Doubling Energy Efficiency at the University of Michigan by 2030

Final Report

By: John Dooley, Whitney Johnson, Divyesh Kumar, Benjamin Kunstman, Kristin Steiner, and Brittany Szczepanik

Faculty Advisor: Dr. Gregory Keoleian

An opus submitted in partial fulfillment of the requirements for the degree of Master of Science in Natural Resources and Environment at the University of Michigan.

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List of Abbreviations

ASHRAE—American Society of Heating, Refrigerating and Air-Conditioning Engineers

Btu—British thermal unit

CHP—Combined Heat and Power Partnership

CPP—University of Michigan Central Power Plant

DOE—United States Department of Energy

ECA—Energy Conservation Account

ECO—Energy Conservation & Outreach

EEI—Environmental and Energy Initiative

EIA—United States Energy Information Administration

EPA—United States Environmental Protection Agency

ERV-Energy Recovery Ventilator

EUI- Energy Use Intensity

GDP—Gross Domestic Product

GHG—Greenhouse Gases

IAEE—International Association of Energy Economics

JCI—Johnson Controls, Inc.

kWh—kilowatt hour

LEED—Leadership in Energy and Environmental Design

MLB: Million Pounds (used for steam measurement)

MMBtus—Million British thermal units

OCS—Office of Campus Sustainability

OSEH—Occupational Safety & Environmental Health

SNRE—University of Michigan School of Natural Resources and Environment

UM—University of Michigan

Executive Summary

Approximately 84 million Americans spend their days in colleges, universities, and public or private primary and secondary schools.[ii] The commercial building sector, which includes educational institutions, accounts for 18.44 percent of overall energy consumption in the United States.[iii] Education buildings are ranked third highest of all commercial buildings, consuming over 600 trillion Btus of energy each year.[iv] Given these consumption levels, educational institutions have an opportunity to make a significant impact to increase energy efficiency in this country. The University of Michigan (herein, also "the University" or "UM") has been working diligently to be leaders in this charge.

In 2012, the Alliance to Save Energy proposed a goal of doubling energy productivity in the United States by 2030, thereby getting twice as much economic output for every unit of energy input.[v] This goal inspired Johnson Controls, Inc. (herein, "Johnson Controls" or "JCI") to approach the University with a Master's Project, enabling a group of students to learn from the expertise of Johnson Controls, and to be active participants in sustainability efforts at the University of Michigan. Additionally, the findings and recommendations developed to increase energy productivity on campus should likely contribute towards the University's existing sustainability goal of reducing greenhouse gas (GHG) emissions.

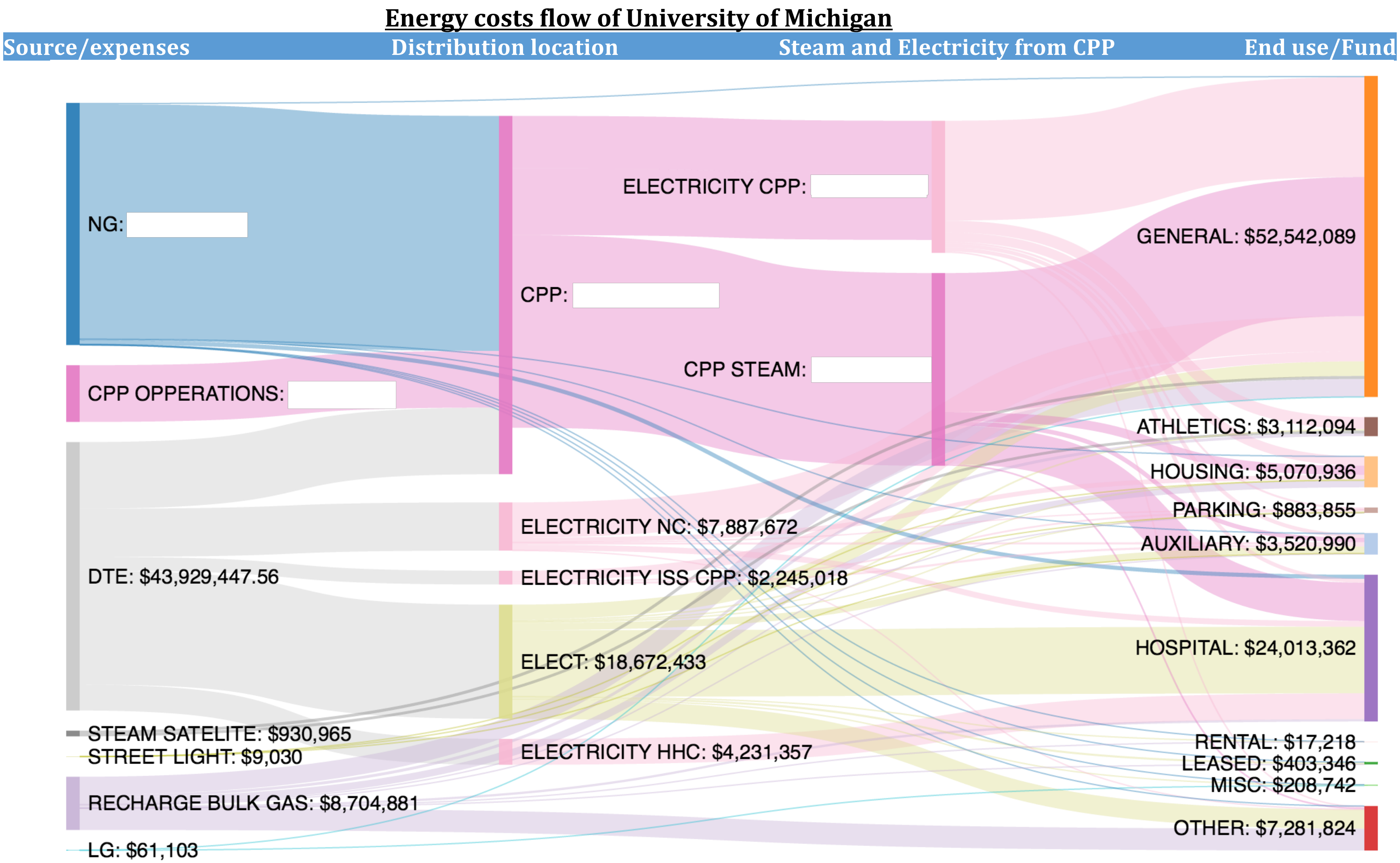
This project seeks to harness the knowledge, technology and best practices honed by Johnson Controls from decades of experience in energy conservation projects, as well as the expertise from the University of Michigan, including various professionals and organizations that actively work towards energy efficiency measures on campus. Leveraging these and other resources, our six graduate student member team (Appendix A) analyzed the University of Michigan's current energy demand and management. We learned about the extensive work the energy management team has already been doing for several decades in some areas on campus, and about what opportunities there are for improvement.

Our master's project team identified several recommendations for furthering the collective energy efficiency performance of the University, as well as recommendations on measures that can be taken in the Samuel T. Dana building (herein, the "Dana building"), which serves as a case study for the project. The key findings and recommendations, both campus-wide and for the Dana building, are detailed here.

