	184.36	610,937	1,315	$7,989.65	$21,639.39	$29,629.04	$4,640.61	$24,649.49	$3,456.76	-$1,183.85
Jun-18	97,203	41.78%	207.87	37.06%	184.36	716,735	1,224	$8,213.66	$25,386.75	$33,600.41	$4,770.73	$28,082.52	$4,231.08	-$539.65
Jul-18	95,436	41.02%	204.10	37.06%	184.36	623,624	1,505	$8,064.32	$22,088.77	$30,153.09	$4,683.99	$34,531.47	$4,231.08	-$452.91
Aug-18	88,366	37.99%	188.98	20.46%	101.79	606,583	1,475	$7,466.96	$21,485.16	$28,952.12	$4,337.02	$33,856.01	$2,336.14	-$2,000.88
Sep-18	83,948	36.09%	179.53	20.46%	101.79	594,551	1,507	$7,093.61	$21,058.99	$28,152.61	$4,120.17	$34,590.41	$2,336.14	-$1,784.03
Oct-18	70,693	37.20%	185.05	20.46%	101.79	598,691	1,350	$5,973.57	$21,205.63	$27,179.20	$3,469.62	$25,316.39	$1,908.61	-$1,561.01
Nov-18	50,369	26.50%	131.85	6.27%	31.20	572,393	1,395	$4,256.17	$20,274.17	$24,530.33	$2,472.10	$26,152.51	$584.99	-$1,887.11
Dec-18	44,183	23.25%	115.65	6.27%	31.20	586,362	1,048	$3,733.48	$20,768.93	$24,502.42	$2,168.51	$19,646.26	$584.99	-$1,583.52
Total	883,664		247		184	7,287,563	1,507	$74,669.61	$258,125.48	$332,795.09	$43,370.23	$330,014.22	$25,980.63	-$17,389.60

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 207.87 kW to save enough money to offset the $4,770.73 increase in usage charges for the month of June. Due to the anticipated relatively flat load profile, the solar is less effective in reducing demand resulting in a total annual net increase of $17,389.60.

2.3.4 Anderson Academic Commons

Table 20: AAC Monthly Usage and Demand with Respective Costs

Anderson Academic Commons								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	73,468	200	$2,602.24	$3,750.00	$6,539.65	$0.035420	$18.75	$0.08901
Feb-18	74,365	194	$2,634.01	$3,637.50	$6,450.64	$0.035420	$18.75	$0.08674
Mar-18	77,631	192	$2,749.69	$3,600.00	$6,562.70	$0.035420	$18.75	$0.08454
Apr-18	75,941	191	$2,689.83	$3,581.25	$6,586.45	$0.035420	$18.75	$0.08673
May-18	90,925	271	$3,220.56	$5,081.25	$8,861.66	$0.035420	$18.75	$0.09746
Jun-18	93,296	213	$3,304.54	$4,888.35	$8,270.39	$0.035420	$22.95	$0.08865
Jul-18	86,180	210	$3,052.50	$4,819.50	$7,724.35	$0.035420	$22.95	$0.08963
Aug-18	86,001	202	$3,046.16	$4,635.90	$7,525.78	$0.035420	$22.95	$0.08751
Sep-18	81,470	216	$2,885.67	$4,957.20	$7,689.85	$0.035420	$22.95	$0.09439
Oct-18	76,426	193	$2,707.01	$3,618.75	$6,943.53	$0.035420	$18.75	$0.09085
Nov-18	72,719	188	$2,575.71	$3,525.00	$6,691.54	$0.035420	$18.75	$0.09202
Dec-18	72,234	175	$2,558.53	$3,281.25	$6,421.44	$0.035420	$18.75	$0.08890
Total	960,656	271	$34,026.44	$49,375.95	$86,267.98			$0.08980

Anderson Academic Commons had an annual average electricity cost of $0.0898 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 21: AAC Monthly Costs with Applied Solar

Anderson Academic Commons with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	14,384	25.46%	37.65	35.03%	51.80	59,084	148	$1,215.49	$2,092.74	$3,308.22	$705.99	$2,778.80	$971.20	$265.21
Feb-18	15,692	27.78%	41.08	47.90%	70.83	58,673	123	$1,325.98	$2,078.19	$3,404.18	$770.17	$2,309.42	$1,328.08	$557.91
Mar-18	25,500	45.14%	66.75	47.90%	70.83	52,131	121	$2,154.72	$1,846.49	$4,001.21	$1,251.52	$2,271.92	$1,328.08	$76.56
Apr-18	23,538	41.67%	61.61	47.90%	70.83	52,403	120	$1,988.98	$1,856.11	$3,845.08	$1,155.25	$2,253.17	$1,328.08	$172.83
May-18	30,077	53.24%	78.73	63.55%	93.97	60,848	177	$2,541.47	$2,155.25	$4,696.72	$1,476.16	$3,319.29	$1,761.96	$285.81
Jun-18	32,038	46.34%	68.52	63.55%	93.97	61,258	119	$2,707.22	$2,169.76	$4,876.97	$1,572.43	$2,731.71	$2,156.64	$584.22
Jul-18	29,684	42.93%	63.48	63.55%	93.97	56,496	116	$2,508.32	$2,001.08	$4,509.40	$1,456.90	$2,662.86	$2,156.64	$699.74
Aug-18	27,461	39.72%	58.73	47.90%	70.83	58,540	131	$2,320.47	$2,073.48	$4,393.95	$1,347.80	$3,010.33	$1,625.57	$277.78
Sep-18	24,846	35.93%	53.13	47.90%	70.83	56,624	145	$2,099.47	$2,005.63	$4,105.10	$1,219.43	$3,331.63	$1,625.57	$406.14
Oct-18	19,615	34.72%	51.34	47.90%	70.83	56,811	122	$1,657.48	$2,012.24	$3,669.72	$962.71	$2,290.67	$1,328.08	$365.37
Nov-18	13,731	24.31%	35.94	35.03%	51.80	58,988	136	$1,160.24	$2,089.37	$3,249.60	$673.90	$2,553.80	$971.20	$297.30
Dec-18	12,423	21.99%	32.52	35.03%	51.80	59,811	123	$1,049.74	$2,118.51	$3,168.25	$609.72	$2,310.05	$971.20	$361.48
Total	268,989		79		94	691,667	177	$22,729.57	$24,498.84	$47,228.42	$13,201.98	$31,823.62	$17,552.33	$4,350.35

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 68.52 kW to save enough money to offset the $1,572.43 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $4,350.35.

2.3.5 Driscoll South

Table 22: Driscoll Monthly Usage and Demand with Respective Costs

Driscoll South								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	32,640	99	$1,156.11	$1,856.25	$3,127.89	$0.035420	$18.75	$0.09583
Feb-18	35,680	102	$1,263.79	$1,912.50	$3,291.74	$0.035420	$18.75	$0.09226
Mar-18	36,160	104	$1,280.79	$1,950.00	$3,380.59	$0.035420	$18.75	$0.09349
Apr-18	38,880	102	$1,377.13	$1,912.50	$3,468.19	$0.035420	$18.75	$0.08920
May-18	37,440	106	$1,326.12	$1,987.50	$3,647.16	$0.035420	$18.75	$0.09741
Jun-18	46,080	109	$1,632.15	$2,501.55	$4,153.15	$0.035420	$22.95	$0.09013
Jul-18	41,600	107	$1,473.47	$2,455.65	$3,876.70	$0.035420	$22.95	$0.09319
~~Aug-18~~	~~40,640~~	~~1,144~~	~~$1,439.47~~	~~$26,254.80~~	~~$27,479.60~~	~~$0.035420~~	~~$22.95~~	~~$0.67617~~
Sep-18	46,720	115	$1,654.82	$2,639.25	$4,216.56	$0.035420	$22.95	$0.09025
Oct-18	37,760	102	$1,337.46	$1,912.50	$3,574.76	$0.035420	$18.75	$0.09467
Nov-18	38,720	96	$1,371.46	$1,800.00	$3,500.95	$0.035420	$18.75	$0.09042
Dec-18	38,400	99	$1,360.13	$1,856.25	$3,542.67	$0.035420	$18.75	$0.09226
Total	476,800	115	$16,888.26	$25,423.20	$43,996.92			$0.09228

Driscoll South had an annual average electricity cost of $0.09228 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 23: Driscoll Monthly Costs with Applied Solar

Driscoll South with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	9,453	26.98%	24.74	32.05%	29.39	23,187	70	$798.78	$821.28	$1,620.06	$463.95	$1,305.13	$551.12	$87.17
Feb-18	9,926	28.33%	25.98	41.76%	38.30	25,754	64	$838.72	$912.22	$1,750.94	$487.15	$1,194.44	$718.06	$230.91
Mar-18	15,125	43.17%	39.59	41.76%	38.30	21,035	66	$1,278.04	$745.07	$2,023.11	$742.32	$1,231.94	$718.06	-$24.26
Apr-18	14,179	40.47%	37.12	41.76%	38.30	24,701	64	$1,198.16	$874.89	$2,073.06	$695.93	$1,194.44	$718.06	$22.13
May-18	18,433	52.62%	48.25	53.44%	49.01	19,007	57	$1,557.61	$673.22	$2,230.83	$904.71	$1,068.59	$918.91	$14.21
Jun-18	19,379	45.19%	41.44	53.44%	49.01	26,701	60	$1,637.49	$945.76	$2,583.26	$951.10	$1,376.80	$1,124.75	$173.65
Jul-18	18,906	44.09%	40.43	53.44%	49.01	22,694	58	$1,597.55	$803.82	$2,401.38	$927.90	$1,330.90	$1,124.75	$196.85
Aug-18	18,717	43.65%	40.03	41.76%	38.30	21,923	77	$1,581.58	$776.52	$2,358.09	$918.63	$1,760.34	$878.91	-$39.72
Sep-18	15,125	35.27%	32.35	41.76%	38.30	31,595	77	$1,278.04	$1,119.10	$2,397.15	$742.32	$1,760.34	$878.91	$136.59
Oct-18	11,816	33.73%	30.93	41.76%	38.30	25,944	64	$998.47	$918.93	$1,917.40	$579.94	$1,194.44	$718.06	$138.12
Nov-18	8,508	24.28%	22.27	32.05%	29.39	30,212	67	$718.90	$1,070.12	$1,789.02	$417.56	$1,248.88	$551.12	$133.56
Dec-18	7,562	21.59%	19.80	32.05%	29.39	30,838	70	$639.02	$1,092.27	$1,731.29	$371.16	$1,305.13	$551.12	$179.96
Total	167,129		48		49	303,591	77	$14,122.37	$10,753.21	$24,875.58	$8,202.67	$15,971.36	$9,451.84	$1,249.17

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 41.44 kW to save enough money to offset the $951.10 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand for most of the year resulting in a total annual net savings of approximately $1,249.17.

2.3.6 Shwayder Art

Table 24: Shwayder Monthly Usage and Demand with Respective Costs

Shwayder Art Building								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	7,887	29	$279.36	$536.51	$683.65	$0.035420	$18.75	$0.08668
Feb-18	8,611	29	$305.01	$536.51	$761.16	$0.035420	$18.75	$0.08839
Mar-18	9,426	29	$333.87	$536.51	$799.52	$0.035420	$18.75	$0.08482
Apr-18	11,483	51	$406.73	$965.08	$1,441.93	$0.035420	$18.75	$0.12557
May-18	16,658	55	$590.02	$1,033.48	$1,730.72	$0.035420	$18.75	$0.10390
Jun-18	18,118	53	$641.75	$1,223.12	$1,879.16	$0.035420	$22.95	$0.10372
Jul-18	17,532	53	$620.97	$1,219.20	$1,808.85	$0.035420	$22.95	$0.10318
Aug-18	15,157	47	$536.86	$1,087.07	$1,596.24	$0.035420	$22.95	$0.10531
Sep-18	15,012	55	$531.71	$1,264.98	$1,760.33	$0.035420	$22.95	$0.11726
Oct-18	10,737	46	$380.30	$865.69	$1,335.85	$0.035420	$18.75	$0.12442
Nov-18	8,267	32	$292.82	$608.12	$973.73	$0.035420	$18.75	$0.11778
Dec-18	8,119	28	$287.57	$517.28	$721.11	$0.035420	$18.75	$0.08882
Total	147,006	55	$5,206.97	$10,393.55	$15,492.25			$0.10538

Shwayder Art had an annual average electricity cost of $0.10538 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 25: Shwayder Monthly Costs with Applied Solar

Shwayder Art Building with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	4,454	27.04%	11.66	19.72%	8.51	3,433	20	$376.40	$121.59	$497.98	$218.62	$377.01	$159.50	-$59.12
Feb-18	4,961	30.11%	12.98	42.39%	18.28	3,651	10	$419.17	$129.31	$548.48	$243.46	$193.71	$342.80	$99.34
Mar-18	7,491	45.47%	19.61	42.39%	18.28	1,934	10	$633.03	$68.52	$701.55	$367.68	$193.71	$342.80	-$24.88
Apr-18	6,985	42.40%	18.28	42.39%	18.28	4,498	33	$590.26	$159.31	$749.57	$342.84	$622.28	$342.80	-$0.03
May-18	8,504	51.61%	22.26	55.06%	23.75	8,154	31	$718.57	$288.81	$1,007.39	$417.37	$588.24	$445.24	$27.87
Jun-18	9,314	46.18%	19.92	55.06%	23.75	8,805	30	$787.01	$311.86	$1,098.87	$457.12	$678.15	$544.97	$87.85
Jul-18	8,656	42.92%	18.51	55.06%	23.75	8,876	29	$731.41	$314.39	$1,045.79	$424.82	$674.22	$544.97	$120.15
Aug-18	7,998	39.66%	17.10	42.39%	18.28	7,159	29	$675.80	$253.58	$929.38	$392.52	$667.48	$419.59	$27.07
Sep-18	6,884	34.14%	14.72	42.39%	18.28	8,128	37	$581.70	$287.88	$869.58	$337.87	$845.39	$419.59	$81.72
Oct-18	5,872	35.64%	15.37	42.39%	18.28	4,865	28	$496.16	$172.32	$668.48	$288.18	$522.88	$342.80	$54.62
Nov-18	3,847	23.35%	10.07	19.72%	8.51	4,420	24	$325.07	$156.56	$481.63	$188.81	$448.62	$159.50	-$29.31
Dec-18	3,543	21.51%	9.27	19.72%	8.51	4,576	19	$299.41	$162.07	$461.47	$173.90	$357.78	$159.50	-$14.41
Total	78,509		22		24	68,498	37	$6,633.98	$2,426.19	$9,060.17	$3,853.20	$6,169.47	$4,224.08	$370.88

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 19.92 kW to save enough money to offset the $457.12 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile during summertime months, the solar is effective in reducing demand enough to offset flatter anticipated wintertime load resulting in a total annual net savings of approximately $370.88.