Key Findings

Campus-wide Energy Consumption and Costs

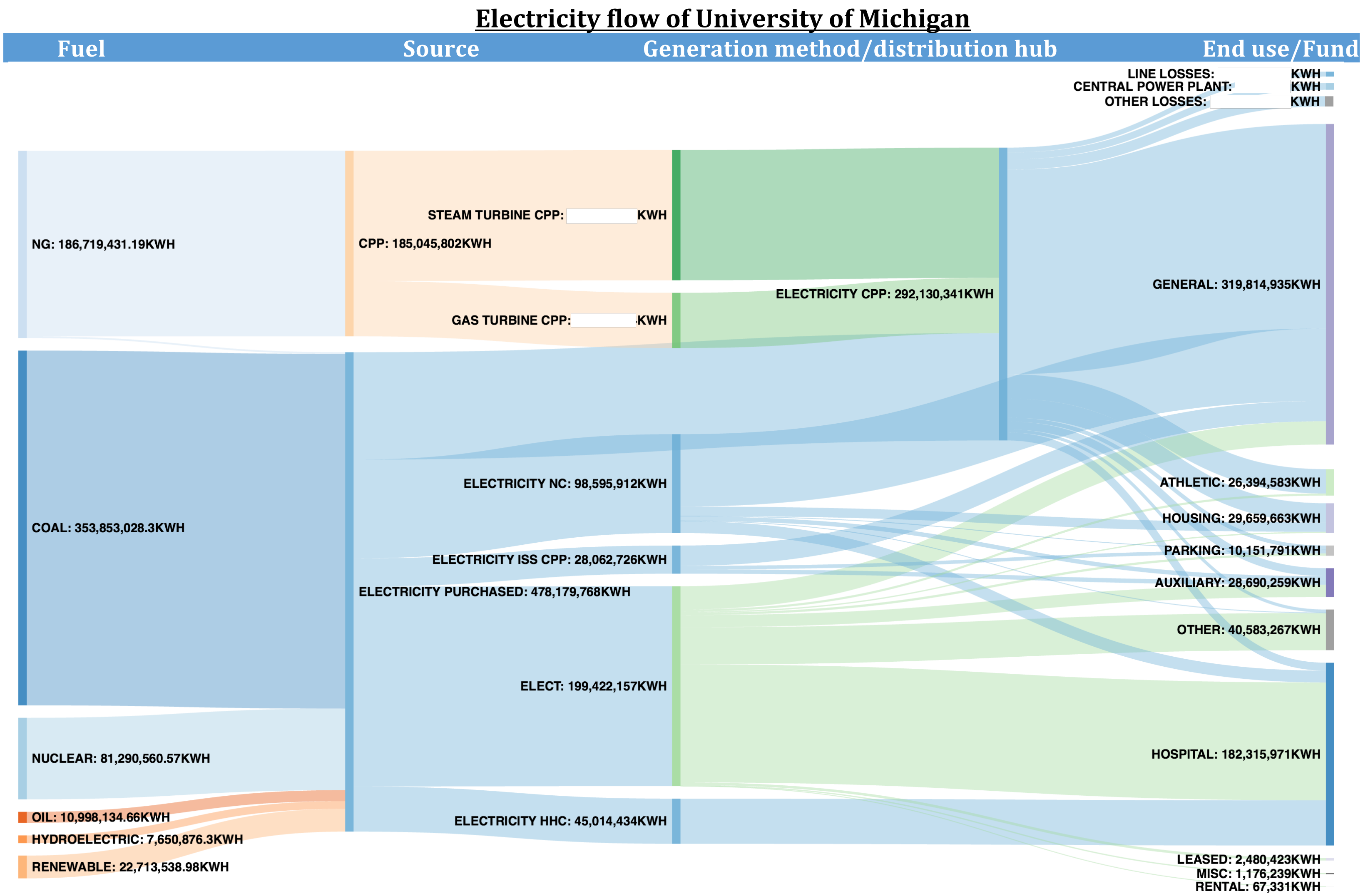
In 2014, the University of Michigan consumed 641 million kilowatt-hours (kWh) of electricity, roughly equating to the electricity consumed by over 78 thousand average Michigan households.[vi,vii] The University pays over $97 million annually for its energy needs, which is approximately 1.5 percent of overall campus expenditures.[viii] To identify where the flow of both energy and costs are coming from—and to where they are going—two Sankey diagrams were developed. The flow of energy costs on campus is presented in ES Figure 5 and a flow of the electricity is shown in ES Figure 2.



ES Figure 1: Flow diagram of energy costs for FY 2014. [ix] The far left side of the diagram breaks down the cost by the fuel source and the middle-left band represents how much energy is purchased by each substation before it is distributed to campus. The center right band illustrates the breakdown of steam costs and electricity generated by the CPP. The far right band breaks down energy cost by fund. As illustrated in this flow chart, the General Fund spends the most on energy, followed by the Hospital Fund and then the Other Fund. The Hospital and General fund use most of the steam generated by the CPP. The colors in the diagram are for guidance in following the financial flow of energy expenses. [x] Some data has ben removed for proprietary data protection.

The financial flow diagram in ES Figure 5 shows the cost of energy, electricity and heat to the different funds, shown on the right side of the diagram. These ten funds represent different areas of the campus and are separated based on their funding source. As is evidenced by this flow diagram, nearly half of the money spent on energy is coming from the General fund, which houses most of the academic buildings on campus. By following the flows to the left, the source and amount of energy can be identified. For the General fund, for example, most of their costs are associated with electricity production from the Central Power Plant (CPP), who in turn purchases their natural gas from DTE Energy (on the far left). Most of the other funds purchase their electricity directly from DTE Energy (DTE), and this represents approximately half of the overall energy costs.

ES Figure 2 illustrates where the energy is coming from and where it is going. The Funds are on the right side of the diagram, and the source of the electricity is similarly described by moving to the left. For example, the General fund consumes approximately half of the University's electricity (indicated by the bar on the far right of the Sankey diagram). Moving backwards, we see that approximately half of the power comes from the CPP, while the other half comes from DTE Energy. The electricity at the CPP is generated by two different types of turbines—steam and gas. The amounts generated can be seen in the tan section of ES Figure 2. This diagram illustrates that the majority of electricity consumed on campus is generated by coal from DTE Energy (on the far left in dark blue).



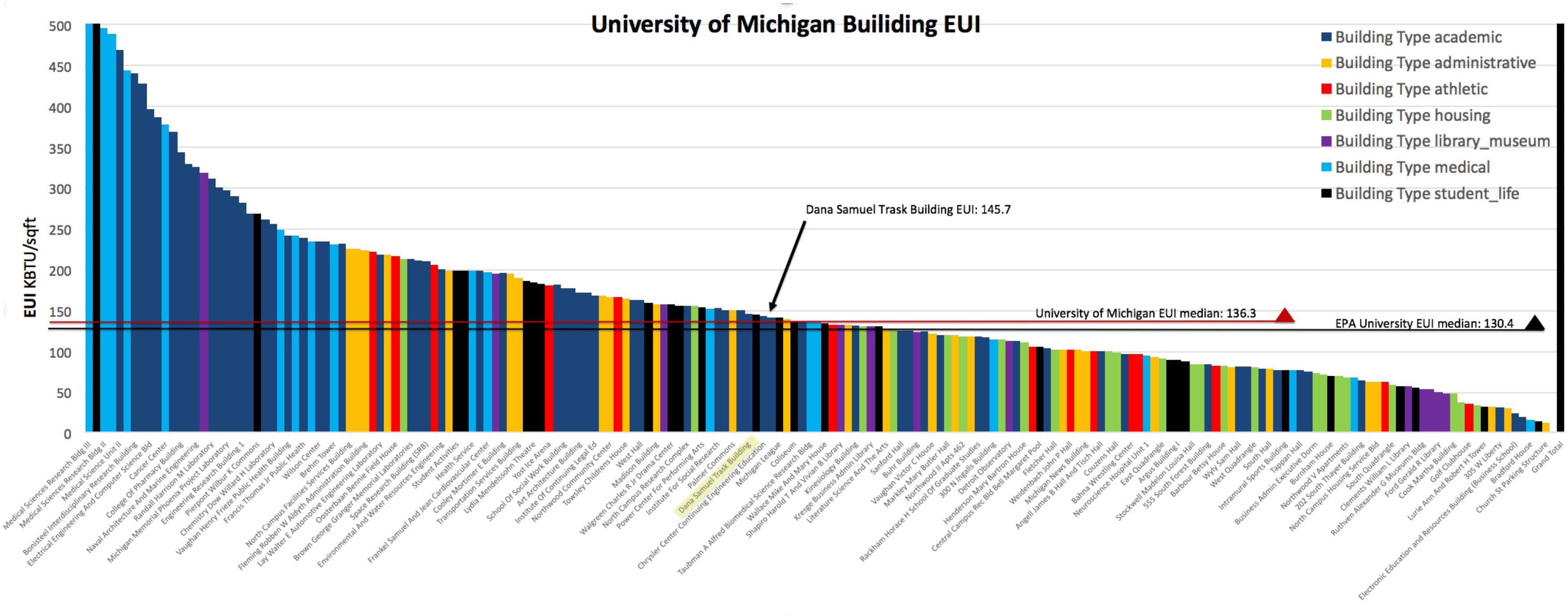
ES Figure 2: Flow diagram of electricity purchased, generated and consumed, by fund. Data is from UM annual report FY 2014. This diagram shows that the CPP supplies about 75% of the General fund, while the rest is purchased from DTE Energy. The far left side of the diagram breaks down the kWh by the energy generation source from DTE Energy, which is approximately 75% coal-based.[xi] The middle-left band represents the total amount of electricity purchased by the University. The center band illustrates the five substations where electricity enters the campus and the additional electricity that is generated by the CPP. The far right band breaks the electricity consumption down by fund. As is illustrated in this flow chart, the General fund consumes the most electricity, followed by the Hospital fund. The Housing fund represents the "Student Life" fund. Some data has ben removed for proprietary data protection.

Building Energy Consumption

To understand building energy consumption on campus, all 188 University buildings were compared based on their Energy Use Intensity (EUI) in kBtu/sqft, which is illustrated in ES Figure 3. In this diagram, the University's buildings are arranged by their EUI, from highest to lowest. Two lines represent the national college median EUI (130.4 kBtu/sqft) as reported by the U.S. EPA, and the University of Michigan's median EUI (136.3 kBtu/sqft). Additionally, the Dana building was analyzed in this report as a case study. It's EUI is of 145.7 kBtu/sqft is highlighted on the figure.

Although the University of Michigan is performing slightly above the national college median, the University is located in an area that requires more energy due to the wide temperature variations and extreme cold associated with their climate zone, which is climate zone 5A. Therefore, although the median is slightly above the college median, this is not a fair benchmark for the University's overall building energy performance. Currently, no reports indicate the EUI college median specifically for climate zone 5A.

To better benchmark the University's EUI performance, Johnson Controls LEAN building analysis tool, which normalizes buildings for weather conditions, was used to analyze 20 campus buildings. The results from this analysis are described in the next section Campus-wide Recommendations.



ES Figure 3: University of Michigan's Energy Use Intensity (EUI) by Building Type, for the year 2014.

Current University Sustainability Goals and Organizational Structure

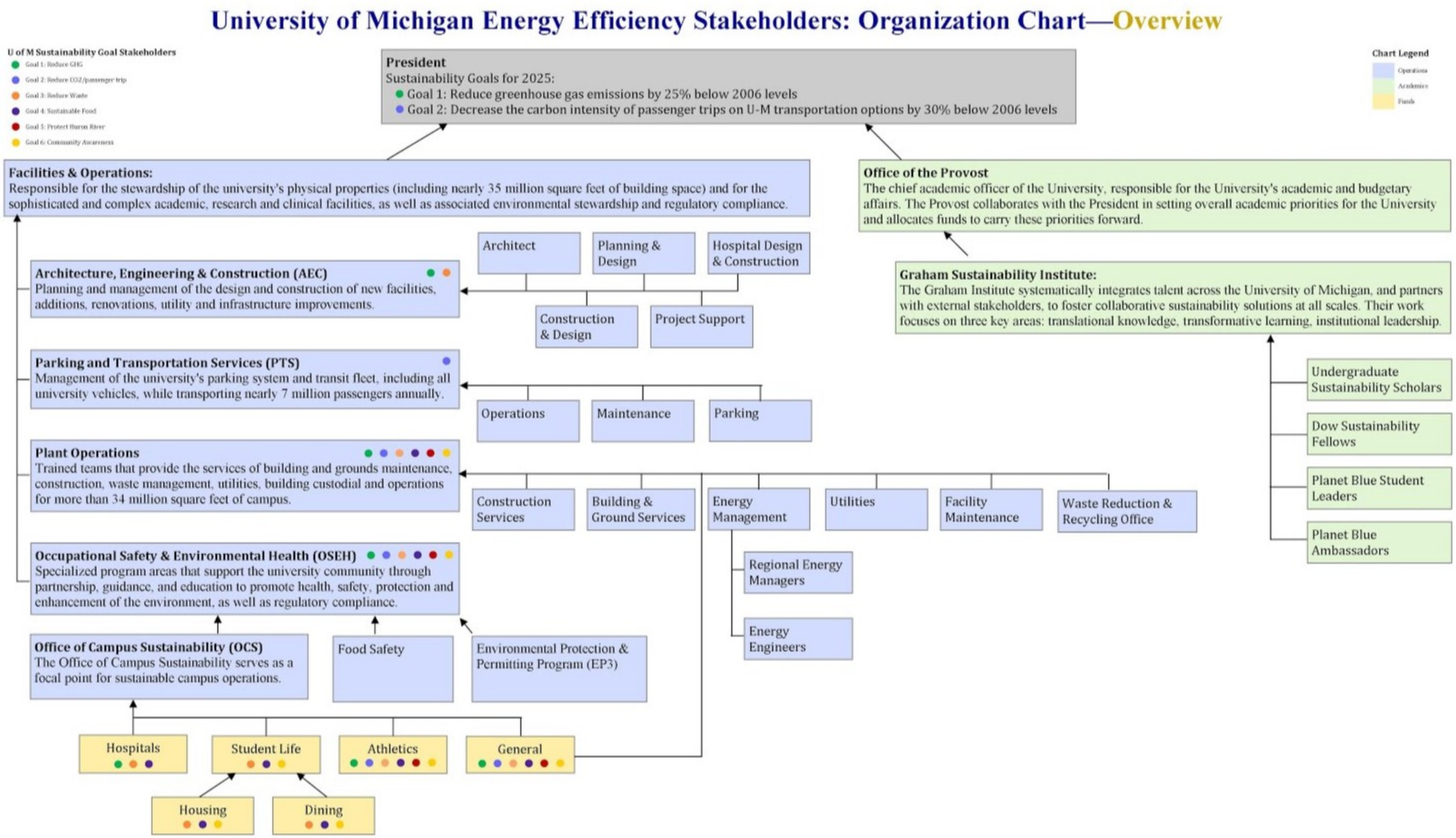
In 2011, then University President, Mary Sue Coleman, committed to achieving six campus-wide sustainability goals in four categories: Climate Action, Waste Prevention, Healthy Environments, and Community Awareness. These goals are outlined ES Table 1.

ES Table 1 Current University Sustainability Goals. All goals use 2006 levels as a baseline and are intended to be reached by the year 2025.

Color Indicator	Category	Goal
●	Climate Action	Reduce greenhouse gas emissions by 25%.
●		Decrease the carbon intensity of passenger trips on U-M transportation options by 30%.
●	Waste Prevention	Reduce waste tonnage diverted to disposal facilities by 40%.
●	Healthy Environments	Purchase 20% of U-M food in accordance with U-M Sustainable Food Purchasing Guidelines.
●		Protect Huron River water quality by minimizing runoff from impervious surfaces and reducing the volume of land management chemicals used on campus by 40%.
●	Community Awareness	Invest in sustainability culture programs to educate our community, track behavior and report on progress over time.

The University of Michigan has two branches that report up to current University President, Mark Schlissel, regarding these sustainability efforts: Facilities & Operations and Academics. These two branches, and their subsequent departments, are shown in ES Figure 4. The sustainability goals that the University has identified as a focus for each branch on the Facilities & Operations side are indicated by the color associated with each goal in ES Table 1. The sustainability goal, to reduce GHG emissions by 25% by 2025, is indicated with a green dot and is the most applicable to this study's goal of doubling energy efficiency. The organization that is most applicable to this study is the Energy Management team, housed under Plant Operations. The four funds specifically targeted in this study are indicated in yellow at the bottom of the figure: the General, Hospital, Athletics and Student Life funds.

There are two important things to note from ES Figure 4. First, the General fund is currently the only fund that the Energy Management team works with, which has huge implications in terms of increasing building efficiency. The Energy Management team audits every building in the General fund every few years and reviews over 100 energy conservation measures (ECMs) that can potentially increase efficiency. In examining energy consumption in these buildings and implementing these ECMs, they have been able to increase efficiency in the entire General Fund by 8 percent each year, for several years. Second, according to the University's description of goals and the departmental responsibility for these goals, the Student Life fund is currently not required to focus on decreasing GHG emissions (as indicated by the lack of a green dot in the Student Life fund).



ES Figure 4: Organizational Chart Overview Data.

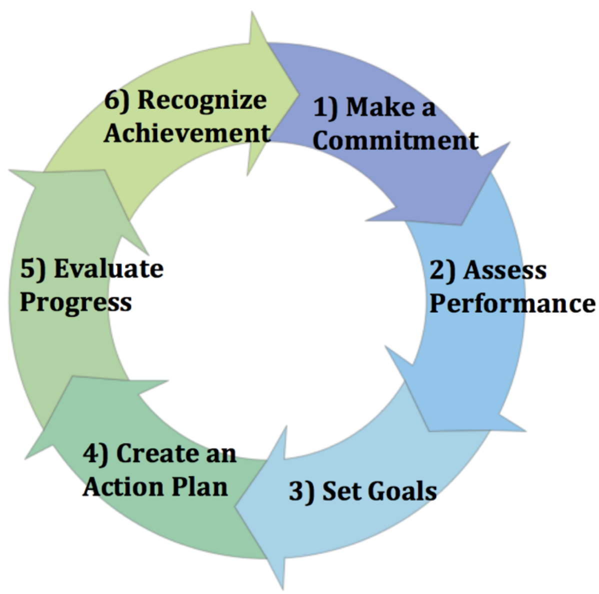
Recommendations

The master's project team identified several opportunities for furthering the collective energy efficiency performance of the University and the Dana building, as detailed here.

Campus-Wide Recommendations

1) Develop and Implement a Campus-Wide Energy Strategy: The entire campus is currently working to meet the same campus sustainability goals, but there is little coordination across campus on how each fund (and each organization) can accomplish these goals. For example, each Fund has their own sustainability plan, but the Funds are not always aware of what the others are doing, how they are doing it, or how they can help each other. Additionally, what serves in the financial best interest of each building may not be in alignment with campus-wide goals.