2.3.7 Boettcher West

Table 26: Boettcher Monthly Usage and Demand with Respective Costs

Boettcher West								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	38,480	96	$1,362.96	$1,800.00	$3,304.02	$0.035420	$18.75	$0.08586
Feb-18	40,400	102	$1,430.97	$1,912.50	$3,429.56	$0.035420	$18.75	$0.08489
Mar-18	39,040	111	$1,382.80	$2,081.25	$3,657.51	$0.035420	$18.75	$0.09369
Apr-18	43,360	126	$1,535.81	$2,362.50	$4,142.78	$0.035420	$18.75	$0.09554
May-18	40,000	124	$1,416.80	$2,325.00	$4,158.75	$0.035420	$18.75	$0.10397
Jun-18	43,920	130	$1,555.65	$2,983.50	$4,603.02	$0.035420	$22.95	$0.10480
Jul-18	40,320	125	$1,428.13	$2,868.75	$4,289.37	$0.035420	$22.95	$0.10638
Aug-18	37,040	126	$1,311.96	$2,891.70	$4,203.85	$0.035420	$22.95	$0.11349
Sep-18	41,920	125	$1,484.81	$2,868.75	$4,292.66	$0.035420	$22.95	$0.10240
Oct-18	39,840	99	$1,411.13	$1,856.25	$3,640.11	$0.035420	$18.75	$0.09137
Nov-18	43,040	91	$1,524.48	$1,706.25	$3,622.83	$0.035420	$18.75	$0.08417
Dec-18	44,240	96	$1,566.98	$1,800.00	$3,767.05	$0.035420	$18.75	$0.08515
Total	491,600	130	$17,412.47	$27,456.45	$47,111.51			$0.09583

Boettcher West had an annual average electricity cost of $0.09583 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 27: Boettcher Monthly Costs with Applied Solar

Boettcher West with Solar															
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipate d Demand Savings	Net Savings
Jan-18	13,098	26.66%	34.29	22.51%	28.95	25,382	67	$1,106.81	$899.02	$2,005.83	$642.87	$1,257.21	$542.79	-$100.08
Feb-18	14,146	28.79%	37.03	42.89%	55.16	26,254	47	$1,195.35	$929.91	$2,125.26	$694.30	$878.30	$1,034.20	$339.91
Mar-18	22,529	45.85%	58.97	42.89%	55.16	16,511	56	$1,903.71	$584.81	$2,488.53	$1,105.73	$1,047.05	$1,034.20	-$71.53
Apr-18	20,433	41.59%	53.49	42.89%	55.16	22,927	71	$1,726.62	$812.06	$2,538.68	$1,002.87	$1,328.30	$1,034.20	$31.33
May-18	25,673	52.25%	67.20	54.09%	69.57	14,327	54	$2,169.35	$507.47	$2,676.82	$1,260.02	$1,020.50	$1,304.50	$44.48
Jun-18	27,140	45.13%	58.04	54.09%	69.57	16,780	60	$2,293.31	$594.36	$2,887.67	$1,332.02	$1,386.80	$1,596.70	$264.68
Jul-18	25,673	42.69%	54.90	54.09%	69.57	14,647	55	$2,169.35	$518.81	$2,688.15	$1,260.02	$1,272.05	$1,596.70	$336.69
Aug-18	23,577	39.20%	50.42	42.89%	55.16	13,463	71	$1,992.26	$476.86	$2,469.12	$1,157.16	$1,625.84	$1,265.86	$108.70
Sep-18	21,481	35.72%	45.94	42.89%	55.16	20,439	70	$1,815.17	$723.94	$2,539.11	$1,054.30	$1,602.89	$1,265.86	$211.56
Oct-18	17,290	35.19%	45.26	42.89%	55.16	22,550	44	$1,460.99	$798.73	$2,259.72	$848.58	$822.05	$1,034.20	$185.62
Nov-18	12,050	24.53%	31.54	22.51%	28.95	30,990	62	$1,018.27	$1,097.65	$2,115.91	$591.44	$1,163.46	$542.79	-$48.65
Dec-18	11,003	22.39%	28.80	22.51%	28.95	33,237	67	$929.72	$1,177.27	$2,106.99	$540.01	$1,257.21	$542.79	$2.78
Total	234,094		67		70	257,506	71	$19,780.91	$9,120.88	$28,901.78	$11,489.31	$14,661.64	$12,794.81	$1,305.50

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 58.04 kW to save enough money to offset the $1,332.02 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand for most of the year resulting in a total annual net savings of approximately $1,305.50.

2.3.8 Sturm Hall

Table 28: Sturm Monthly Usage and Demand with Respective Costs

Sturm Hall								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	59,360	156	$2,102.53	$2,925.00	$5,179.18	$0.035420	$18.75	$0.08725
Feb-18	65,760	152	$2,329.22	$2,850.00	$5,318.34	$0.035420	$18.75	$0.08088
Mar-18	64,960	149	$2,300.88	$2,793.75	$5,296.33	$0.035420	$18.75	$0.08153
Apr-18	58,880	157	$2,085.53	$2,943.75	$5,282.11	$0.035420	$18.75	$0.08971
May-18	58,880	146	$2,085.53	$2,737.50	$5,274.18	$0.035420	$18.75	$0.08958
Jun-18	54,240	151	$1,921.18	$3,465.45	$5,411.25	$0.035420	$22.95	$0.09976
Jul-18	51,840	119	$1,836.17	$2,731.05	$4,488.26	$0.035420	$22.95	$0.08658
Aug-18	52,160	143	$1,847.51	$3,281.85	$5,055.13	$0.035420	$22.95	$0.09692
Sep-18	64,800	146	$2,295.22	$3,350.70	$5,543.26	$0.035420	$22.95	$0.08554
Oct-18	60,160	151	$2,130.87	$2,831.25	$5,455.51	$0.035420	$18.75	$0.09068
Nov-18	64,160	139	$2,272.55	$2,606.25	$5,395.78	$0.035420	$18.75	$0.08410
Dec-18	57,600	145	$2,040.19	$2,718.75	$5,230.09	$0.035420	$18.75	$0.09080
Total	712,800	157	$25,247.38	$35,235.30	$62,929.42			$0.08828

Sturm Hall had an annual average electricity cost of $0.08828 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 29: Sturm Monthly Costs with Applied Solar

Sturm Hall with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipate d Demand Savings	Net Savings
Jan-18	9,924	27.47%	25.98	45.06%	42.60	49,436	113	$838.59	$1,751.02	$2,589.61	$487.08	$2,126.19	$798.81	$311.73
Feb-18	10,397	28.78%	27.21	50.38%	47.63	55,363	104	$878.52	$1,960.97	$2,839.49	$510.27	$1,956.88	$893.12	$382.85
Mar-18	15,595	43.17%	40.82	50.38%	47.63	49,365	101	$1,317.79	$1,748.50	$3,066.29	$765.41	$1,900.63	$893.12	$127.71
Apr-18	15,123	41.86%	39.58	50.38%	47.63	43,757	109	$1,277.85	$1,549.89	$2,827.74	$742.21	$2,050.63	$893.12	$150.91
May-18	19,092	52.85%	49.98	69.83%	66.03	39,788	80	$1,613.29	$1,409.28	$3,022.58	$937.05	$1,499.46	$1,238.04	$300.99
Jun-18	19,848	44.89%	42.45	69.83%	66.03	34,392	85	$1,677.18	$1,218.15	$2,895.34	$974.16	$1,950.09	$1,515.36	$541.20
Jul-18	18,903	42.75%	40.43	69.83%	66.03	32,937	53	$1,597.32	$1,166.62	$2,763.94	$927.77	$1,215.69	$1,515.36	$587.59
Aug-18	17,958	40.62%	38.40	50.38%	47.63	34,202	95	$1,517.45	$1,211.43	$2,728.89	$881.38	$2,188.67	$1,093.18	$211.80
Sep-18	15,595	35.27%	33.35	50.38%	47.63	49,205	98	$1,317.79	$1,742.84	$3,060.62	$765.41	$2,257.52	$1,093.18	$327.77
Oct-18	12,760	35.32%	33.40	50.38%	47.63	47,400	103	$1,078.19	$1,678.92	$2,757.11	$626.24	$1,938.13	$893.12	$266.88
Nov-18	8,979	24.86%	23.50	45.06%	42.60	55,181	96	$758.73	$1,954.51	$2,713.24	$440.69	$1,807.44	$798.81	$358.12
Dec-18	8,034	22.24%	21.03	45.06%	42.60	49,566	102	$678.86	$1,755.63	$2,434.49	$394.30	$1,919.94	$798.81	$404.51
Total	172,208		50		66	540,592	113	$14,551.57	$19,147.77	$33,699.34	$8,451.96	$22,811.27	$12,424.03	$3,972.06

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 42.45 kW to save enough money to offset the $974.16 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $3,972.06.

2.3.9 Knudson Hall

Table 30: Knudson Monthly Usage and Demand with Respective Costs

Knudson Hall								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	7,600	46	$269.19	$862.50	$863.18	$0.035420	$18.75	$0.11358
Feb-18	8,320	46	$294.69	$862.50	$901.86	$0.035420	$18.75	$0.10840
Mar-18	8,480	87	$300.36	$1,631.25	$2,070.42	$0.035420	$18.75	$0.24415
Apr-18	8,480	86	$300.36	$1,612.50	$2,048.68	$0.035420	$18.75	$0.24159
May-18	9,920	96	$351.37	$1,800.00	$2,439.72	$0.035420	$18.75	$0.24594
Jun-18	11,760	48	$416.54	$1,101.60	$1,520.67	$0.035420	$22.95	$0.12931
Jul-18	10,400	48	$368.37	$1,101.60	$1,472.78	$0.035420	$22.95	$0.14161
Aug-18	9,120	82	$323.03	$1,881.90	$2,239.81	$0.035420	$22.95	$0.24559
Sep-18	8,320	55	$294.69	$1,262.25	$1,524.93	$0.035420	$22.95	$0.18328
Oct-18	5,680	48	$201.19	$900.00	$774.30	$0.035420	$18.75	$0.13632
Nov-18	6,560	48	$232.36	$900.00	$811.47	$0.035420	$18.75	$0.12370
Dec-18	6,720	48	$238.02	$900.00	$817.92	$0.035420	$18.75	$0.12171
Total	101,360	96	$3,590.17	$14,816.10	$17,485.74			$0.17251

Knudson Hall had an annual average electricity cost of $0.172151 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 31: Knudson Monthly Costs with Applied Solar

Knudson Hall with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	2,222	26.20%	5.82	30.58%	6.79	5,378	39	$187.78	$190.48	$378.26	$109.07	$735.19	$127.31	$18.25
Feb-18	2,400	28.30%	6.28	46.31%	10.28	5,920	36	$202.80	$209.69	$412.49	$117.79	$669.70	$192.80	$75.01
Mar-18	3,689	43.49%	9.66	46.31%	10.28	4,791	77	$311.71	$169.70	$481.41	$181.05	$1,438.45	$192.80	$11.75
Apr-18	3,493	41.19%	9.14	46.31%	10.28	4,987	76	$295.19	$176.63	$471.81	$171.45	$1,419.70	$192.80	$21.35
May-18	4,444	52.40%	11.63	44.34%	9.84	5,476	86	$375.56	$193.94	$569.50	$218.13	$1,615.43	$184.57	-$33.57
Jun-18	4,889	47.09%	10.46	44.34%	9.84	6,871	38	$413.11	$243.37	$656.49	$239.95	$875.69	$225.91	-$14.04
Jul-18	4,533	43.67%	9.69	44.34%	9.84	5,867	38	$383.07	$207.80	$590.86	$222.50	$875.69	$225.91	$3.41
Aug-18	4,000	38.53%	8.55	46.31%	10.28	5,120	72	$338.00	$181.35	$519.35	$196.32	$1,645.91	$235.99	$39.67
Sep-18	3,644	35.10%	7.79	46.31%	10.28	4,676	45	$307.96	$165.61	$473.56	$178.87	$1,026.26	$235.99	$57.12
Oct-18	3,111	36.68%	8.14	46.31%	10.28	2,569	38	$262.89	$90.99	$353.88	$152.69	$707.20	$192.80	$40.11
Nov-18	2,044	24.10%	5.35	30.58%	6.79	4,516	41	$172.76	$159.94	$332.70	$100.34	$772.69	$127.31	$26.97
Dec-18	1,911	22.53%	5.00	30.58%	6.79	4,809	41	$161.49	$170.33	$331.82	$93.80	$772.69	$127.31	$33.52
Total	40,382		12		10	60,978	86	$3,412.30	$2,159.83	$5,572.13	$1,981.96	$12,554.58	$2,261.52	$279.56

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 10.46 kW to save enough money to offset the $239.95 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand for most of the year resulting in a total annual net savings of approximately $279.56.

2.3.10 Frontier Hall

Table 32: Frontier Monthly Usage and Demand with Respective Costs

Frontier Hall								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	27,040	83	$957.76	$1,556.25	$2,617.11	$0.035420	$18.75	$0.09679
Feb-18	28,000	80	$991.76	$1,500.00	$2,590.08	$0.035420	$18.75	$0.09250
Mar-18	29,440	81	$1,042.76	$1,518.75	$2,676.46	$0.035420	$18.75	$0.09091
Apr-18	29,280	81	$1,037.10	$1,518.75	$2,707.42	$0.035420	$18.75	$0.09247
May-18	36,000	82	$1,275.12	$1,537.50	$3,029.86	$0.035420	$18.75	$0.08416
Jun-18	36,160	115	$1,280.79	$2,639.25	$3,977.13	$0.035420	$22.95	$0.10999
Jul-18	35,360	108	$1,252.45	$2,478.60	$3,698.66	$0.035420	$22.95	$0.10460
Aug-18	31,520	99	$1,116.44	$2,272.05	$3,361.59	$0.035420	$22.95	$0.10665
Sep-18	31,520	92	$1,116.44	$2,111.40	$3,185.11	$0.035420	$22.95	$0.10105
Oct-18	29,920	82	$1,059.77	$1,537.50	$2,862.21	$0.035420	$18.75	$0.09566
Nov-18	26,240	74	$929.42	$1,387.50	$2,554.17	$0.035420	$18.75	$0.09734
Dec-18	27,520	73	$974.76	$1,368.75	$2,588.36	$0.035420	$18.75	$0.09405
Total	368,000	115	$13,034.56	$21,426.30	$35,848.16			$0.09741

Frontier Hall had an annual average electricity cost of $0.09741 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 33: Frontier Monthly Costs with Applied Solar

Frontier Hall with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	3,316	18.97%	8.68	46.84%	21.43	23,724	62	$280.23	$840.29	$1,120.52	$162.76	$1,154.48	$401.77	$239.00
Feb-18	3,954	22.62%	10.35	64.24%	29.39	24,046	51	$334.12	$851.71	$1,185.83	$194.07	$948.92	$551.08	$357.02
Mar-18	6,505	37.22%	17.03	64.24%	29.39	22,935	52	$549.68	$812.35	$1,362.03	$319.27	$967.67	$551.08	$231.81
Apr-18	6,505	37.22%	17.03	64.24%	29.39	22,775	52	$549.68	$806.69	$1,356.37	$319.27	$967.67	$551.08	$231.81
May-18	9,439	54.01%	24.71	83.43%	38.17	26,561	44	$797.57	$940.80	$1,738.37	$463.25	$821.88	$715.62	$252.36
Jun-18	9,566	44.72%	20.46	83.43%	38.17	26,594	77	$808.35	$941.95	$1,750.30	$469.51	$1,763.33	$875.92	$406.40
Jul-18	9,503	44.42%	20.32	83.43%	38.17	25,857	70	$802.96	$915.87	$1,718.83	$466.38	$1,602.68	$875.92	$409.53
Aug-18	8,929	41.74%	19.09	64.24%	29.39	22,591	70	$754.46	$800.19	$1,554.65	$438.21	$1,597.53	$674.52	$236.31
Sep-18	7,398	34.58%	15.82	64.24%	29.39	24,122	63	$625.13	$854.40	$1,479.53	$363.09	$1,436.88	$674.52	$311.43
Oct-18	4,847	27.73%	12.69	64.24%	29.39	25,073	53	$409.56	$888.09	$1,297.65	$237.89	$986.42	$551.08	$313.19
Nov-18	3,253	18.61%	8.51	46.84%	21.43	22,987	53	$274.84	$814.22	$1,089.06	$159.63	$985.73	$401.77	$242.13
Dec-18	3,138	17.95%	8.21	46.84%	21.43	24,382	52	$265.14	$863.62	$1,128.76	$154.00	$966.98	$401.77	$247.77
Total	76,352		25		38	291,648	77	$6,451.72	$10,330.18	$16,781.90	$3,747.34	$14,200.18	$7,226.12	$3,478.78

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 20.46 kW to save enough money to offset the $469.51 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $3,478.78.