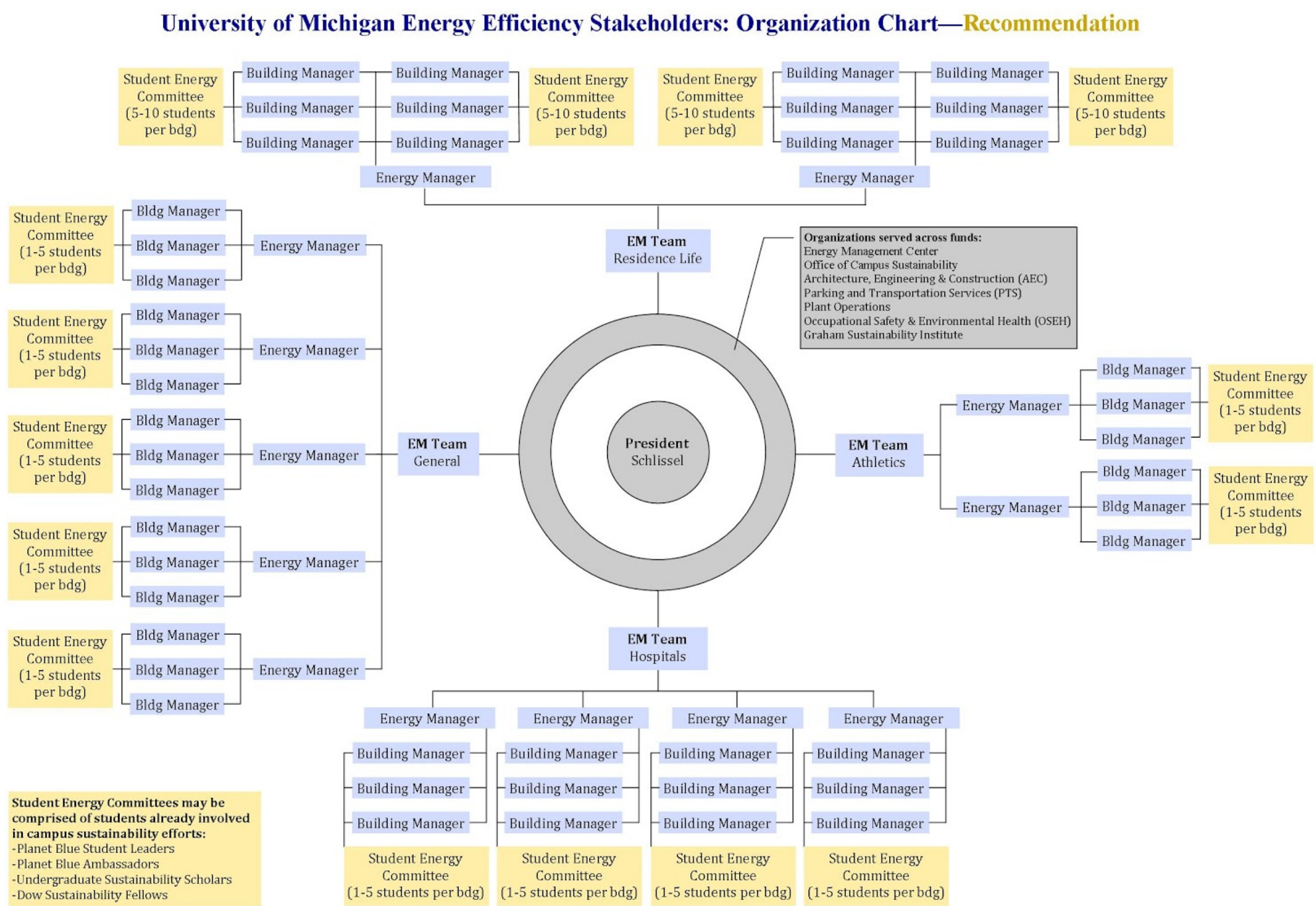
Better communication, coordination and efficiency gains would be achieved if a clear strategy were outlined. A suggested framework of how to achieve this is illustrated in ES Figure 5. Increasing the role of the Office of Campus Sustainability to not only report on the progress towards the campus sustainability goals (as they do currently), but to also own and guide the strategy to attain those goals, would dramatically increase the momentum of current initiatives on campus and encourage the sharing of best practices. As it currently stands, the University has gone through the first three steps of this plan: make a commitment, assess performance and set goals. The next step would be to create a campus-wide action plan that propels all funds on a path to meet the sustainability goals set in 2011.



ES Figure 5: Suggested Sustainability Strategy. The University of Michigan has achieved three of the six steps, including making a commitment to reduce energy, assessing energy performance, and setting energy goals. The next step is for the University of Michigan to create a campus-wide action plan in order for the entire University to make progress towards their energy goals.

2) Centralize Energy Management's role with recommended organization structure: Energy Management currently operates in the University's General Fund, which houses approximately half of the campus buildings. While there is an interest for decreasing energy consumption in the Athletic, Hospital, and Student Life Funds, and much has been done to set sustainability initiatives, they currently do not have in-house professionals capable of executing energy efficiency projects at the level conducted by Energy Management. By centralizing Energy Management's role as shown in ES Figure 6, all buildings on campus will have the ability to leverage their experience and expertise, while enhancing communication and the sharing of best-practices throughout the University and its various funds.

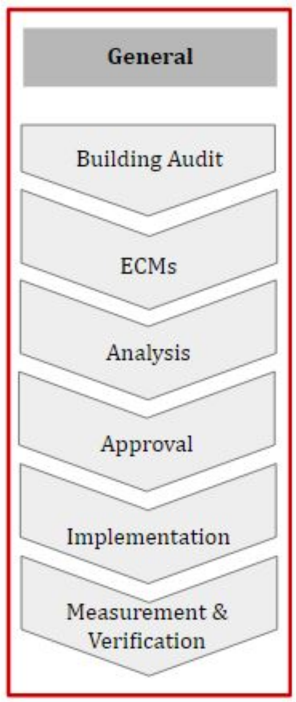
The recommended organization structure in ES Figure 6 has an Energy Management team dedicated to each of the four funds analyzed in this study: General, Hospital, Athletics and Student Life. It is recommended that an Energy Manager be responsible for 3-6 buildings, and to work closely with the building managers to improve operational energy efficiency (indicated in blue). Additionally, to further drive positive sustainability behavior, it is recommended that each of the buildings have a Student Energy Committee comprised of between 1-10 students (indicated in yellow). These students would be responsible for hosting events, informing their peers on best energy practices and reporting recommendations and achievements to the building managers.



ES Figure 6: Suggested Campus-Wide Energy Stakeholder Organizational Chart. This organization chart is meant to represent average ratios of energy managers to building managers to student energy leaders; however, the size and function of the building should be considered in assigning energy managers.

Another advantage of reorganizing the Energy Management team across all funds is that it will allow for standardization of the energy conservation measure (ECM) process. Currently, each fund has its own method to assess and choose which ECM's are implemented, as shown in ES Figure 7.

The General Fund currently identifies ECMs based on building audits, which is the industry standard (outlined in red). This same process should be implemented across campus, which will ensure that the most effective energy saving projects are chosen and, ultimately, implemented.



ES Figure 7: Different ECM methods across Funds. The Energy Management team has implemented the General Fund ECM process. A red box drawn around the General Fund ECM structure highlights the process that is both the industry standard and that is recommended for all funds.