2.3.11 Ammi Hyde

Table 34: Ammi Hyde Monthly Usage and Demand with Respective Costs

Ammi Hyde								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	14,880	53	$527.05	$993.75	$1,602.59	$0.035420	$18.75	$0.10770
Feb-18	17,440	56	$617.72	$1,050.00	$1,750.04	$0.035420	$18.75	$0.10035
Mar-18	16,160	67	$572.39	$1,256.25	$1,936.86	$0.035420	$18.75	$0.11986
Apr-18	18,240	88	$646.06	$1,650.00	$2,446.06	$0.035420	$18.75	$0.13410
May-18	20,320	81	$719.73	$1,518.75	$2,444.56	$0.035420	$18.75	$0.12030
Jun-18	21,440	93	$759.40	$2,134.35	$2,948.47	$0.035420	$22.95	$0.13752
Jul-18	19,840	94	$702.73	$2,157.30	$2,869.23	$0.035420	$22.95	$0.14462
Aug-18	16,960	79	$600.72	$1,813.05	$2,424.01	$0.035420	$22.95	$0.14293
Sep-18	19,520	96	$691.40	$2,203.20	$2,847.82	$0.035420	$22.95	$0.14589
Oct-18	15,520	65	$549.72	$1,218.75	$1,929.59	$0.035420	$18.75	$0.12433
Nov-18	13,760	48	$487.38	$900.00	$1,546.68	$0.035420	$18.75	$0.11240
Dec-18	12,800	48	$453.38	$900.00	$1,489.91	$0.035420	$18.75	$0.11640
Total	206,880	96	$7,327.69	$17,795.40	$26,235.82			$0.12682

Ammi Hyde had an annual average electricity cost of $0.12682 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 35: Ammi Hyde Monthly Costs with Applied Solar

Ammi Hyde with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	2,696	25.99%	7.06	25.21%	6.85	12,184	46	$227.85	$431.54	$659.39	$132.34	$865.39	$128.36	-$3.98
Feb-18	3,082	29.70%	8.07	64.16%	17.42	14,358	39	$260.40	$508.57	$768.98	$151.25	$723.28	$326.72	$175.47
Mar-18	4,623	44.55%	12.10	64.16%	17.42	11,537	50	$390.61	$408.66	$799.26	$226.88	$929.53	$326.72	$99.84
Apr-18	4,417	42.57%	11.56	64.16%	17.42	13,823	71	$373.25	$489.61	$862.85	$216.79	$1,323.28	$326.72	$109.92
May-18	5,393	51.98%	14.12	64.42%	17.50	14,927	64	$455.71	$528.71	$984.42	$264.69	$1,190.70	$328.05	$63.36
Jun-18	5,650	44.49%	12.08	64.42%	17.50	15,790	76	$477.41	$559.29	$1,036.70	$277.29	$1,732.82	$401.53	$124.24
Jul-18	5,393	42.47%	11.53	64.42%	17.50	14,447	77	$455.71	$511.71	$967.42	$264.69	$1,755.77	$401.53	$136.84
Aug-18	5,072	39.94%	10.85	64.16%	17.42	11,888	62	$428.58	$421.07	$849.66	$248.93	$1,413.15	$399.90	$150.97
Sep-18	4,494	35.39%	9.61	64.16%	17.42	15,026	79	$379.76	$532.22	$911.97	$220.57	$1,803.30	$399.90	$179.33
Oct-18	3,724	35.89%	9.75	64.16%	17.42	11,796	48	$314.66	$417.82	$732.48	$182.76	$892.03	$326.72	$143.96
Nov-18	2,568	24.75%	6.72	25.21%	6.85	11,192	41	$217.00	$396.42	$613.42	$126.04	$771.64	$128.36	$2.32
Dec-18	2,311	22.28%	6.05	25.21%	6.85	10,489	41	$195.30	$371.51	$566.81	$113.44	$771.64	$128.36	$14.92
Total	49,423		14		17	157,457	79	$4,176.24	$5,577.13	$9,753.37	$2,425.68	$14,172.55	$3,622.85	$1,197.17

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 12.08 kW to save enough money to offset the $277.29 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand for most of the year resulting in a total annual net savings of approximately $1,197.17.

2.3.12 Central Receiving & Purchasing

Table 36: CR/P Monthly Usage and Demand with Respective Costs

Central Receiving & Processing								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	3,680	12	$130.35	$225.00	$387.45	$0.035420	$18.75	$0.10529
Feb-18	3,520	12	$124.68	$225.00	$367.95	$0.035420	$18.75	$0.10453
Mar-18	2,880	19	$102.01	$356.25	$515.75	$0.035420	$18.75	$0.17908
Apr-18	3,600	13	$127.51	$243.75	$424.98	$0.035420	$18.75	$0.11805
May-18	4,240	22	$150.18	$412.50	$643.78	$0.035420	$18.75	$0.15183
Jun-18	5,360	24	$189.85	$550.80	$780.58	$0.035420	$22.95	$0.14563
Jul-18	5,440	24	$192.68	$550.80	$770.53	$0.035420	$22.95	$0.14164
Aug-18	5,440	23	$192.68	$527.85	$746.55	$0.035420	$22.95	$0.13723
Sep-18	4,640	21	$164.35	$481.95	$662.91	$0.035420	$22.95	$0.14287
Oct-18	3,760	14	$133.18	$262.50	$460.38	$0.035420	$18.75	$0.12244
Nov-18	3,440	14	$121.84	$262.50	$446.86	$0.035420	$18.75	$0.12990
Dec-18	2,720	12	$96.34	$225.00	$338.02	$0.035420	$18.75	$0.12427
Total	48,720	24	$1,725.66	$4,323.90	$6,545.74			$0.13435

Central Receiving & Purchasing had an annual average electricity cost of $0.13435 per kWh. The demand reduction savings do not exceed the increase in usage costs resulting in an anticipated increase in electricity costs.

Table 37: CR/P Monthly Costs with Applied Solar

Central Receiving & Processing with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	1,451	17.25%	3.80	8.55%	1.88	2,229	10	$122.57	$78.97	$201.54	$71.19	$189.70	$35.30	-$35.89
Feb-18	1,625	19.31%	4.25	20.61%	4.54	1,895	7	$137.28	$67.13	$204.41	$79.74	$139.92	$85.08	$5.34
Mar-18	2,379	28.28%	6.23	20.61%	4.54	501	14	$201.02	$17.75	$218.77	$116.76	$271.17	$85.08	-$31.68
Apr-18	2,263	26.90%	5.92	20.61%	4.54	1,337	8	$191.21	$47.36	$238.57	$111.06	$158.67	$85.08	-$25.99
May-18	2,959	35.18%	7.75	30.93%	6.81	1,281	15	$250.05	$45.37	$295.41	$145.23	$284.83	$127.67	-$17.56
Jun-18	3,075	29.87%	6.58	30.93%	6.81	2,285	17	$259.85	$80.93	$340.78	$150.93	$394.53	$156.27	$5.35
Jul-18	2,959	28.74%	6.33	30.93%	6.81	2,481	17	$250.05	$87.87	$337.92	$145.23	$394.53	$156.27	$11.04
Aug-18	2,628	25.53%	5.62	20.61%	4.54	2,812	18	$222.10	$99.59	$321.69	$129.00	$423.72	$104.13	-$24.87
Sep-18	2,379	23.11%	5.09	20.61%	4.54	2,261	16	$201.02	$80.09	$281.11	$116.76	$377.82	$104.13	-$12.62
Oct-18	2,089	24.83%	5.47	20.61%	4.54	1,671	9	$176.50	$59.19	$235.70	$102.52	$177.42	$85.08	-$17.44
Nov-18	1,335	15.87%	3.49	8.55%	1.88	2,105	12	$112.77	$74.58	$187.34	$65.50	$227.20	$35.30	-$30.20
Dec-18	1,218	14.49%	3.19	8.55%	1.88	1,502	10	$102.96	$53.18	$156.14	$59.80	$189.70	$35.30	-$24.50
Total	26,359		8		7	22,361	18	$2,227.37	$792.01	$3,019.38	$1,293.72	$3,229.21	$1,094.69	-$199.02

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 6.58 kW to save enough money to offset the $150.93 increase in usage charges for the month of June. Due to the anticipated afternoon load profile, the solar is less effective in reducing demand resulting in a total annual net increase of $199.02.

2.3.13 University Technology Services

Table 38: UTS Monthly Usage and Demand with Respective Costs

University Technology Services								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	124,800	226	$4,420.42	$4,237.50	$8,814.57	$0.035420	$18.75	$0.07063
Feb-18	133,600	227	$4,732.11	$4,256.25	$9,135.57	$0.035420	$18.75	$0.06838
Mar-18	124,480	222	$4,409.08	$4,162.50	$8,835.80	$0.035420	$18.75	$0.07098
Apr-18	131,360	211	$4,652.77	$3,956.25	$8,980.52	$0.035420	$18.75	$0.06837
May-18	119,520	205	$4,233.40	$3,843.75	$8,722.38	$0.035420	$18.75	$0.07298
Jun-18	132,960	200	$4,709.44	$4,590.00	$9,250.51	$0.035420	$22.95	$0.06957
Jul-18	112,000	195	$3,967.04	$4,475.25	$8,209.31	$0.035420	$22.95	$0.07330
Aug-18	111,520	190	$3,950.04	$4,360.50	$8,073.26	$0.035420	$22.95	$0.07239
Sep-18	117,760	197	$4,171.06	$4,521.15	$8,569.70	$0.035420	$22.95	$0.07277
Oct-18	108,160	197	$3,831.03	$3,693.75	$8,360.85	$0.035420	$18.75	$0.07730
Nov-18	126,880	202	$4,494.09	$3,787.50	$9,247.29	$0.035420	$18.75	$0.07288
Dec-18	128,160	197	$4,539.43	$3,693.75	$9,202.67	$0.035420	$18.75	$0.07181
Total	1,471,200	227	$52,109.90	$49,578.15	$105,402.43			$0.07164

University Technology Services had an annual average electricity cost of $0.07164 per kWh. Though this is lower than the cost of the solar energy, the demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 39: UTS Monthly Costs with Applied Solar

University Technology Services with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	2,703	35.04%	7.08	19.38%	3.91	122,097	222	$228.43	$4,324.67	$4,553.09	$132.68	$4,164.12	$73.38	-$59.30
Feb-18	2,761	35.78%	7.23	80.99%	16.36	130,839	211	$233.29	$4,634.33	$4,867.61	$135.50	$3,949.57	$306.68	$171.18
Mar-18	4,066	52.70%	10.64	80.99%	16.36	120,414	206	$343.61	$4,265.05	$4,608.66	$199.58	$3,855.82	$306.68	$107.10
Apr-18	3,336	43.24%	8.73	80.99%	16.36	128,024	195	$281.89	$4,534.61	$4,816.50	$163.73	$3,649.57	$306.68	$142.95
May-18	4,199	54.42%	10.99	82.53%	16.67	115,321	188	$354.79	$4,084.68	$4,439.47	$206.07	$3,531.23	$312.52	$106.44
Jun-18	4,227	44.76%	9.04	82.53%	16.67	128,733	183	$357.22	$4,559.71	$4,916.93	$207.48	$4,207.48	$382.52	$175.04
Jul-18	4,199	44.46%	8.98	82.53%	16.67	107,801	178	$354.79	$3,818.32	$4,173.11	$206.07	$4,092.73	$382.52	$176.45
Aug-18	4,026	42.63%	8.61	80.99%	16.36	107,494	174	$340.21	$3,807.43	$4,147.64	$197.60	$3,985.13	$375.37	$177.77
Sep-18	3,739	39.59%	8.00	80.99%	16.36	114,021	181	$315.91	$4,038.64	$4,354.55	$183.49	$4,145.78	$375.37	$191.88
Oct-18	3,163	41.00%	8.28	80.99%	16.36	104,997	181	$267.31	$3,718.98	$3,986.29	$155.26	$3,387.07	$306.68	$151.42
Nov-18	2,013	26.09%	5.27	19.38%	3.91	124,867	198	$170.10	$4,422.79	$4,592.89	$98.80	$3,714.12	$73.38	-$25.42
Dec-18	1,725	22.36%	4.52	19.38%	3.91	126,435	193	$145.80	$4,478.31	$4,624.11	$84.69	$3,620.37	$73.38	-$11.31
Total	40,158		11		17	1,431,042	222	$3,393.34	$50,687.51	$54,080.85	$1,970.95	$46,303.02	$3,275.13	$1,304.18

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 9.04 kW to save enough money to offset the $207.48 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand for most of the year resulting in a total annual net savings of approximately $1,304.18.

2.3.14 Cherrington (SIE) Complex

Table 40: Cherrington Monthly Usage and Demand with Respective Costs

Cherrington (SIE) Complex								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	49,920	122	$1,768.17	$2,287.50	$4,177.95	$0.035420	$18.75	$0.08369
Feb-18	55,680	142	$1,972.19	$2,662.50	$4,774.01	$0.035420	$18.75	$0.08574
Mar-18	49,600	137	$1,756.83	$2,568.75	$4,507.41	$0.035420	$18.75	$0.09088
Apr-18	53,920	158	$1,909.85	$2,962.50	$5,127.31	$0.035420	$18.75	$0.09509
May-18	55,840	176	$1,977.85	$3,300.00	$5,758.81	$0.035420	$18.75	$0.10313
Jun-18	62,240	177	$2,204.54	$4,062.15	$6,309.35	$0.035420	$22.95	$0.10137
Jul-18	58,720	192	$2,079.86	$4,406.40	$6,413.58	$0.035420	$22.95	$0.10922
Aug-18	54,080	179	$1,915.51	$4,108.05	$5,955.75	$0.035420	$22.95	$0.11013
Sep-18	62,400	188	$2,210.21	$4,314.60	$6,373.03	$0.035420	$22.95	$0.10213
Oct-18	52,480	163	$1,858.84	$3,056.25	$5,359.68	$0.035420	$18.75	$0.10213
Nov-18	55,040	137	$1,949.52	$2,568.75	$4,972.23	$0.035420	$18.75	$0.09034
Dec-18	52,800	130	$1,870.18	$2,437.50	$4,741.80	$0.035420	$18.75	$0.08981
Total	662,720	192	$23,473.54	$38,734.95	$64,470.91			$0.09728

Cherrington (SIE) Complex had an annual average electricity cost of $0.09728 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 41: Cherrington Monthly Costs with Applied Solar

Cherrington (SIE) Complex with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	3,410	26.59%	8.93	53.88%	18.09	46,510	104	$288.18	$1,647.37	$1,935.55	$167.38	$1,948.29	$339.21	$171.82
Feb-18	3,573	27.85%	9.35	71.18%	23.90	52,107	118	$301.90	$1,845.64	$2,147.54	$175.35	$2,214.38	$448.12	$272.76
Mar-18	5,684	44.31%	14.88	71.18%	23.90	43,916	113	$480.30	$1,555.50	$2,035.81	$278.97	$2,120.63	$448.12	$169.14
Apr-18	5,278	41.15%	13.82	71.18%	23.90	48,642	134	$446.00	$1,722.90	$2,168.89	$259.05	$2,514.38	$448.12	$189.07
May-18	6,658	51.91%	17.43	80.93%	27.17	49,182	149	$562.64	$1,742.01	$2,304.65	$326.80	$2,790.49	$509.51	$182.72
Jun-18	6,821	43.44%	14.59	80.93%	27.17	55,419	150	$576.36	$1,962.95	$2,539.31	$334.77	$3,438.51	$623.64	$288.88
Jul-18	6,658	42.41%	14.24	80.93%	27.17	52,062	165	$562.64	$1,844.02	$2,406.66	$326.80	$3,782.76	$623.64	$296.85
Aug-18	6,382	40.65%	13.65	71.18%	23.90	47,698	155	$539.31	$1,689.45	$2,228.76	$313.25	$3,559.55	$548.50	$235.25
Sep-18	5,603	35.68%	11.98	71.18%	23.90	56,797	164	$473.44	$2,011.75	$2,485.20	$274.99	$3,766.10	$548.50	$273.51
Oct-18	4,710	36.71%	12.33	71.18%	23.90	47,770	139	$397.97	$1,692.03	$2,089.99	$231.15	$2,608.13	$448.12	$216.97
Nov-18	3,167	24.69%	8.29	53.88%	18.09	51,873	119	$267.60	$1,837.35	$2,104.94	$155.43	$2,229.54	$339.21	$183.78
Dec-18	3,086	24.05%	8.08	53.88%	18.09	49,714	112	$260.74	$1,760.88	$2,021.62	$151.44	$2,098.29	$339.21	$187.77
Total	61,031		17		27	601,689	165	$5,157.08	$21,311.84	$26,468.92	$2,995.38	$33,071.06	$5,663.89	$2,668.51

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 14.59 kW to save enough money to offset the $334.77 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $2,668.51.

2.3.15 Fisher Early Learning Center

Table 42: Fisher Monthly Usage and Demand with Respective Costs

Fisher Early Learning Center								
Month	Usage (kWh)	Billed Demand (kW)	Usage Charges	Demand Charges	Total Charges	Cost/kWh	Cost/kW	Average Cost/kWh
Jan-18	10,320	40	$365.53	$750.00	$1,145.16	$0.035420	$18.75	$0.11097
Feb-18	10,400	40	$368.37	$750.00	$1,161.90	$0.035420	$18.75	$0.11172
Mar-18	9,040	51	$320.20	$956.25	$1,370.39	$0.035420	$18.75	$0.15159
Apr-18	10,320	62	$365.53	$1,162.50	$1,641.40	$0.035420	$18.75	$0.15905
May-18	14,160	72	$501.55	$1,350.00	$2,063.06	$0.035420	$18.75	$0.14570
Jun-18	17,280	78	$612.06	$1,790.10	$2,448.91	$0.035420	$22.95	$0.14172
Jul-18	15,280	71	$541.22	$1,629.45	$2,184.99	$0.035420	$22.95	$0.14300
Aug-18	15,440	69	$546.88	$1,583.55	$2,141.96	$0.035420	$22.95	$0.13873
Sep-18	12,800	72	$453.38	$1,652.40	$2,064.75	$0.035420	$22.95	$0.16131
Oct-18	10,160	46	$359.87	$862.50	$1,340.88	$0.035420	$18.75	$0.13198
Nov-18	10,400	40	$368.37	$750.00	$1,236.63	$0.035420	$18.75	$0.11891
Dec-18	9,520	39	$337.20	$731.25	$1,152.89	$0.035420	$18.75	$0.12110
Total	145,120	78	$5,140.15	$13,968.00	$19,952.92			$0.13749

Fisher Early Learning Center had an annual average electricity cost of $0.13749 per kWh. Fortunately, this is higher than the cost of the solar energy. The demand reduction savings exceeded the increase in usage costs resulting in net annual savings.

Table 43: Fisher Monthly Costs with Applied Solar

Fisher Early Learning Center with Solar														
Month	Anticipated Monthly Production (kWh)	Break-Even Demand Reduction Ratio	Break-Even Demand Reduction (kW)	Anticipated Demand Reduction Ratio	Anticipated Demand Reduction (kW)	Remaining Energy Req (kWh)	Remaining Demand Req (kW)	Solar PPA Charge	Remaining Usage Charge	Total Usage Charge	Usage Charge Increse	Remaining Demand Charge	Anticipated Demand Savings	Net Savings
Jan-18	2,186	39.54%	5.72	53.63%	7.76	8,134	32	$184.73	$288.10	$472.83	$107.29	$604.47	$145.53	$38.24
Feb-18	2,124	38.41%	5.56	63.87%	9.24	8,276	31	$179.45	$293.15	$472.60	$104.23	$576.66	$173.34	$69.11
Mar-18	2,623	47.44%	6.87	63.87%	9.24	6,417	42	$221.67	$227.28	$448.95	$128.75	$782.91	$173.34	$44.59
Apr-18	2,405	43.49%	6.29	63.87%	9.24	7,915	53	$203.20	$280.36	$483.56	$118.02	$989.16	$173.34	$55.32
May-18	2,686	48.57%	7.03	71.52%	10.35	11,474	62	$226.95	$406.42	$633.37	$131.82	$1,155.90	$194.10	$62.28
Jun-18	2,717	40.15%	5.81	71.52%	10.35	14,563	68	$229.59	$515.82	$745.41	$133.35	$1,552.52	$237.58	$104.23
Jul-18	2,655	39.22%	5.68	71.52%	10.35	12,625	61	$224.31	$447.19	$671.50	$130.29	$1,391.87	$237.58	$107.30
Aug-18	2,598	38.39%	5.56	63.87%	9.24	12,842	60	$219.56	$454.85	$674.41	$127.53	$1,371.38	$212.17	$84.64
Sep-18	2,498	36.92%	5.34	63.87%	9.24	10,302	63	$211.12	$364.88	$576.00	$122.62	$1,440.23	$212.17	$89.55
Oct-18	2,436	44.05%	6.38	63.87%	9.24	7,724	37	$205.84	$273.59	$479.42	$119.56	$689.16	$173.34	$53.78
Nov-18	1,874	33.89%	4.90	53.63%	7.76	8,526	32	$158.34	$302.00	$460.33	$91.97	$604.47	$145.53	$53.56
Dec-18	1,843	33.32%	4.82	53.63%	7.76	7,677	31	$155.70	$271.93	$427.63	$90.43	$585.72	$145.53	$55.10
Total	28,644		7.03		10.35	116,476	67.65	$2,420.45	$4,125.57	$6,546.02	$1,405.87	$11,744.43	$2,223.57	$817.70

For the solar instillation to be profitable, the demand reduction savings must break-even with the increase in usage costs. For example, the demand reduction must be greater than 5.81 kW to save enough money to offset the $133.35 increase in usage charges for the month of June. Due to the anticipated primarily daytime load profile, the solar is effective in reducing demand over the entire year resulting in a total annual net savings of approximately $817.70.

2.3.16 Costs Summary

Each building was then analyzed for overall savings in respect to the size, in kW, of the installation. The results can be found below.

Table 44: Summary of Costs Associated with Solar Projects

Summary									
Building	Annual Anticipated Production	Annual Demand Charge	Annual Usage Charge	Estimated Annual Usage Charge w/Solar	Estimated Annual Demand Savings w/Solar	Annual Net Savings w/Solar	Percent Savings	Percent Size	Savings/Size Ratio
Ritchie	883,664	$355,994.85	$289,424.86	$332,795.09	$25,980.63	-$17,389.60	-2.69%	29.45%	-9.15%
AAC	268,989	$49,375.95	$34,026.44	$47,228.42	$17,552.33	$4,350.35	5.22%	54.56%	9.56%
Driscoll	167,129	$25,423.20	$16,888.26	$24,875.58	$9,451.84	$1,249.17	2.95%	79.74%	3.70%
Shwayder Art	78,509	$10,393.55	$5,206.97	$9,060.17	$4,224.08	$370.88	2.38%	78.24%	3.04%
Boettcher West	234,094	$27,456.45	$17,412.47	$28,901.78	$12,794.81	$1,305.50	2.91%	98.93%	2.94%
Sturm	172,208	$35,235.30	$25,247.38	$33,699.34	$12,424.03	$3,972.06	6.57%	60.23%	10.90%
Knudson	40,382	$14,816.10	$3,590.17	$5,572.13	$2,261.52	$279.56	1.52%	23.13%	6.57%
Frontier	76,352	$21,426.30	$13,034.56	$16,781.90	$7,226.12	$3,478.78	10.09%	39.78%	25.38%
A Hyde	49,423	$17,795.40	$7,327.69	$9,753.37	$3,622.85	$1,197.17	4.77%	28.29%	16.84%
C R/P	26,359	$4,323.90	$1,725.66	$3,019.38	$1,094.69	-$199.02	-3.29%	91.74%	-3.59%
UTS	40,158	$49,578.15	$52,109.90	$54,080.85	$3,275.13	$1,304.18	1.28%	8.90%	14.42%
Mudd	134,209	$66,319.65	$64,134.68	$70,721.65	$12,201.34	$5,614.37	4.30%	24.00%	17.93%
Fisher	28,644	$13,968.00	$5,140.15	$6,546.02	$2,223.57	$817.70	4.28%	18.56%	23.06%
	2,200,119					$6,351.10			

The building with the most anticipated savings is Frontier Hall followed by Fisher Early Leaning Center as the installation with the most savings with respect to the size of the installation. Ritchie Athletic Complex and Central Receiving & Processing are projected to see an annual increase due to the solar output being less effective on demand response. Bound by the PPA agreement, the output of each solar instillation is fixed. Therefore, the annual usage cost increase can be calculated with relatively low uncertainty. Due to only 1 of the 18 buildings with solar installations having real-time meter data, it is difficult to determine the actual effectiveness of the solar output regarding demand reduction. However, based on the contracted output, it will be at least be known the required demand reduction to break-even on the increase in usage costs. As more buildings gain the ability to track real-time load data, the more accurate analysis will be on effectiveness of renewable penetration and other energy related projects. The total savings for the buildings studied is $6,351.10

2.3.17 Discussion on the savings due to carbon cost and value of lost load

There is indirect savings associated with the production of the renewable energy. By applying the social cost of carbon to the energy produced by the solar instillations, additional benefit can be determined. Xcel energy's generation portfolio averages 1.338 pounds per kWh as billed to commercial tariff customers. Therefore, the amount of CO_2 saved from emission is approximately 1,472 tons. By applying the $22-28 per ton cost of carbon range. It can be concluded that the rooftop solar project saved between $32,381 and $41,213 in social carbon costs annually.

Additionally, there may be value in reducing load lost during an outage. A best-case-scenario approach would assume that the solar installation be operational and be able to supply load not requiring connection to the utility grid. In this case, solar output during outage would offset the approximate value of lost load at $8 per kWh. For example, if Ritchie Athletic Complex experienced an outage lasting 1 hour during the middle of the day in September, the savings would be approximately 450 kWh x $8/kWh = $3,600. This is assuming the solar installation at Ritchie is operating at full output during the outage and can be directly applied to load without being supplied by the utility grid. However, this may not be likely because severe weather often causes outage resulting in an inevitable reduction of solar output and building systems usually operate at a minimum load without linear reduction.

3 Discussion on Developing Energy Projects and Other Smart Technology Projects on Campus

3.1 Overview of the Smart Campus Initiative expansion

The DU Rooftop Solar Project is just the beginning of the university's commitment to a more sustainable future. It is evident that there can be cost savings by installing renewable capacity and continuing to reinvest the 'Green Fund' into upgrades within buildings and other campus infrastructure. In Chapter 1, an overview of other campus' projects was presented based on several categories. Each one of these categories provides an opportunity for the university to forward its commitment to a sustainable future. Most projects proposed below are eligible for 'Green Fund' investment.

3.2 Expanding energy related projects within the Smart Campus Initiative

The following projects pertaining to Microgrid/Energy/Storage/CO2 have been identified as priority opportunities for the university:

- Expanded in-network energy with localized renewable generation/energy storage
- Smart metering of all buildings' natural gas and electricity (by sub category)
- Introduction of energy storage
- Introduction of geothermal energy
- Introduction of demand response (load curtailment)
- Increase reliability infrastructure

Figure 20: Installation of Solar Tree on DU Campus[4]

Pertaining to Transportation, the following have been identified as university priorities:

- Implementation of smart parking infrastructure
- Introduction of eBikes and other mobility devices
- Expansion of ride sharing initiatives
- Implementation of smart intersection infrastructure and traffic tracking

[4] Photo courtesy of Lynn Bailey

Figure 21:Smart Intersection Graphic[5]

The following have been identified as university priorities pertaining to waste:

- Introducing sensors for waste pickup efficiency to also allow for collection weights and reporting analysis of area behavior

The following have been identified as university priorities pertaining to heating & cooling:

- Expanding heat recovery system networks
- Implementing additional passive solar systems

[5] https://baystateherald.com/2019/07/24/smart-transportation-system-market-development-growing-popularity-emerging-trends-and-status-forecast-2019-2026/

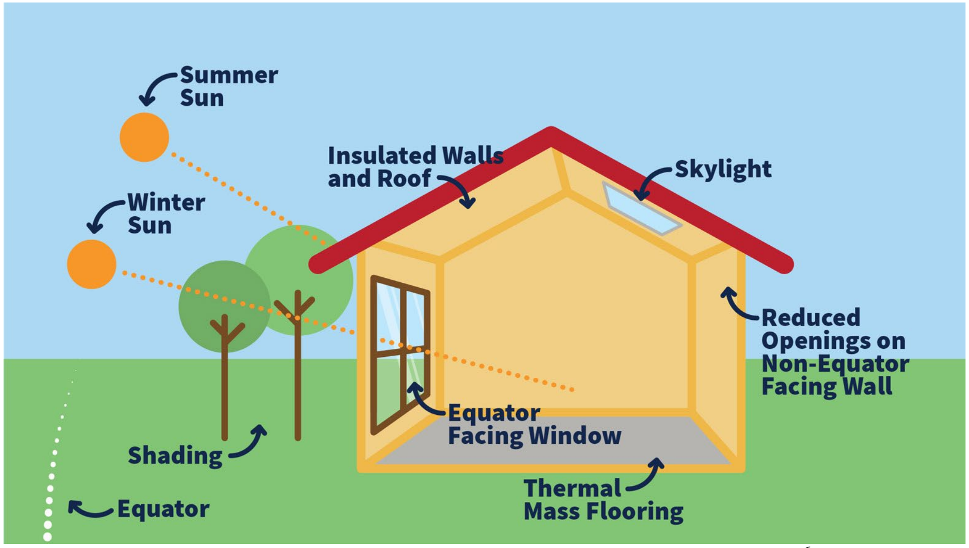

Figure 22: Illustration of Passive Solar Design[6]