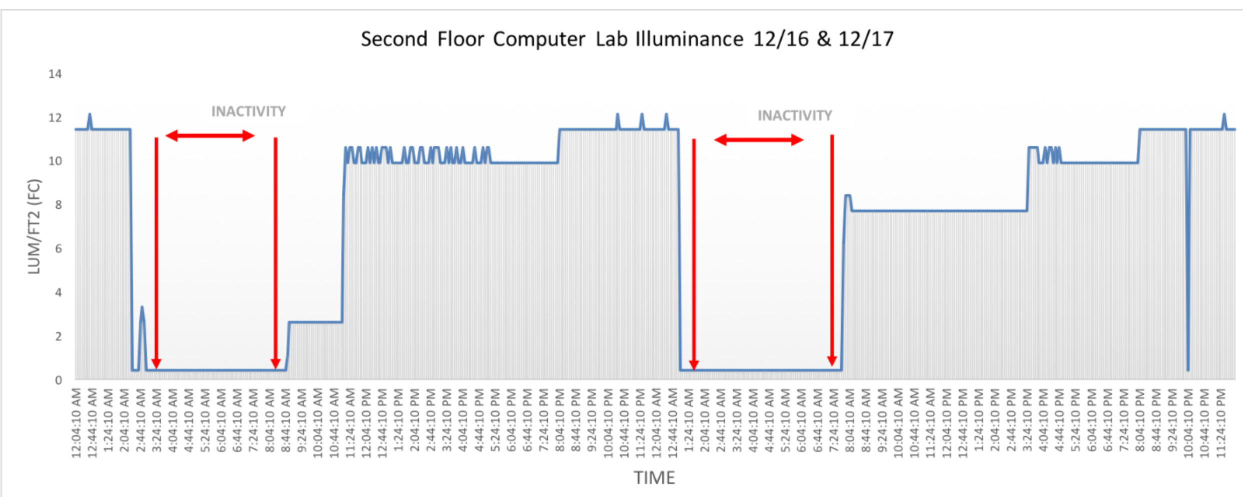
3) Increase Focus on Large Energy Consumers through Building Demand-side Initiatives: Twenty campus buildings were analyzed using Johnson Control's LEAN analysis software. The results show a possible financial savings of 21 percent in mixed-use buildings and 13 percent in single use buildings, which could result in an avoided utility cost of $4 million each year. If a similar savings of 15 percent were realized in all 188 buildings, the University would effectively avoid $14.6 million in utility costs annually.

Most of these mixed-use buildings have both office spaces and laboratories, suggesting there is a large opportunity for increasing lab energy efficiency on campus. Given that those buildings have the highest energy consumption and energy intensity, the University should secure a specialist specifically dedicated to auditing laboratories on campus. This specialist should become well versed in the efficiency recommendations outlined by the International Institute for Sustainable Laboratories, whose mission is "to engage all stakeholders in advancing the safety and sustainability of laboratories and other high-tech facilities globally."[xii] The University should also focus on additional opportunities for demand-side projects, including securing green certification for each of the labs and investing in real-time displays of energy consumption on buildings across campus.

Dana Building Recommendations

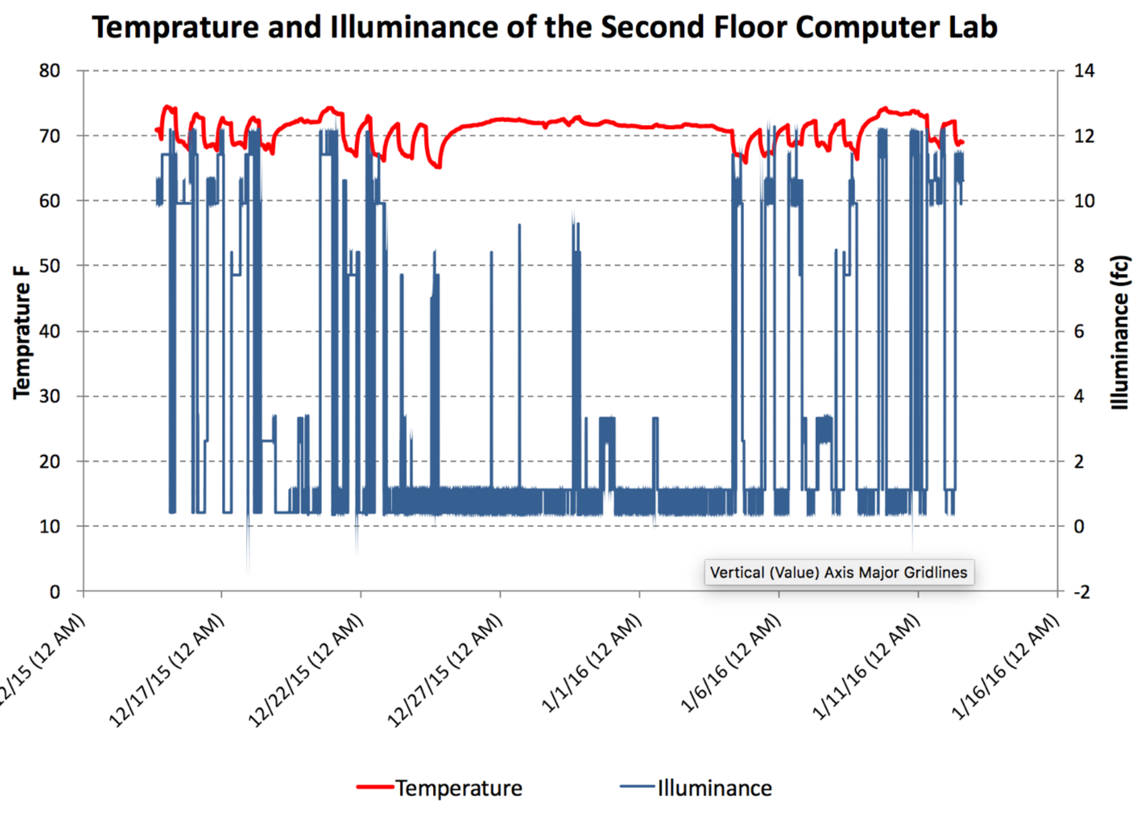
The Dana building was analyzed as a case study to identify building-specific recommendations for increasing energy efficiency. By utilizing JCI's LEAN Analysis tool and conducting subsequent Dana building audits, the team has identified the following recommendations to increase energy efficiency:

1) **Building Use Management:** With the exception of midterms and finals periods, the majority of classrooms and computer labs are unused during late night and early morning hours. Dana building classrooms and computer labs are operational 24 hours a day, giving students access to the building's resources at all times. Although private study areas are highly sought out by students, utilizing large lecture halls for only a few people is wasteful. Other spaces are available for studying in the Dana building and in other buildings on campus, so access should be restricted to an appropriate percentage of classrooms and computer labs to consolidate students and save on energy. ES Figure 8 shows long periods of inactivity in the second floor computer lab, which correspond with the suggested times that this, and similar rooms, should be closed—from 12 p.m. to 7 a.m.



ES Figure 8: Second Floor Illuminance from HOBO loggers in Dana building.

2) System Changes to Building Operation and Temperature Set-points: The data loggers from this study revealed an average room temperature of 72 degrees, as shown in ES Figure 9. This temperature remained constant over winter break, when few occupants were in the building. The temperature should therefore be significantly lowered during times of reduced use, such as winter break, and could be lowered overall to possibly 70 degrees.



ES Figure 9: Illuminance and Temperature, Dana Second Floor Computer Lab, over a one-month period. The two-week period of low illuminance in the middle of the graph occurred during winter break. The temperature of the lab could be reduced over the entire period, and significantly reduced during the break.

The Dana building could further reduce energy consumption and therefore increase energy efficiency by installing timers, additional sensors, and improving the scheduling. These upgrades would allow for optimal and automatic adjustments to building lighting and heating loads. An additional follow-up audit by the Energy Management team is recommended to expand upon data collected during walkthroughs with Johnson Controls and the project team to identify additional areas for operational changes to the Dana building.

Johnson Controls Recommendations

Johnson Controls has identified some general areas of improvement throughout the campus using LEAN Analysis software, and has identified some specific opportunities through building audits performed in the Dana building. However, as the Energy Management team already performs similar building audits in General fund buildings, there is less opportunity for JCI to engage with the General fund. It would be more fruitful for JCI to approach other funds, including—but not limited to—Athletics, Student life, and Hospitals. There is also the potential for JCI to apply the LEAN Energy Analysis to the rest of campus, especially non-General fund buildings, to focus efforts on the largest opportunities.

JCI may also want to pursue supply-side solutions for the University. Although this study did not investigate supply-side energy management, JCI is currently working with Stanford University on an energy management software for their Separate Heat and Power (SHP) facility. A new version of this software will soon be released by JCI that specifically targets Combined Heat and Power (CHP) facilities, which would apply to the Michigan Central Power Plant. This software may be an opportunity for JCI and the University to further work together.

Project Revision: Energy Productivity to Energy Efficiency

Johnson Control's initial project proposal focused on increasing energy productivity at the University. The graduate team sought to understand how increased energy productivity at educational institutions could best contribute to reducing GHG emissions on campus. The team then intended to craft practical recommendations for the University to identify energy-saving projects, both short-term and long-term, and create a clear road map for JCI's services and expertise to assist in increasing campus sustainability.

Johnson Controls had envisioned that the master's project would utilize the International Association of Energy Economics (IAEE) equation for energy productivity, the measurement of GDP produced per unit of energy use,[xiii] to increase productivity of the University's campus buildings and operations. However, the University's role as a research-focused institution, instead of having a focus on the production of goods and services, made it difficult to model within IAEE's definition of energy productivity. With a sufficient understanding of the criteria and measurement for energy productivity established, the master's project team deemed avoided energy cost as the most practical for purposes of the master's project objectives and for providing impact to the University and its long-term strategy to reduce its carbon footprint.