The following have been identified as university priorities pertaining to lighting and light pollution:

- Expand efficient lighting upgrades
- Introduce smart campus lighting in both exterior/interior installations

The following have been identified as university priorities pertaining to water:

- Install smart metering to track real-time usage
- Implement grey water recovery
- Implement rainwater collection

[6] https://carbontrack.com.au/blog/passive-solar-design/

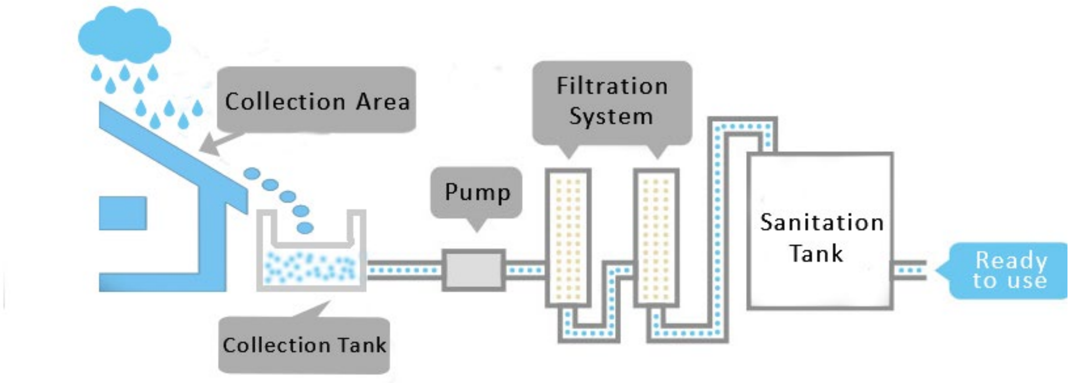

Figure 23: Rainwater Collection Process[7]

The following have been identified as university priorities pertaining to health/wellness/social justice/education:

- Install air quality sensors
- Install a broader network of weather sensors
- Install facial recognition cameras
- Implement exercise promotion initiatives/active living measurement

The following have been identified as university priorities pertaining to IoT:

- Expand a dynamic wireless network to handle peak demand
- Implement IoT appliance integration for demand response & usage tracking
- Implement Wi-fi tracking for campus utilization analysis

3.3 Strategy for the smart campus initiative expansion related to energy

To achieve these outlined priorities, the university must take a hierarchical approach. Certain projects will be easier to complete than others while some projects will require

[7] http://www.neoakruthi.com/blog/rainwater-harvesting-methods.html

the completion of simpler projects before being achievable. The following is a hierarchical approach to achieving the outlined smart campus priorities.

3.3.1 Pertaining to Microgrid/Energy/Storage/CO2:

For a level one approach, the university is already pursuing integration of renewable energy generation on existing buildings. The partnership with Pivot Energy provides the university with localized PV generation on 18 buildings across campus. By continuing this trend, the University should install additional PV generation and other renewable generation capacity, if applicable, on any new structures built as outlined in the framework plan.

Additionally, any new structure built, should be installed with smart metering, broken down by subcategory. For example, a new residence hall should separate electricity, natural gas, and water metering by the service of the building such as, lighting, dining, HVAC etc. and the data be accessible real time for institutional analysis.

For a level two approach the university should implement all suggestions in level one with the addition of energy storage as an important catalyst to maximize the benefits of renewable generation. By installing battery storage, the university can store energy during low-load hours and dramatically reduce the overall energy cost by discharging during peak hours. The amount of energy storage is highly scalable and can me optimized for desired energy savings.

The most significant form of cost savings comes from reducing demand charges. To best reduce demand charges, the university would implement an energy storage scheme alongside any local renewable generation such as the rooftop solar project. Energy storage is scalable and associated cost savings can be tailored to the needs of the application. Additional information on the amount of cost savings can be found in later discussions on cost savings.

For a level three approach the university should implement all suggestions in level one and two with the addition of geothermal energy. Though it may be costly, it is a great way to offset heating costs in the long term. Geothermal may be desirable in new university building developments. Specifically, highways like I-25 hold heat longer than smaller streets, parking lots, and green space. With the close proximity to I-25, the development of the north campus may be able to incorporate heat recovery from the interstate.

Also, advanced electric reliability involves demand response by dynamic load curtailments. Many new smart appliances can be enabled to shut off during high demand times. Alternatively, sections of electric load can be curtailed with smart breakers to potentially prevent outages and reduce overall cost.

3.4 Strategy for the smart campus initiative expansion in other categories

3.4.1 Pertaining to Transportation:

For a level one approach, sensors should be installed to monitor the occupancy of each space as the university builds additional parking structures. By installing smart parking sensors in each parking space, the lot can be monitored for illegal parking and notify patrons of availability.

As a supplement to installing parking sensors, they could monitor how many vehicles coming to campus are single occupancy vehicles (SOV). The university should offer incentives for not driving to campus and/or encouraging carpooling. Such incentives could be included as discounts in parking fees etc.

For a level two approach, the university should implement all suggestions in level one with the addition of mobility devices. The university used to have the Denver B-Cycle program with was underutilized then went away. Then the university hosted the private ‘ofo’ bikes which became popular and ultimately evolved into the scooter presence on campus. Mobility devices such as these seems to come in waves but are popular nonetheless. The university could invest in its own mobility devices to serve the campus community and be charged by renewable sources.

For a level three approach, the university should implement all suggestions in levels one and two with the addition of smart intersections. The university’s main campus is bordered by a major thruway on the east. Implementing smart intersections that monitor vehicle speeds, the amount of traffic present, any hazards, and adjusts accordingly while analyzing data to communicate in real time to an operator is the premier smart technology package. This implementation offers multiple avenues of achieving smart city objectives.

Additionally, autonomous vehicles and shuttles would be another premier implementation putting the university well ahead of the pack in smart transportation technology on the campus. Initially, simple routs should be a first start then as the technology becomes safer, additional autonomous vehicles serving the perimeter could be implemented also.

3.4.2 Pertaining to Waste:

For a fundamental approach, the university should install sensors on existing and new waste receptacles that sense the amount of refuse they contain. This will allow the university to monitor and optimize refuse pickup. Additionally, the collected refuse should be weighed and reported so the data can be accessed by members of the community for analysis. Additionally, the campus dining should weigh and report their food waste in the open access reporting system.

Based on the analysis obtained from the sensors and the weighing, behavior of students and the campus community can be analyzed and used by interested parties for incentives.

3.4.3 Pertaining to Heating/Cooling:

For a level one approach, Heat recovery should be implemented as it is fundamental in a complete smart campus portfolio. The extent of implementing heat recovery on campus may differentiate between levels of achievement but the base level of implementing heat recovery would be to install a heat recovery in any new buildings, especially residence halls.

For a level two approach, Heat recovery implementation can be expanded to include a waste heat circuit between buildings with heat recovery systems to optimize the efficiency.

For a level three approach, the addition of a central energy processing center and waste heat recovery systems in existing buildings would place the university as a leader in smart heating technology.

3.4.4 Pertaining to Lighting/Light Pollution:

For a level one approach, the university should install efficient LED smart campus lighting in any new developments around campus. By installing lighting that can sense the amount of light required and does so using efficient LEDs, the university would not only achieve smart campus lighting status but also save energy costs due to exterior lighting.

For a level two approach, the university should implement all suggestions in level one with the addition of replacing the existing campus lighting infrastructure with smart efficient lighting to achieve a uniform cost savings initiative. With the entire campus' lighting smart connected, the university will achieve a superior level of smart lighting initiative. The luminosity data collected from the lighting network should be reported in an open access portal, so it can be used for analysis by the campus community.

For a level three approach, the university should implement all suggestions in levels one and two with the addition of smart interior lighting. Motion lighting is already being implemented in most university buildings. By expanding on this concept, the university should implement network connected smart interior lighting in any new building. Network connected lighting provides the ability to change lighting in a building from a remote location as well as obtaining valuable information on how the lighting of a building is used.

3.4.5 Pertaining to Water:

For a level one approach, the university should implement rainwater collection. Fortunately, Colorado is famed for having over 300 days of sunshine a year. However, it still rains in Denver. By collecting rainwater, the university can implement a direct initiative for smart water technology on campus. Network connected sensors should be implemented to monitor collection cistern levels and adjusts the quantity of utility water used during irrigation of campus green space. By implementing rainwater collection and smart monitoring, the university will achieve the implementation of smart water related technology and save water/money.

Additionally, any new building built on campus should have its water smart metered. If the building has multiple water systems i.e. residence hall with dining, then the systems should be sub-metered. This will allow the university to monitor water consumption and use the data for analysis by the campus community.

For a level two approach, the university should implement all suggestions in level one with the addition of expanding installation of smart metering on existing buildings to achieve the next level of water related smart campus technology. With the installation of smart metering across campus, the university can better analyze water usage between zones and identify any potential hot spots or issues.

For a level three approach, the university should implement all suggestions in levels one and two with the addition of grey water recovery. Most grey water produced by a campus is reusable dependent on where it is collected and how it is treated. To achieve the premier level of a water related smart campus initiative, the university should implement grey water recovery system(s). This would dramatically put the university ahead of the smart campus pack and have the potential of saving significant amounts of water.

3.4.6 Pertaining to Health/Wellness/Social Justice/Education:

For a level one approach, the university should focus on respiratory health as a significant concern in an urban environment. Denver often issues ozone alerts during summer months and wood burning restrictions in the wintertime. The university can participate in health monitoring by installing smart sensors across campus that monitor weather & air quality to report in an open access network. This would alert the campus community of any potential health risks and indicate healthier sections of the campus. Additionally, the weather sensors will indicate temperature, wind, and solar incidence for example around campus to be analyzed by the campus community.

For a level two approach, the university should implement all technologies in level one with the addition of wellness technology. Wellness is a core value of the university and thus should be promoted. Smart technology should be implemented to monitor campus community members' commitment to an active lifestyle. Community members can opt-in to a fitness initiative and be tracked on the number of times they cross campus for example. Checkpoints around campus can be installed that community members can check-in at to receive points etc.

For a level three approach, the university should implement all technologies in levels one and two with the addition of smart surveillance technology. Facial recognition software is becoming increasingly prevalent in institutions. The university should implement facial recognition technology on campus for purposes of security, health, and analysis. Smart surveillance can offer benefits such as authentication when entering buildings/rooms, identifying wanted persons, and identifying at risk individuals not attending class. The system could also be used to analyze the number of visitors to campus.

3.4.7 Pertaining to IoT:

For a fundamental approach to smart campus technology, wireless networks are the backbone of any smart technology. The university should implement a smart network infrastructure that dynamically handles the traffic through multiple channels. Distributed network control in its own concept is a smart technology. Fundamentally, a strong network would put the university in a position to support all smart technologies for the other categories and adapt additional smart technologies as they become available. See

3.5 Discussion on Cost Savings from Smart Campus Initiative

3.5.1 Cost savings related to energy

Like with the currently implemented rooftop solar project. The university may save money with the installation of additional renewable and local generation. The university may decide to purchase generation infrastructure outright or continue to contract the output using a PPA. In the first scenario, explicit savings would be recovered in the long term as the amount of demand savings *and* usage savings would pay off any initial capital investment costs along with the cost of maintaining the equipment. Through the PPA scenario like with Pivot Energy, explicit savings are only recovered through the demand savings associated with the output *unless* the associated PPA charge for the output is less than that of Xcel's usage charge. Both scenarios, carry the implicit savings as described with VOLL and social cost of carbon.

Metering of energy usage is essential for not only energy utility companies but for the end consumer also. Because the university had real time meters installed on a few buildings, this project was made possible. If the university installed accurate meters on all its buildings to monitor energy usage. The data gathered would be used in projects like this for years to come. The inherent cost savings are expressed implicitly in other aspects like localized generation and demand reduction. Metering owned by the university can also help alleviate discrepancies in billing meters and provide redundancy in case of system error.

Energy storage is becoming more economically viable for institutions as technology becomes more advanced and cheaper to produce. According to the National Renewable Energy Laboratory's recent report, the average engineering, procurement, and construction (EPC) cost of utility-scale lithium-ion energy storage is approximately $500/kWh and $500/kW of installed capacity for a 1-hour duration system [20]. If the university installed on of these storage schemes on a rooftop solar project building where the load peak occurs offset to the solar output peak, additional cost savings can be realized. For example, AAC's solar installation is estimated to reduce the energy demand in the morning hours beyond the maximum demand occurring later in the day. Therefore, the demand reduction savings is underutilized. If a 50kW 1-hour system was installed at AAC. It would cost roughly $50,000 EPC according to NREL. The additional demand reduction achieved would be at best 50 kw or approximately $1,150 and $940 of demand savings during summer and winter demand months respectively. Thus, the initial costs of the energy storage would recover in approximately 50 months. Accuracy in knowing when to discharge the energy storage would be achieved form the value of installing meters at each building.

3.5.2 Cost savings related to other categories

It is difficult to determine the actual cost savings associated with other smart campus initiatives explicitly. Certain projects will carry more weight in saving costs than others. Implicit value of certain projects such as transportation initiatives and titles associated with achieving smart campus benchmarks first is difficult to quantify proactively. The status achieved by the university as a key campus implementing smart technologies is nearly priceless. Value is also obtained by forming relationships with other agencies implementing similar initiatives like the City of Denver.

3.6 Alignment to the City of Denver's Smart City Initiative

Figure 24: City of Denver Smart City Initiative Logo

Inspired by the U.S. Department of Transportation's Smart City Challenge, the city of Denver has adopted a smart city initiative to think of transformative, multidisciplinary Smart City projects that could improve mobility. Denver's smart city does not stop at increasing mobility but also aims to reduce crime, pollution, and congestion while addressing the city's aging infrastructure. The initiative contains the core values of: access, connection, efficiency, equity, health, inclusion, innovation, partnership, safety, and sustainability. All of these core principles align with the proposed Smart Campus Framework enhancement either directly of subsequently through other avenues.

The city has outlined the plan by 4 categories: Healthy People & Places, Connected Mobility, IoT Platform and Data Management, and Innovative Pilots & Partnerships.

The Healthy People and Places initiative focuses to use real-time hyper-local air quality data to empower communities, families, and schools to limit exposure and reduce pollution through behavior change, advocacy, and community engagement according to the website. The initiative plans to use the rich social community of schools as a vehicle to deliver air quality and respiratory health education. With the implementation of the university's smart technology centered around air quality and weather monitoring, the university can be directly part of Denver's Healthy People & Places initiative.

The Connected Mobility Initiative plans to utilize Intelligent Transportation Systems (ITS) to progressively handle how traffic and mobility are handled such as wireless communications, car navigation, and traffic signal regulation. The university would be helping the city through implementing wireless networks and smart devices that monitor traffic to and around campus. Additionally, autonomous vehicles and mobility devices implemented by the university would directly relate to the city's approach of transportation automation.

The IoT Platform and Data Management Initiative enables the city to progress the smart city framework through an enterprise data management system (EDM). The EDM system takes data from thousands of different sensors to provide real-time data to city employees. Data comes from resources like the traffic management center, police, bus, rail, road sensors, street lights, weather sensors, and universities. This equips Denver to improve the access and utilization of city services. By collecting the data as outlined in the smart campus framework, the university and the city will strengthen the bond of collaboration.

The Innovative Pilots & Partnerships Initiative directly mentions the University of Denver as a key partner in collaborating for the smart city framework. The Solar Decathlon was part of this initiative. The city's plan also includes an outline of utilizing living labs as a sandbox for emerging technologies. The University, in its research-oriented structure, will be a key partner in furthering the city's living lab approach.

3.7 Conclusion

As institutions embrace rapidly changing technology, energy infrastructure and other campus initiatives will benefit. Academic campuses everywhere are innovating new uses for smart technologies. The University of Denver has the opportunity to be one of these pioneering institutions even though the current number of smart campus initiatives is less than other campuses globally. With the expansion of the "Utility Reinvestment Fund" into the "Green Fund," the university can invest and implement many projects that utilize mart technologies. Projects centered around global topics may encompass multiple aspects of a few different focuses. However, none of the academic institution's campus initiatives include integration of smart technologies in *all* topics. As the DU Campus Framework Plan is expanded, smart technologies can be integrated in each category putting DU at the forefront at an all-encompassing 'Smart Campus.' Explicit savings will be realized by these projects both long-term and short-term, but the main value will reside in implicit status and external effects on innovating additional technologies centered around smart campus infrastructure.

References

[1] Robert W. Galvin Center for Electricity Innovation, "Microgrid at IIT," 2019. [Online]. Available: http://www.iitmicrogrid.net/csmart.aspx. [Accessed 15 January 2018].

[2] S. Bracco, "Economic and Environmental Performances Qualification of the University of Genoa Smart Polygeneration Microgrid," in *2nd IEEE ENERGYCON Confrence & Exhibition*, Florence, 2012.

[3] University of Minnesota Morris, "Sustainability Goals & Initiatives," Regents of the UNiversity of Minnesota, 2018. [Online]. Available: https://morris.umn.edu/sustainability/sustainability-goals-initiatives. [Accessed 10 9 2018].

[4] University of Twente, "Solar Powered E-Bikes," 2016. [Online]. Available: https://www.utwente.nl/en/organization/news-agenda/special/2016/living-smart-campus/2nd-call-projects/solar-e-bikes/. [Accessed 15 6 2018].

[5] Ohio State University, "eBike Project," [Online]. Available: u.osu.edu/smartcampus/projects/ebike-project/. [Accessed 15 1 2019].

[6] eleven-X, "eleven-X and University of British Columbia Partner for Smart Campus Pilot Project to Monitor Accessible Parking Spaces," Globe Newswire, 30 October 2017. [Online]. Available: https://www.globenewswire.com/news-release/2017/10/30/1160069/0/en/eleven-X-and-University-of-British-

Columbia-Partner-for-Smart-Campus-Pilot-Project-to-Monitor-Accessible-Parking-Spaces.html. [Accessed 9 10 2019].

[7] Texas A&M University, "Smart Campus Transportation," [Online]. Available: https://smartcampus.tti.tamu.edu/. [Accessed 9 10 2019].

[8] Technical University of Denmark, "Smart treash collection," [Online]. Available: www.smartcampus.dtu.dk/cases/smart-trash-collection. [Accessed 9 10 2019].

[9] S. Panchanathan and N. O'Connor, "Smart Stadium Initiative/Smart Living," [Online]. Available: www.smartcampus.dtu.dk/cases/smart-trash-collection. [Accessed 9 10 2019].

[10] Stanford University, "Stanford Energy System Innovations (SESI)," [Online]. Available: https://sustainable.stanford.edu/campus-action/stanford-energy-system-innovations-sesi. [Accessed 10 9 2018].

[11] M. Shahidehpour, "Streetlights are Getting Smarter: Integrating an Intelligent Communications and Control System to the Current Infrustructure," *IEEE Power and Energy Magazine,* vol. 13, no. 3, pp. 67-80, 2015.

[12] University of California Davis, "UC Davis Smart Lighting Initiative," [Online]. Available: https://cltc.ucdavis.edu/project/uc-davis-smart-lighting-initiative. [Accessed 9 10 2019].

[13] Western Kentucky University, "WKU Office of Sustainability - Campus Rainwater Collection," [Online]. Available:

https://www.wku.edu/sustainability/rainwatercollection.php. [Accessed 9 10 2019].

[14] T. Bindi, "Curtin University deploying sensors and analytics to create 'smart campus'," CBS, 2019. [Online]. Available: https://www.zdnet.com/article/curtin-university-deploying-sensors-and-analytics-to-create-smart-campus/. [Accessed 15 6 2018].

[15] W. Sirui and Z. Jiawen, "Universities Develop APP to Rule Morning Exercise," Shanghai International Studies University, [Online]. Available: http://en.shisu.edu.cn/resources/features/smart-campus-exercise-app. [Accessed 15 9 2018].

[16] Cornell University, "Energy Management Overview," [Online]. Available: https://fcs.cornell.edu/departments/energy-sustainability/energy-management-overview. [Accessed 9 10 2019].

[17] Georgia Institute of Technology, "Tech's Campus gets 'smart'," 2015. [Online]. Available: https://www.news.gatech.edu/2015/05/26/tech’s-campus-gets-‘smart’. [Accessed 9 10 2019].

[18] London Economics International, "Estimating the Value of Lost Load," London Economics, London, 2013.

[19] D. T. Shindell, "The social cost of atmospheric release," Springer, New York, 2015.

[20] R. Fu, T. Remo and R. Margolis, "2018 U.S. Utility-Scale Photovoltaics-Plus-Energy Storage System Costs Benchmark," National Renewable Energy Laboratory, Golden, 2018.

[21] T. Chapman, "A Solution to the Plastics Problem?," 24 January 2019. [Online]. Available: https://www.du.edu/news/solution-plastics-problem.

[22] T. Ahrens, "DU increases investment in solar power," *University of Denver Magazine,* vol. Summer 2019, p. 1, 2019.

[23] D. A. Asaleye and M. D. Murphy, "Monetary savings produced by multiple microgrid controller configurations in a smart grid scenario," IEEE, Cork, 2016.

[24] J. Xiaoling, "Analysis of Microgrid Comprehensive Benefits and Evaluation of Its Economy," State Grid Energy Research Institute, Beijing, 2014.

[25] A. A. Adam and A. Badea, "Top-down model for the calculation of energy savings," IEEE, Bucharest, 2015.

[26] L. Steg, R. Shwom and T. Dietz, "What Drives Energy Consumers?," *IEEE Power & Energy Magazine,* vol. 10, no. 1109, pp. 20-28, 2018.

[27] J. L. White-Newsome and B. N. Sanchez, "Climate change and health: Indoor heat exposure in vulnerable populations," *Environmental Research,* vol. 1, no. 112, pp. 20-27, 2012.

[28] D. Hernandez, "Energy Insecurity: A Framework for Understanding Energy, the Built Environment, and Health Among Vulnerable Populations in the

Context of Climate Change," *American Journal of Public Health,* vol. 103, no. 4, pp. 32-36, 2013.

[29] J. Stonewall, W. Hauang and M. Dorneich, "Energy Use and Weatherization Practices: Applications for Agent-Based Modeling to Support Vulnerable Populations," in *Human Factors and Ergonomics Society General Meeting*, Boston, 2018.

[30] M. R. Maghami and A. Maghoul, "Hybrid Renewable Energy as Power Supply for Shelter during Natural Disasters," in *IEEE International Conference on Automatic Control and Intelligent Systems*, Shah Alam, 2016.

Appendix A

Mudd Heat Map

MUDD

Sep-18	DAY	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23	188.82	187.88959	186.1377	183.563	178.4334	181.1775	185.4105	188.4142	185.8533	183.2479	192.9955	192.3986	211.05	196.955	177.7175	185.9095	194.1813	199.8438	205.0518	175.7408	196.8687	184.1736	196.5867	182.4515	188.9181	193.2265	189.3768	185.8266	184.2005	189.8795
22	188.9851	184.7929	192.9964	195.5625	177.521	193.91	193.9758	180.5717	185.258	186.7701	191.4068	191.4514	206.1615	197.357	179.1679	188.0297	198.6842	204.691	202.3619	194.5464	194.2257	191.4119	201.3794	189.904	192.5582	193.1485	191.1717	188.826	183.2274	187.7116
21	190.882	185.58326	183.5234	191.9865	182.0518	200.3435	197.7712	180.0553	184.755	196.1465	198.9835	196.5421	218.0763	201.775	181.9909	185.3045	201.9199	215.5234	208.1248	192.3746	195.28	189.4709	188.7312	207.6884	198.0669	195.4259	191.7044	195.6394	190.7661	188.5037
20	184.7132	187.04632	184.1563	191.4412	183.9927	198.3643	197.1409	181.4516	189.4319	203.8911	205.7491	205.3863	227.4919	203.1552	188.581	197.0239	212.4498	223.6	208.7341	192.3891	211.4069	190.0865	187.8196	209.8043	202.1801	187.0548	205.7605	195.9412	186.8606	190.5044
19	184.8315	193.94346	189.6905	197.4763	186.5639	199.0097	191.592	196.8276	197.1726	216.5799	221.8743	210.6151	223.0206	212.5125	196.7343	198.2318	218.5289	224.8694	211.4184	195.6718	205.1535	190.3495	191.7253	209.4562	198.608	196.9301	209.2974	200.3568	196.4771	189.665
18	193.0181	196.38638	196.9403	206.6735	209.4452	201.6017	202.0067	195.0146	195.8736	217.2406	222.843	218.4867	233.8932	224.9145	199.7553	197.7142	219.2182	229.4693	217.5608	209.4971	209.917	190.0797	196.5695	208.1462	212.9014	207.3544	201.4582	205.4937	205.8121	198.0822
17	196.071	193.92446	195.2859	228.3101	218.7798	207.2656	211.539	203.018	196.0695	238.5453	227.1745	242.1086	250.4064	232.1126	212.4255	202.8645	230.7923	238.9559	230.074	226.2233	232.7985	194.5005	199.1989	216.1744	221.3708	227.0891	201.7085	210.9716	214.3052	205.778
16	195.9539	192.82852	192.2895	240.6978	230.2388	229.1027	224.1104	212.8487	202.3793	253.9051	233.7316	263.4585	262.7712	242.514	210.3329	213.7974	243.4395	247.0126	258.8721	251.5918	239.8233	198.3499	204.4572	228.115	229.2391	246.5617	210.5101	218.8583	225.1852	206.2824
15	193.7971	192.66372	200.0412	252.1789	239.6316	231.0809	239.7408	210.9738	210.7704	271.1897	241.6945	264.3462	263.0611	245.4292	213.0489	215.4695	252.9188	258.1748	260.7233	255.3698	240.2801	207.8861	208.2228	232.1955	240.6846	242.257	220.5699	216.0838	202.3006	206.1292
14	193.9738	191.15667	202.668	247.2131	248.8918	234.7679	252.5735	209.8617	215.3995	266.7596	253.654	262.7584	260.7811	255.3054	210.8143	213.6753	264.1237	271.2544	257.3468	256.1983	234.3434	204.5686	205.1777	224.2488	239.3082	240.8892	229.1878	228.6654	199.3963	215.0217
13	191.7791	194.87161	212.55	240.226	242.4523	226.3844	238.3008	211.3248	208.3031	256.8868	252.5358	260.0252	257.7257	250.37	201.9489	211.9798	270.1124	266.1413	254.5843	251.9383	242.8538	198.5282	196.3212	236.9301	247.0598	253.3324	239.8438	230.9258	194.3584	188.0185
12	182.5429	186.37341	205.8635	236.8552	241.0168	249.9947	230.9528	214.8388	207.5396	255.8639	246.209	252.66	255.8248	249.3796	193.4611	203.6985	249.7784	263.676	254.4838	249.1159	247.5207	193.5222	190.8115	241.4071	229.4376	259.6814	235.9765	232.6988	194.0605	188.3838
11	189.3989	182.48795	207.3678	233.8264	235.3347	248.1559	236.1402	207.8308	211.07	243.0306	241.951	248.1823	246.1819	231.2555	201.5067	200.6955	249.8638	251.7506	259.8247	246.9205	245.165	195.4483	186.1168	243.0402	223.1734	241.4165	234.7901	245.302	199.0811	188.4154
10	196.0903	184.35249	199.113	224.1963	242.9792	239.8513	242.2452	212.7299	198.0489	252.265	225.6999	245.2688	248.1971	245.1836	211.9005	200.2659	248.8326	241.5858	253.0744	243.175	232.0288	198.5337	187.8562	241.1952	221.1503	238.7326	243.0996	231.2053	208.6466	186.795
9	194.8672	189.47442	204.7805	223.9922	231.1734	211.2518	231.2434	199.0486	196.4999	235.7806	233.1894	246.4765	236.0793	242.2915	200.844	191.3244	238.7706	236.0472	244.0415	230.6286	225.7733	203.7466	187.8566	238.3272	215.4205	229.4799	224.7966	225.0825	185.6336	185.3787
8	185.0903	193.9335	195.0314	212.5384	189.451	203.4346	192.5201	176.2296	195.4007	220.8323	219.6079	239.097	221.8008	230.2132	200.1783	190.4841	215.3039	222.3764	232.6142	226.4447	202.1653	196.1983	183.461	225.35	210.952	217.6786	199.4054	215.8666	183.9181	182.4954
7	174.5994	173.96714	192.4252	178.4977	178.3426	190.5408	176.6055	172.1135	170.7957	187.7903	204.7365	218.5924	197.8901	198.4127	183.9711	171.7131	202.7168	187.3043	201.338	216.609	180.6845	183.8053	167.48	203.1522	186.7157	191.496	188.4318	187.3906	179.4678	182.792
6	180.3708	180.77194	196.065	181.1363	177.2151	194.7218	180.3369	182.6881	181.0475	193.6898	187.7288	188.9235	203.3207	199.8305	184.3828	183.9171	182.282	186.5449	189.2744	205.8447	184.1598	188.0534	172.5094	179.1488	185.0966	189.1395	189.2381	192.9754	189.0308	188.0529
5	178.2825	175.46786	193.0048	173.4191	174.0853	178.2807	175.6108	178.7417	175.5647	183.74	178.8166	182.7325	195.944	196.0094	184.7576	171.3287	182.8939	178.2791	184.2927	197.7273	176.3796	187.5641	171.6744	174.4608	185.1573	186.7234	186.5262	186.9445	186.3606	185.1027
4	179.4015	173.02962	194.3813	173.4542	175.0664	179.0711	177.167	177.0172	171.9496	179.9863	178.9393	183.4107	183.1019	196.1745	185.7915	182.2872	184.9275	188.0012	186.3795	201.5755	176.7466	187.9826	172.846	177.8065	186.457	187.8094	187.7159	186.6751	185.1027	186.0872
3	175.4205	172.61205	193.8328	173.9255	175.4771	177.755	175.6493	178.0616	170.0519	182.2974	182.5309	183.9123	185.0324	195.1046	183.2866	192.6311	185.3568	191.9643	202.0058	202.6503	175.9217	188.7744	172.7962	176.3483	185.2087	188.1225	188.3805	187.1159	186.5092	186.219
2	174.4894	186.63952	193.4775	174.9021	182.3017	178.4414	175.8939	175.5493	174.201	181.263	191.1859	195.0715	181.3501	194.9073	183.9448	187.5092	182.817	190.6918	196.3879	203.7595	174.6087	190.5847	173.2425	180.8652	185.3814	187.8005	190.4578	186.7622	185.8772	185.8316
1	178.8093	190.84858	193.896	175.9166	182.0769	177.7173	176.6019	174.7128	190.4288	181.4251	186.2908	201.3145	199.2405	193.4417	177.7846	187.2189	178.3557	189.9886	196.5477	202.3368	174.178	187.8676	171.0822	181.0666	183.8709	188.6248	191.8348	188.2974	186.6479	184.5457
0	184.8243	190.14397	193.5234	189.2735	181.7676	178.7558	181.7119	174.9307	189.0391	193.0292	182.315	199.4777	197.7437	210.6344	199.1519	184.9192	179.6119	190.3141	191.7992	203.0121	174.8784	194.8347	170.6954	196.8617	182.0618	189.3618	191.1776	189.1652	185.8331	184.9866
Total	4473.012	4481.1893	4699.041	4927.263	4864.29	4910.981	4886.84	4594.854	4602.903	5182.156	5101.844	5292.697	5366.146	5245.239	4693.479	4657.993	5187.88	5298.06	5308.916	5231.341	4973.161	4636.321	4484.618	5004.144	4951.039	5079.336	4942.42	4933.07	4639.059	4578.707