The graduate team further concluded that avoided energy cost could be strongly aligned with increasing energy efficiency and thereby reducing the amount of energy required by the University for its buildings and operations. Increased energy efficiency has already been an on-going focus of the University's campus sustainability goals, and viewing the project with this lens—rather than energy productivity—seemed appropriate.

This clarified definition for energy productivity also better aligns with Energy Management's projects across campus and therefore provides the most effective opportunity for developing a collective strategy to reduce energy consumption at the University. With the support of our master project's academic advisor and Johnson Controls, the project refocused to reducing the overall building energy consumption by 50 percent of the baseline consumption for the year 2014 through 2030.

Introduction:

Rationale for Energy Efficiency Goals

Climate change is one of the most important environmental challenges the world faces today, and there is scientific evidence indicating that the earth's temperature is increasing. Since 1880, global average surface temperatures have increased by 0.85° C.[xiv] Driven by an increased level of anthropogenic GHG emissions since the pre-industrial era, the International Panel on Climate Change (IPCC) *Fifth Assessment Report* concludes that human influence is extremely likely (>95 percent certainty) to be the dominant cause of this observed warming. [xv] These increases in temperature will continue unless drastic measures are taken to prevent it. The report states, "Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of pervasive and irreversible impacts for people and ecosystems."[xvi]

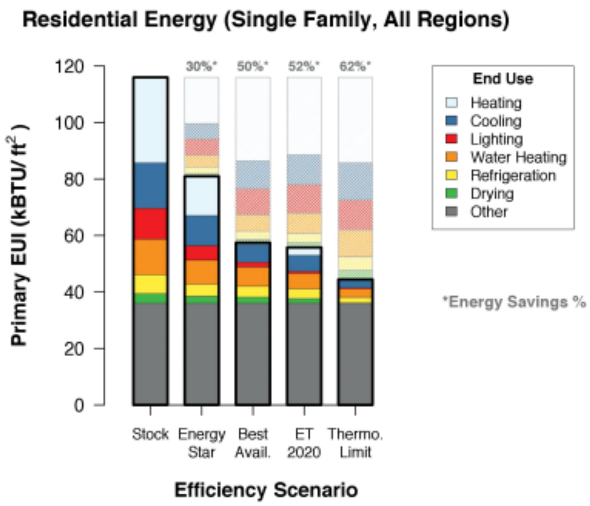
Globally, this issue is gaining attention and mitigation strategies are being proposed with increasing urgency. On December 12, 2015, the Conference of Parties met at the 2015 Paris Climate Conference (COP21) to form the Paris Agreement—the first legally binding international climate deal consisting of a long-term goal of keeping global average temperature below a 2°C increase.[xvii] Although creating an action plan was legally binding, the actual follow-through on that plan is not. However, this agreement seeks to track the Intended Nationally Determined Contributions (INDCs) for participating countries by reconvening every 5 years to assess progress and set new targets.[xviii]

The United States presented its INDC of a 26-28% reduction in GHG emissions (below 2005 levels) by 2025, with the intention of meeting these goals without utilizing international market mechanisms.[xix] However, policies meant to help meet these goals, such as the Clean Power Plan, are being met with a high degree of opposition.[xx] In addition, climate change mitigation can be a large investment.[xxi] In order to meet the targets outlined in their INDC, the United States would have to dedicate much more of their budget to these GHG reduction strategies.

There are many opportunities for decreasing GHG emissions and, ultimately, a combination of efforts must be implemented to reach emissions reduction goals. One advantageous strategy is focusing on the reduction of energy use and GHG intensity of current end-use sectors. The residential and commercial building sectors currently account for 70% of electricity consumption and 54% of natural gas consumption nationally, emitting over 33% of the U.S. GHG emissions, more than any other sector.[xxii]

Increasing energy efficiency in the building sector can have a major impact on decreasing demand for electricity and natural gas, lowering GHG emissions, and avoiding unnecessary energy waste. The magnitude of energy efficiency savings potential is demonstrated in Figure 1 and Figure 1, comparing 2010 baseline energy use intensity (EUI) to efficiency scenarios.[1]

[1] ET 2020 is the Emerging Technology Program's targets for the year 2020.



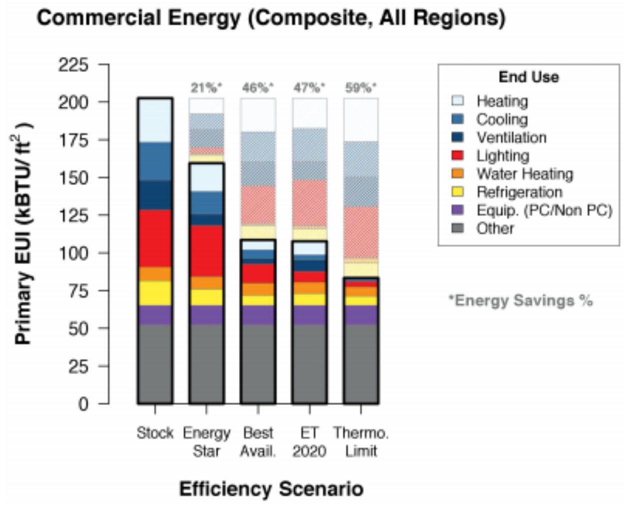


Figure 1: Residential Energy Efficiency Scenarios.[xxiii]

Figure 2: Commercial Energy Efficiency Scenarios.[xxiv]

Addressing building energy efficiency is also a cost-effective strategy, as the avoided energy costs from long-term projects can offset, or potentially overcome, costs of implementation. These savings can make building energy efficiency projects an attractive option for a wide range of building types and their managers. One example of wide-scale implementation is President Obama's Better Buildings Challenge, which has encouraged collaboration between cities, utilities, businesses and schools to share best practices and encourage collaboration. Since 2011, this initiative has resulted in energy savings of $840 million.[xxv]

University campuses similarly present a unique opportunity to reduce energy consumption and increase building efficiency. Academic institutions can potentially pursue more aggressive energy conservation measures because capital cost constraints are less of an issue when compared to small businesses or residential buildings. Additionally, many campuses are more likely to make these capital investments because of their buildings' longevity. A small business owner may not be able to justify high capital cost energy efficiency measures if he/she does not know whether they will remain in business, whereas a University can more confidently anticipate their operation for decades. Lastly, academic institutions have access to students, faculty, and research centers that can investigate innovative solutions to building efficiency. Campuses represent a significant opportunity to test new ideas in the efficiency arena, such as building management controls, sensors, and behavior change techniques.

This study seeks to assess the energy savings potential of the University of Michigan by establishing a baseline for the current energy consumption, as well as analyze the Samuel T. Dana building more closely as a case study.

Project Objectives

The core objectives are detailed in Table 1 below.

Table 1: Masters Project objectives.

Deliverable	Objective
Organizational Chart	Establish relationships amongst energy stakeholders on campus and understand hierarchy for ECM improvements
Flow Diagram and Energy Analysis	Create flow diagrams for the entire campus showing kWh consumed, Btus consumed and cost to the University
Building Analysis (LEAN)	Use LEAN Analysis to identify energy efficiency projects and compare to existing work done by the University
Building Audit	Observe building audit by Energy Management team and JCI experts for one campus building and provide recommendations
Building Upgrades	For one building on campus, identify demand-side building upgrades and create template to reach 50 percent efficiency
Timeline for future Masters Project	With JCI client, determine future master's project and develop a proposal for work to be done in the second year of this case study

With a focus on demand-side energy consumption, the master's project analyzed current energy usage across the University by compiling metering data and publicly available utility bills from each building. The University of Michigan tracks building energy use by using the metrics of Btu per square foot (Btu/ft^2) and Btu per square foot per capita ($Btu/ft^2/capita$). The master's project team used these data and metrics for an original assessment to establish a baseline, and for setting target goals for future energy management projects at the University.

Project Client: Johnson Controls, Inc.

Incorporated in 1885 to manufacture, install, and service automatic temperature regulation systems for buildings, Johnson Controls has since become a globally diversified company in the building and automotive industries. Johnson Controls specializes in producing automotive parts such as batteries and HVAC equipment, to optimize efficiencies of buildings, automotive batteries, electronics and interior systems for automobiles. As a global technology and industrial leader serving customers in more than 150 countries,[xxvi] the company's expanded services provide it with the opportunity to create significant impact for sustainability.