Olin Heat Map

Olin

Sep-18	DAY	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23	38.2441	40.704702	56.93693	64.14031	44.72029	48.40305	31.59369	46.38534	68.321	66.66757	72.18306	63.1043	68.66406	52.17638	54.91312	60.42799	71.76172	60.85659	52.99736	49.31313	42.91539	32.91576	50.88332	45.46143	44.91645	41.20248	41.62687	28.41493	25.78401	43.24188
22	43.65026	36.486979	58.44382	58.259	44.14165	53.71611	42.06126	47.49119	72.84002	71.2275	77.99582	66.18201	75.25055	44.87453	55.62864	68.1313	74.33029	67.79909	67.15794	57.13515	47.5617	46.00431	59.69079	46.67083	44.94831	41.20256	41.41527	28.166	25.57874	42.21702
21	36.40784	45.536756	60.59127	68.54405	44.4059	56.17411	42.98974	54.43479	68.2418	74.81996	80.8582	72.5072	89.47351	54.04116	58.50737	64.82525	88.20259	74.63464	73.2545	70.44924	76.81706	44.34691	63.93997	58.90757	45.41316	41.59826	44.85296	28.20932	40.86029	43.4322
20	41.97269	45.183047	62.1162	68.76537	43.46769	59.70943	48.87839	53.77379	72.51868	108.8645	112.1447	83.01787	94.90052	64.67412	67.30406	67.6143	92.67541	120.4476	87.81549	90.28696	72.92425	51.31057	68.95995	67.87382	76.94197	67.37487	82.71938	35.69595	55.65028	41.51582
19	46.57772	48.163532	62.26263	85.48789	42.36521	49.43256	46.53292	55.43838	82.44257	113.4655	123.3357	92.97743	103.2741	100.6811	72.19139	72.48665	102.7421	136.0625	103.5513	115.9538	84.4391	53.71674	75.03597	72.28192	90.73254	85.83526	99.43649	36.26999	69.83174	41.14289
18	51.4814	59.548924	52.28256	96.36797	65.19088	44.99123	55.19202	69.23778	76.49317	117.7854	124.3244	133.1466	106.4145	113.5186	78.59395	76.57346	98.82007	133.2576	98.23045	115.0504	88.48221	66.8485	76.66805	73.75884	81.51347	94.14208	108.4255	47.02516	76.84238	27.3769
17	59.45607	61.855829	59.52576	100.1281	62.84854	70.24003	87.23618	71.61821	73.9337	135.2754	137.8075	144.9527	140.6992	127.1539	85.79672	84.65249	139.6274	137.2239	104.514	123.3907	96.85444	69.9538	73.41715	104.0405	94.78574	102.7189	110.4955	58.58157	85.07307	23.30527
16	59.50984	59.454459	56.36288	111.4476	65.08286	79.05417	91.16272	74.5234	71.38712	139.9541	139.4751	145.6869	148.8368	126.3206	90.60085	90.08307	148.8309	148.4965	135.929	129.1398	103.7409	72.48691	72.27299	111.5275	96.47491	106.8061	115.8012	76.356	84.82324	23.33693
15	62.23394	59.787154	52.9332	113.1516	73.40701	80.56668	91.4718	74.021	78.7382	142.1717	139.4807	147.3458	148.5312	128.6287	86.941	85.53288	148.8403	148.2656	144.2923	130.8705	108.3357	71.69933	74.03444	119.3668	98.89613	114.8315	125.0494	81.67504	56.51766	41.11201
14	64.92103	56.748165	52.40258	113.8423	95.44518	84.10482	99.17683	75.65968	76.51223	141.5168	134.3675	147.7073	146.9854	134.5767	84.85248	87.9671	146.7415	144.8827	137.8518	127.9344	104.0274	71.09433	75.25252	122.8542	97.72934	110.965	121.2185	82.66078	49.38293	39.58676
13	87.17778	55.151345	52.61597	117.151	104.246	89.8453	102.3823	92.92776	73.96467	137.9888	127.0853	142.6733	141.8218	141.4933	83.77628	84.71809	144.2673	138.1894	130.6643	121.1093	110.5969	71.13033	74.0216	114.0583	89.34471	101.3165	110.8778	67.92656	43.26198	26.08685
12	83.69702	47.717617	43.65517	114.7574	107.7479	87.17289	99.46358	88.3969	73.91846	127.061	130.3856	139.012	132.2064	139.7496	75.72398	82.84685	142.978	127.622	128.2198	117.6568	113.0073	66.48892	70.91498	106.5651	84.43709	96.66974	109.9038	61.02699	45.14443	26.3655
11	80.12732	45.254661	44.49023	111.3213	103.4763	87.78614	92.53369	84.63465	68.43335	115.5147	136.8717	132.4484	125.9497	126.0623	70.51516	78.21183	132.6029	117.6474	122.1235	110.4496	108.7341	59.19924	67.86598	103.7219	87.82074	87.36264	101.4442	59.25059	40.56571	25.52701
10	70.18577	36.203066	41.38262	100.7766	97.18501	76.6632	85.77831	75.67054	56.70086	107.0465	125.066	118.1431	115.2543	111.8862	65.68909	74.59343	116.011	108.6662	114.7896	99.91975	92.69868	52.87397	57.06651	94.57056	64.00302	84.89361	92.40828	59.0123	48.64141	24.2571
9	65.25039	41.552686	39.17988	89.09817	83.35212	67.10128	75.2336	64.92051	45.77996	102.5785	112.5161	107.8343	106.1155	99.58462	55.12679	57.21774	102.8449	97.80725	101.6931	89.50604	80.13832	57.67795	57.33258	85.17073	60.63145	57.91097	82.79893	57.23028	24.85186	24.03185
8	55.36577	35.694998	35.52081	72.56439	73.22058	59.63575	66.88848	62.3397	40.96647	79.80253	98.03923	89.76876	90.47189	77.74965	35.13424	42.68931	91.15122	82.1638	83.95095	77.00652	57.76016	28.85168	29.27133	77.72894	54.74144	57.85544	51.58147	51.9661	25.24608	24.36543
7	56.3217	22.667665	22.60774	63.1621	68.07935	42.12445	65.7515	37.27098	28.91451	68.10784	84.91891	72.18024	78.91151	58.64038	30.36655	29.82634	68.72434	72.49864	66.52744	70.69969	35.73479	29.06031	28.78418	72.99501	45.06185	46.84714	44.78448	41.08726	25.767	25.13193
6	24.67912	23.122456	23.04956	60.85138	61.61354	40.25856	69.24699	30.29647	29.23243	51.64981	71.22166	72.41528	65.09604	34.49788	30.93031	29.71631	57.98112	54.28676	57.45776	64.87445	34.06647	30.37814	29.55852	64.8137	36.91122	39.01373	38.30142	38.68725	26.1183	25.5288
5	26.45021	24.924807	24.64199	32.49693	34.64968	31.14719	37.4335	32.29475	31.08035	31.81857	51.12447	40.7379	40.81034	28.86226	32.88662	31.96217	41.41526	28.54338	28.15954	42.94148	28.95254	31.67019	31.69443	47.98627	29.42803	31.96469	31.60092	31.9326	28.2021	27.00873
4	25.44546	24.354142	24.6781	32.85383	34.67164	31.44802	37.9597	32.27424	30.62813	31.871	48.59309	41.19069	44.01066	28.41316	32.73742	40.36824	43.99953	28.55215	29.01663	54.83297	29.19958	31.96959	31.23792	45.50811	29.41947	31.54241	31.79193	31.93515	27.97583	26.38108
3	25.068	24.206851	24.65347	32.27163	34.73445	31.11884	38.08998	32.37669	30.65607	31.17747	50.50579	42.11624	27.17333	27.94776	31.7781	33.86443	51.58709	38.7164	41.51071	31.76089	28.73209	31.94093	30.69064	36.39427	29.7489	32.01294	31.15427	31.7135	28.02175	26.66393
2	25.39559	34.1327	26.70539	31.63707	43.1817	31.64493	38.65627	32.53491	31.19008	31.77186	59.73146	42.95638	35.96297	27.95273	31.78707	49.65103	44.47328	41.89193	47.28211	31.4292	28.53117	31.3594	30.22813	35.90271	30.08354	32.3329	31.29887	31.91266	27.96797	26.74552
1	25.02223	37.96627	37.17373	39.19627	60.52701	39.31286	44.51484	31.80347	41.0165	42.41305	59.53666	50.91242	50.81454	40.84213	31.47401	44.49469	46.60522	57.25822	51.75589	41.93799	37.91807	30.23148	30.56421	35.92314	36.48751	42.1628	35.60975	40.53147	28.01271	26.18041
0	34.25963	44.848856	41.3205	54.77635	61.28286	48.10235	53.28442	31.26819	44.99705	72.38836	67.80794	70.30031	64.13245	69.38545	43.47549	51.23517	50.21294	69.74463	60.34308	50.07549	46.83812	37.45289	30.62136	45.65421	42.89506	45.04056	40.71026	41.29512	28.37771	26.97155
Total	1188.901	1011.2677	1055.533	1833.049	1549.043	1389.754	1543.513	1351.593	1368.907	2142.939	2365.377	2259.317	2241.761	1959.713	1386.733	1489.69	2247.427	2235.515	2069.089	2013.724	1659.006	1171.562	1290.008	1789.727	1493.366	1593.603	1725.308	1148.563	1018.499	727.5134