Johnson Controls has been involved in over 500 renewable energy projects, which effectively reduced carbon dioxide emissions by 15 million metric tons and generated savings of over $7.5 billion since the year 2000.[xxvii] Several of these energy saving projects have been at educational institutions across the country, including at Louisiana State University[xxviii] and the University of Hawai'i Community Colleges.[xxix] Johnson Controls has also completed projects locally, including the replacement of over 1,700 outdated exterior lights with new LED fixtures in the Ann Arbor School District.[xxx]

Johnson Controls in the Campus Energy industry

Johnson Controls has several campus energy efficiency projects using their performance contracting approach. With this method, JCI essentially funds the capital costs associated with a major project and the institution pays them back through realizations in the energy savings over time. In campuses, especially public ones, financing energy efficiency projects can be deprioritized because education is the University's main concern. Performance contracting by private companies such as JCI can help financially support these energy-saving projects by both eliminating the financial risk for campuses and allowing them an avenue to pursue sustainability initiatives without tying up their existing budgets. Saving energy by performance contracting can create jobs, focus investment in new growth industries, lower energy and operating costs, reduce carbon emissions, mitigate financial risk, and create healthier, safer and more comfortable environments for students.

Prior to project implementation, project costs (such as energy audits), engineering (technical support) and construction are documented by JCI in the form of a contract with their client. Once a partnership is established and JCI has conducted the appropriate energy audits and assessments, they share their findings with the campus in the form of Energy Conservation Measures (ECMs). The campus chooses the ECMs with the shortest payback period and/or highest return on investment (ROI). This form of performance contracting has become standard in the energy industry.

Finally, after an ECM is implemented, JCI performs a Measurement and Verification (M&V) process to ensure projects are successfully managed. This critical component of the performance-contracting program provides customers with the annual data to share for the life of the contract. For example, at the University of Massachusetts, JCI had a 10-year performance contract beginning in 2004 and implemented 38 ECMs worth $40 million the upfront cost.[2] The energy conservation projects allowed the university to repay through the savings over the lifetime of the contract signed between JC and the University.

Case study: Stanford University

With funding and resources from JCI, the master's project team attended a three-day visit to Stanford University, Palo Alto, CA (refer to Appendix B:
Tour at Stanford University's New Separate Heat Recovery Power Plant). The team's goals were to understand the supply and demand of energy on Stanford's campus, to look at their current energy conservation strategies, and to understand the role of Johnson Controls in helping to Stanford to reach their energy goals. The following sections summarize the information and learnings the team gathered from this visit.

[2] Using Performance Contracting and Incentives to Accelerate Energy Efficiency Projects by Johnson controls.

Administrative System:

Land Building and Real Estate (LBRE), in addition to constructing and maintaining 8,100 acres of the Stanford campus (compared to 20,965 acres of Ann Arbor campus), is also responsible for the energy retrofit and the renewable energy programs at the University[xxxi]. The Sustainability & Energy Management (SEM) – a subdivision of LBRE – consists of Utilities Services, Parking and Transportation Services, and the Office of Sustainability. The SEM team is responsible for developing strategic long-term goals for energy use, greenhouse gas emissions reduction, water use, waste reduction, green building and transportation, as well as developing and administering a communications and community relations program to support the initiative and an evaluation and reporting program to monitor its effectiveness.

The Energy Retrofit Program (ERP) was initially created to handle small to medium-sized projects at Stanford. However, the limited scope neglected larger projects offering potential for significantly higher returns, but requiring much more capital investment. To address these funding needs, Stanford developed a second program to target large-scale energy efficiency and resource reduction projects on campus: The Whole Building Energy Retrofit Program (WBERP)[xxxii]. Since 2002 the program has saved over 176 million kWh, or enough to power the entire campus for 8 months.[xxxiii]

While many early energy retrofits were undertaken by Stanford's ERP, the University developed the WBERP to implement large-scale, multi-million-dollar energy retrofits beyond the scope of the existing ERP's available funds. The University's Vice President of LBRE started the WBERP in 2004. The program was created to: 1) investigate and create opportunities to implement energy-efficient technologies in all existing energy-use systems instead of focusing on specific end-use opportunities like lighting or motor retrofits; and 2) create a team composed of Stanford staff—including the SEM and in-house construction managers—along with external contractors and consultants, who could develop large-scale energy savings projects on campus.

Since LBRE created the ERP, they have reported saving more than 20 GWh of electricity between 1996 and 2005 through its energy efficiency program alone. Most of these savings were through its campus-wide lighting programs—such as green lighting, LED exit signs and converting to compact fluorescent lights. The mechanical retrofitting programs—such as HVAC upgrades, variable speed drive and refrigeration upgrades—contributed to 20% of their total savings.

Operation Process – ERP

Any groups affiliated with Stanford University can initiate projects, and thereby, seek funding that has potential to reduce their utility bill. As shown in Figure 3, the ERP team reviews the project funding and approves projects that have 5 years or fewer simple payback period, and/or also have strong return on investment. Upon the selection of the project, a competitive bidding, along with the maintenance or renovation projects, is scheduled twice a year. The winning bid starts the construction process to set the energy levels as per required by the project manager. The completed task is verified and maintained by the ERP team, who then transfers the fund from SEM to the individual project. "We expect energy savings to persist for many years after the project is completed," said Scott Gould, Senior Energy Engineer. "We are diligent to ensure that the savings will last for the life of a project."

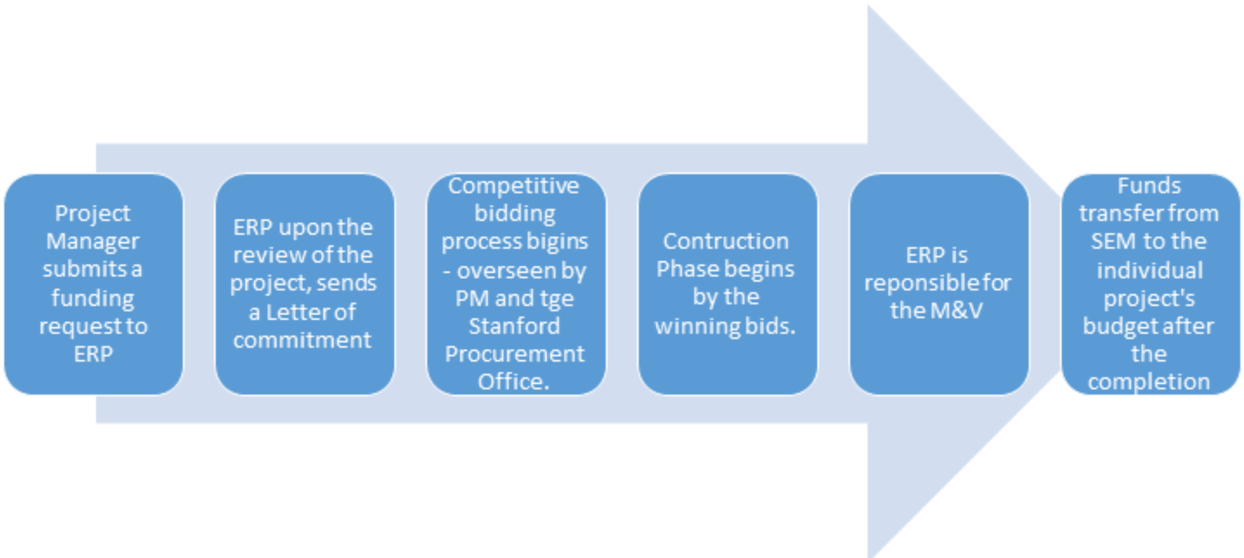


Figure 3: Process for an Energy Retrofit Project at the Stanford University.

Stanford University buildings are individually metered, which Mr. Gould credited for facilitating the identification of the top 25 energy-consuming buildings on campus. Next, the University communicates that these 25 buildings are eligible to apply for funding from the WBERP. The WBERP program manager then prioritized the buildings within that list to identify the projects with the shortest payback period. Other factors, such as the age of the building and construction impact to occupants, are also taken into consideration.

While these considerations are important in deciding the order that projects receive funding, there are other factors at play on the Stanford campus. One such factor is the important influence a Project Manager can exert to lobby for moving a specific project higher on the list of priorities.

Funding – ERP

Funding for the ERP comes from the electricity, steam, and chilled water utility recharge rates, and thereby, repaid to each of the projects according to the amount of energy the project saves after the building upgrade. Instead of receiving the upfront budgets for building upgradation, each of the projects receives funding up to $50,000 in the form of rebate upon the completion of the project. ERP funding is offered on a first-come, first-served basis. If the requests for ERP funding exceed the available funding, then the projects with the shortest payback period are funded first.[xxxiv] Projects are ranked and funded on a simple payback basis and must have a better than five year simple payback period to qualify for funding.