Nagel Heat Map

Nagel

Sep-18	DAY	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23	242.3695	240.02576	246.7409	237.6895	222.2079	222.0304	221.8055	241.2152	241.3623	240.1826	247.6534	250.2116	254.4747	244.5443	244.905	240.7898	241.4459	238.369	240.1775	221.2711	225.2021	221.2825	237.0674	224.2474	224.2823	225.4439	225.2291	224.7244	224.6204	221.8058
22	242.1453	246.35371	232.4051	238.259	221.5495	222.4766	222.378	249.0085	247.3475	244.2227	245.4159	232.3517	232.7177	251.5957	238.7588	240.0605	237.281	237.7136	259.8155	220.9154	239.1835	223.7659	245.7542	223.7802	223.6205	224.2925	224.7955	224.2295	224.6525	222.7683
21	242.3922	231.28728	239.8088	240.6427	222.3001	228.1124	241.0345	231.0723	235.238	241.6715	238.3081	243.1285	242.8938	234.0199	236.6007	239.3133	238.6251	238.5686	248.5357	240.7174	243.0798	247.9901	245.997	224.463	224.8821	222.664	224.3557	224.2932	224.0298	222.1845
20	236.9407	238.82113	239.0931	240.0858	222.384	241.6613	244.6846	239.3939	238.8077	239.9344	239.4227	252.0922	255.7004	248.7087	256.0657	255.1354	252.4131	253.3712	246.1713	231.5592	232.1579	233.3366	241.0429	236.0149	225.5978	225.0352	223.5001	222.7005	240.1445	222.2946
19	236.006	238.16856	239.2844	238.2882	221.9177	255.2279	236.9975	247.3905	238.564	257.2785	259.6714	261.3569	258.8454	257.0033	256.988	257.1521	261.1831	258.4584	255.8138	241.6231	241.2022	240.5958	254.9308	253.8598	226.7607	224.9537	233.9143	222.3856	229.3137	223.0803
18	238.8284	236.80278	237.3874	237.3314	221.5228	238.6089	242.267	254.7353	249.7021	259.0156	261.0872	258.1582	257.1779	255.5937	259.2917	257.7069	260.0343	260.2433	260.3055	242.8949	239.2411	249.6485	259.134	237.8091	227.6504	225.9412	252.9407	223.0164	240.2094	222.2608
17	241.2237	241.29306	238.3381	240.134	224.182	241.1001	246.5115	262.6267	261.7629	261.9285	262.9008	261.3681	262.9872	259.0414	260.7961	263.1881	261.3866	262.2784	261.9106	258.2087	253.8266	263.3274	261.4823	246.0776	227.7672	229.0536	232.8144	225.0747	238.2738	225.2565
16	240.3235	240.10525	237.2968	239.0845	225.7921	241.7989	264.2891	263.2542	262.432	261.9347	259.7465	263.5525	263.5077	263.3414	261.7778	265.6266	263.2362	263.3565	250.7619	261.8122	263.8225	262.2276	265.5721	243.7138	228.7063	245.9049	241.0162	228.734	239.6322	227.001
15	236.584	237.8546	237.3632	242.496	225.2629	249.7654	262.076	263.3044	263.0381	258.8145	257.3841	259.7467	257.6562	260.794	257.6871	262.2685	264.1614	262.4268	254.8956	260.3683	262.0846	260.8871	265.9091	243.072	225.6205	242.918	240.5904	227.9383	241.2536	227.6936
14	237.2751	239.13748	237.4591	242.3415	252.6655	256.9812	261.8169	258.9584	261.631	260.7992	258.83	257.7698	259.1532	261.6586	258.6071	264.1815	264.5412	260.0373	258.6789	260.652	262.7356	262.4178	261.883	243.827	225.2801	245.6276	240.1394	228.1074	239.2445	227.5013
13	238.2956	236.73483	237.3994	240.8711	237.3057	257.7869	260.5592	258.2473	263.5914	259.5034	256.4583	260.4996	256.3033	257.6732	258.8724	261.4288	263.4667	258.162	259.8346	258.8025	257.3378	261.1589	257.9849	243.1475	225.7412	260.4354	240.2603	228.3248	239.8348	226.9893
12	237.949	236.11828	237.7241	241.4468	260.6286	256.9773	258.607	257.6234	259.0388	258.382	256.8478	260.1366	256.3681	257.5305	260.8746	260.526	258.1285	259.5038	258.0996	259.8078	260.3313	262.627	258.9761	245.1844	225.2196	237.6344	241.0022	227.7858	239.5574	226.4419
11	236.8128	236.00703	239.5305	237.9657	257.6412	258.6664	259.1981	257.9108	262.4235	260.4768	257.0156	257.4102	256.8939	260.5611	256.3437	261.6173	258.1594	260.3603	261.8755	262.5563	261.8005	259.5651	241.166	261.1741	225.8087	227.7356	256.5186	227.1747	240.7868	225.6866
10	236.231	236.11366	239.968	239.8345	257.1896	258.3307	262.2041	258.2144	260.8752	251.3385	256.3881	259.9092	258.2665	257.2908	256.8197	259.8896	259.2911	262.4059	258.8963	258.6969	263.3794	256.7681	242.0603	262.7406	225.8143	226.3075	230.1473	226.6022	249.8667	223.8012
9	238.2206	236.56798	238.3744	241.8741	257.408	222.3742	254.693	259.1574	260.1532	238.9504	259.9821	258.7823	255.7199	259.4446	259.7189	259.1852	261.8823	262.2269	257.3393	258.2997	263.6103	259.5059	244.8078	245.7098	225.6056	224.8039	226.9623	228.1279	224.032	222.3744
8	245.3341	241.44134	238.2911	244.5411	223.4446	221.9712	222.2167	237.9238	260.6725	255.7658	257.3259	259.3815	244.4619	258.3508	262.6388	260.6309	257.5941	261.0134	257.487	258.5206	223.7146	258.4794	245.9611	224.1785	226.0553	225.7106	226.7248	227.1561	223.2296	222.1012
7	237.5782	246.27637	241.2609	237.128	223.2212	221.7507	221.4958	220.8423	224.0758	253.4271	260.6645	258.5125	240.1014	225.867	234.1908	259.9538	260.8845	255.0859	255.8531	256.9052	224.1425	236.5991	222.0184	226.7671	226.1747	227.6082	228.1308	227.2553	224.1378	221.1164
6	224.46	220.60314	220.4223	221.0959	222.4483	221.9192	222.247	220.293	224.9971	223.2426	246.4676	234.4927	243.7229	226.9307	224.5695	224.6685	243.2961	222.42	220.924	230.6197	221.162	221.8463	224.0501	228.2821	224.008	226.7762	227.5157	227.5015	224.1071	221.3878
5	225.644	221.45495	231.4868	220.6479	221.7452	221.6125	220.7512	221.8715	226.6992	223.7072	223.7822	224.5969	245.6663	224.973	226.3481	224.4969	222.5757	222.8375	221.2445	238.7925	221.4051	223.3003	225.1065	227.2152	223.4787	223.7096	225.8299	226.4565	225.3937	222.4229
4	224.8948	220.90211	240.6518	220.1333	220.7849	220.5489	219.5498	221.7989	227.0374	222.29	223.2947	221.8877	241.6602	223.3738	225.9898	224.5546	221.9101	219.9254	219.8758	238.2915	220.0699	222.8986	224.9957	245.4362	222.5403	222.1574	221.6002	221.5957	223.9362	223.0044
3	223.3564	219.4729	247.18	220.2091	220.43	220.4283	220.6803	221.0863	224.5599	222.4637	223.5599	222.935	242.4698	223.5859	225.0758	224.452	237.8962	226.3906	220.0914	237.8333	220.6968	222.5935	223.9083	226.4996	222.5891	221.5263	221.8484	222.0898	223.0158	221.6601
2	223.1624	219.11427	228.8829	220.1268	220.6451	220.7508	221.1218	220.7646	223.9724	223.0761	223.9705	223.1651	223.9077	223.9366	224.4582	241.1658	239.421	237.5964	235.3536	245.3107	221.0373	222.3042	222.9156	224.8973	223.4161	221.954	222.6437	223.1447	222.7257	222.1262
1	223.4037	229.1492	239.9716	221.1773	226.3458	221.664	222.5662	222.9984	225.207	225.0797	244.9861	242.6452	223.7974	224.6723	225.421	251.2002	249.7251	244.2889	241.2737	233.6394	221.8673	222.6231	222.2569	225.8374	223.392	223.3986	223.658	224.5673	223.711	222.5557
0	222.8391	242.01116	239.6947	221.6033	240.7415	221.9965	222.4969	221.6991	233.4516	224.1225	242.0309	244.1696	239.3156	228.0071	235.3625	233.8696	230.7583	236.7427	242.8994	242.2643	222.0779	221.3878	221.1196	224.9899	224.5649	224.6003	224.876	225.5833	223.5064	223.7758
Total	5632.27	5631.8169	5706.015	5625.008	5549.764	5644.541	5732.247	5811.391	5876.64	5867.608	5963.194	5968.26	5973.769	5888.498	5908.162	5993.062	6009.298	5963.783	5948.114	5920.363	5765.169	5817.137	5816.1	5688.924	5404.576	5506.193	5557.014	5414.57	5549.215	5367.29

Daniels Heat Map

Daniels

Sep-18	DAY	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
23	147.4163	150.50998	158.8069	179.7467	169.2423	167.4791	149.4145	145.8096	159.8348	168.8426	167.5925	170.299	177.2228	154.3607	151.6081	166.9323	173.935	188.6137	163.692	173.9827	188.4486	162.624	169.8225	168.6359	171.8736	179.3754	169.4432	173.5672	156.862	161.7295
22	151.8264	153.10922	157.7775	192.8715	187.8892	183.9829	150.4969	148.4235	159.298	190.1105	194.1243	197.9264	189.328	159.3827	154.5396	156.7658	192.6314	198.9174	192.3401	195.5755	189.1676	173.5468	164.8491	193.6998	196.4981	194.3688	190.3311	176.1847	165.5261	151.1021
21	154.9048	154.41871	159.3577	195.4562	186.6428	188.3892	154.4068	150.8099	160.2468	213.3253	206.8121	231.6642	203.1409	164.3164	166.2757	160.4819	218.3369	222.999	226.1929	205.8126	197.6267	182.9041	167.1944	219.8657	225.4666	216.653	206.1445	178.5953	171.1862	159.5084
20	154.3945	154.33982	161.8686	199.4386	192.2758	191.9281	157.3637	157.0899	182.1768	228.6515	218.7947	243.2512	217.2797	167.7473	175.9715	163.6233	233.36	224.3898	240.2735	222.3529	198.1669	183.5904	186.767	230.7986	238.9533	228.5308	223.3423	179.1983	172.6196	179.456
19	149.8167	152.1381	156.4263	202.1391	195.972	194.6373	155.7273	177.0184	177.5703	247.3495	226.9453	266.5146	248.7423	181.8441	175.601	168.7161	274.2056	256.8685	287.9606	243.7222	223.8136	185.0531	190.3777	273.839	249.8504	282.7637	254.8267	213.7151	174.355	183.8819
18	148.3441	146.4052	163.312	195.1892	199.366	196.6962	173.2659	181.9997	170.6885	254.0279	238.2877	277.1662	269.2173	205.2855	172.281	161.5672	284.8545	268.1336	297.3615	299.8115	221.2827	184.0405	177.0166	280.5837	260.7071	286.812	272.1325	216.6497	171.712	169.3748
17	146.6843	142.83121	160.3109	214.5455	231.1896	222.9539	209.3239	190.3935	164.1431	279.4299	280.6732	285.3033	294.5333	222.3365	175.4931	155.0347	293.075	284.4686	292.6677	370.1585	231.2532	187.7385	174.0981	283.3627	288.624	285.8577	288.2235	236.7282	170.283	169.3871
16	161.5704	143.37147	162.5645	249.0063	248.898	227.3583	222.4873	189.8637	165.4605	291.6073	286.8398	295.2906	294.0893	243.4777	174.3766	179.4268	320.7082	293.4511	295.9437	357.0022	252.4583	198.4155	179.2261	291.9039	299.5741	298.52	279.4495	273.5747	169.5683	173.0291
15	174.9028	143.64475	164.2106	274.0711	259.7569	237.9429	233.2131	181.6253	161.4913	298.7254	295.0204	306.3527	298.5766	262.9087	172.6181	176.798	352.0369	306.0828	306.4054	315.0249	260.3325	201.0583	183.1311	309.4817	313.3494	316.0783	284.2284	297.4778	172.722	182.0646
14	171.2249	144.53943	179.9386	273.4055	284.4679	236.5365	240.8586	182.4421	162.4473	298.6876	299.4434	309.4849	313.7712	259.8178	175.326	179.0591	344.8772	311.7749	305.8745	294.1593	265.2707	202.3239	186.0088	305.1417	351.5984	307.434	294.3448	311.9889	175.3512	193.1749
13	170.1287	142.54498	146.6894	259.275	283.7063	239.2943	254.7128	185.2277	161.9784	291.794	304.2765	300.5151	314.6245	264.0749	177.1644	182.1553	293.2632	313.1312	296.0992	300.2643	277.7243	201.5045	186.6107	307.5363	367.222	315.0189	304.3022	305.2017	178.9064	193.3676
12	166.1692	145.41191	156.2636	261.3535	272.1003	240.1648	247.3184	189.8702	164.3866	293.7029	292.3487	295.1769	304.3377	270.8474	182.3943	178.3297	307.5864	310.8499	296.3015	306.2578	280.4169	200.5676	176.3957	302.608	364.4238	330.7587	309.1904	298.9347	181.0479	181.9921
11	161.3358	144.77235	146.5568	259.9064	266.3922	235.8933	243.4248	191.0199	161.5439	302.6603	291.8815	299.8974	302.59	271.7203	184.5579	184.5788	310.3642	307.6956	294.563	311.432	288.58	197.5898	172.1506	313.2927	345.6681	339.8037	296.3586	300.8222	179.3149	182.6297
10	164.0491	144.0142	150.3463	244.5317	257.6716	229.0768	243.7708	193.4699	163.9624	300.4956	287.4326	297.5143	298.7055	275.3533	183.777	155.3305	310.8455	300.1008	297.8795	310.576	276.588	200.5781	172.6602	303.4509	328.818	318.88	292.8197	300.271	178.4124	180.943
9	160.3352	143.25692	152.3491	242.1499	237.7763	220.4462	225.8446	188.2472	164.0249	274.714	268.011	266.9297	280.2983	274.6191	172.4487	150.6946	319.4913	278.9133	290.3413	277.5131	294.8918	201.366	170.1452	290.7128	300.2185	291.642	268.3026	292.7533	181.3258	177.5876
8	166.878	147.73523	155.8623	239.2335	230.4861	211.9516	209.9961	188.1536	167.7278	254.4845	260.5814	253.7286	266.4898	262.7072	169.6772	152.2832	278.7117	268.4928	269.3587	268.8881	291.6628	221.8252	180.5178	270.7666	282.8004	267.0262	245.3695	276.3811	181.1105	178.6967
7	151.8506	139.75892	143.9918	194.529	194.1669	182.5426	190.1679	169.6832	160.1454	221.2835	203.586	217.0413	215.6243	226.4964	164.161	143.4651	266.4101	218.8482	231.0873	215.7495	261.9016	208.5056	175.4157	232.8811	224.8901	218.6271	198.5697	218.4174	172.6499	164.6249
6	151.7114	141.37388	144.6863	192.6499	180.7762	169.5885	166.1825	164.7866	139.0912	220.1207	186.5011	197.7184	192.0866	198.4678	166.4041	149.6871	247.4481	199.3793	212.5467	188.1425	227.3674	206.1372	179.6751	205.6594	201.6998	176.6972	166.949	165.8046	178.0736	162.9787
5	140.6771	145.70426	144.7181	142.6771	147.4829	125.5795	150.8985	149.9037	143.3996	144.5761	141.8968	146.1357	138.6287	136.9223	153.708	145.1603	136.632	138.1204	141.9179	142.0009	150.7528	165.2525	153.9267	136.5656	137.0995	134.3165	132.6235	131.2264	153.8775	144.4143
4	142.2258	147.3552	147.273	152.6746	152.5091	128.8317	144.7073	151.6061	143.11	126.1312	131.6855	136.42	131.5781	127.4301	152.1746	145.1728	126.2567	126.5876	133.9901	137.6472	141.783	166.1227	153.6655	129.7642	131.9695	128.9614	124.8661	127.3098	153.0913	147.1714
3	139.2175	146.84542	147.3395	152.282	151.2499	128.845	143.9239	150.549	143.449	125.7813	131.6168	135.1193	128.909	126.4368	152.0919	146.0572	125.9846	127.6219	130.749	134.0809	135.8036	164.752	153.5859	126.0109	130.4575	125.3941	121.5015	120.8873	155.0243	145.6879
2	137.5638	146.50143	145.8564	129.8038	137.4384	131.5977	132.6624	150.1345	146.1606	130.5376	137.1464	138.1143	132.0732	134.6298	154.6287	145.6973	130.4656	135.8149	137.1668	139.0469	142.8077	163.6837	151.7236	134.3776	135.8883	131.2269	126.572	133.6811	153.6025	149.857
1	137.599	146.24583	146.772	145.7854	156.4064	145.3569	155.2382	149.6488	144.4016	153.9722	163.8942	152.9472	156.1132	166.6939	151.497	145.9185	154.2902	162.1486	160.2957	164.1324	161.1998	164.6204	150.0527	167.3866	149.7991	161.2969	146.2325	158.1061	154.7808	149.7989
0	138.5184	148.70342	146.0522	156.3963	166.9536	151.2454	161.9499	149.1543	145.7788	162.7777	172.6557	164.2513	169.2912	178.739	153.4848	146.8461	161.8979	181.3695	173.2389	172.3442	173.2653	169.2576	149.4548	176.0994	165.9376	172.4173	170.7988	167.7382	152.5455	149.9064
Total	3689.345	3515.5318	3699.33	4949.118	4990.817	4588.319	4517.356	4076.93	3812.517	5473.789	5388.048	5584.763	5537.251	4936.616	4012.26	3839.782	5857.668	5624.773	5674.247	5745.678	5332.566	4493.058	4104.472	5654.425	5863.387	5708.461	5366.922	5255.215	4053.949	4032.365

Appendix B

Campus Map with Solar Installations

Update to System Parameters

2019/2020 Project Completion	kW Size
Ritchie Center	748.11
Hampden Center	229.02
Anderson Academic Commons	189.09
Sturm Hall	116.16
Schwayder Art	54.87
UTS	26.4
Fisher Early Learning Center	19.8
Frontier Hall	56.76
Seeley Mudd	91.41
Boettcher West	154.77
Knudson Hall	26.4
Ammi Hyde	33
Central Receiving	26.4
Cherrington Hall	41.25
AOB	49.83
Driscoll South	109.56
TOTAL	**1972.83**
2020 Project Completion	
Career Achievement Center	62.7
First Year Residence Hall	65.5
TOTAL	**128.2**
All Sites	**2101.03**