The ERP divides projects from the applicant pool into four areas of campus specialization: Academic Zones, the School of Medicine (SOM), Residential and Dining Enterprises (R&DE), and Department of Athletics (Academic Zones), Physical Education and Recreation (DAPER). Since ERP is funded by the utilities ratepayers itself, these four categories were devised based on the largest consumers of energy at the Stanford campus. The revenue generated by the ratepayers are the weighted percentages that the ERP takes into consideration when they are allocating funds for potential projects. The weighted percentages reflect the proportion of total campus electrical consumption that these departments individually consume. As shown in Table 2, the Academic Zones group consumes the most, by far.

Table 2: Electricity distribution by funds.

GROUP	% OF TOTAL ELECTRICAL CONSUMPTION
Academic Zones	57%
SOM	17%
R&DE	14%
DAPER	4%

Johnson Controls at Stanford – Enterprise Optimization Solution (EOS)

During the team's visit to Stanford University, Joseph Stagner, Executive Director, Department of Sustainability and Energy Management at Stanford, and Bob Turney, JCI fellow and Advanced Development Lead, gave a brief overview of Stanford's cutting-edge energy supply system known as the Stanford Energy System Innovations (SESI).

Stanford collaborated with Johnson Controls to transform a new plant optimization model patented by Stanford (previously known as Central Plant Optimization Model, CEPOM) into an industrial-grade software, known as Enterprise Optimization Solution (EOS) licensed by JCI.

The EOS is an energy modeling and dispatch system using over 1,220 variables, including the following: building occupancy, ambient conditions, time of year, projected energy prices, weather forecast, current system conditions, etc. The EOS uses these variables to develop 15-minute dispatches to predict the energy demand on campus and to automatically manage the plant, essentially putting the system in "autopilot."[xxxv] The system predicts the University's background electrical profile (electricity used by the buildings) for the next seven days and schedules heat recovery operation in hours each day to minimize Stanford's overall electrical footprint on the grid. A high-level visual of the EOS system is provided in Figure 4.

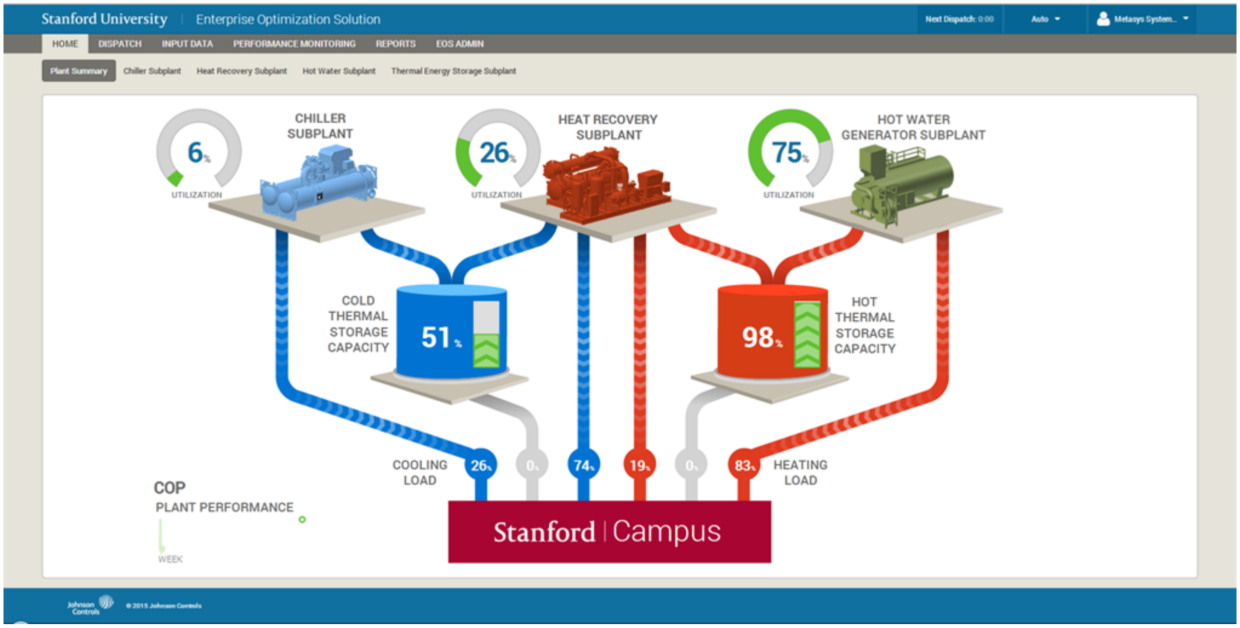


Figure 4: Snapshot of Enterprise Optimization Solution (EOS) Dashboard.

JCI's role in developing software for Stanford highlights a small segment of building and energy control technology that JCI can offer. In the following section, a short list of JCI's building control technology and audit methodologies are explained.

Technology & JCI

Johnson Controls is a global technology leader specializing in building efficiency, batteries, distributed energy storage, and automotive seating. JCI offers a number of products and services as part of their "buildings" group including air systems, building management, HVAC controls, HVAC equipment, security and fire safety, refrigeration, and replacement parts and supplies. Within these categories, JCI offers several mechanisms to reduce energy consumption or improve efficiency. A few of their innovative products are highlighted below.

Air Systems – Health, comfort, and productivity are improved by optimizing the airflow through a building. JCI's YORK® Energy Recovery Ventilator (ERV) not only provides increased ventilation rates, it also "enable[s] buildings to capture existing heat and repurpose the heat into preheating the fresh air brought in from the outside."[xxxvi] Densely occupied areas need fresh air to lower the CO_2 level and keep occupants alert. When fresh air is brought into a building, tempered air must be exhausted back outside to equalize the pressure. However, this tempered air has an energy cost. The air must be warmed up in the winter and cooled down in the summer to meet occupant comfort levels. An ERV captures roughly 70% of that warm or cool energy from the air leaving the building and puts it back into the fresh air entering the building. This recapturing of energy lowers the demand on the rooftop ventilation unit, resulting in less energy consumption and lower utility costs. Per JCI's estimates, the payback period for an ERV in Michigan is typically 12 years.

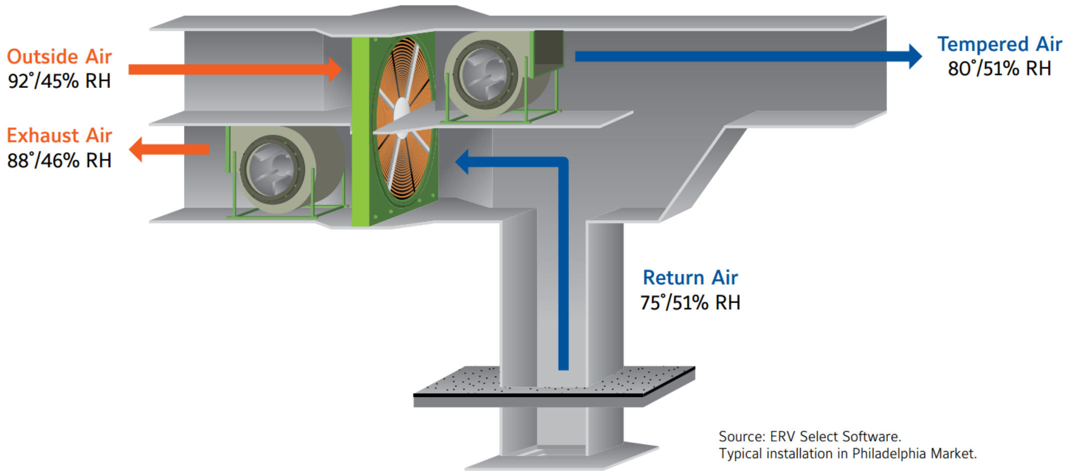


Figure 5: Typical HVAC System Using Energy Recovery – Summer Operation.

Table 3: Typical Savings Realized By Using A York® Unitized ERV.

Supply cfm	Exhaust cfm	Collg Saved MBtu	Cooling $ Saved	Heating Saved MBtu	Heating $ Saved	Fan kWh Used	Fan $ Spent	Net Savings
3100	3000	157,501	2,065	177,485	2,275	13,733	1,467	2,873

Building Management – As observed in Table 3 it is estimated that building automation systems can save 5-30% on utility costs by automating the HVAC and lighting systems.[xxxvii] JCI's Metasys® Building Automation System is a dynamic system that connects a building's HVAC, lighting, security and protection systems. The controls and wireless interface can monitor every zone of the building to make instant adjustments for occupancy while maintaining comfort and productivity. In addition to monitoring energy usage, the automation system is capable of collecting data from each zone so that the operators can identify mechanical problems early. Correcting mechanical or operational problems early offers invaluable energy and emissions savings.

JCI offers a host of products as part of their Metasys® system including software, network engines, controllers, and thermostats. For example, their Advanced Field Equipment Controllers feature "a real-time clock and support time-based tasks – enabling them to monitor and control schedules, calendars, alarms, and trends".[xxxviii] These controllers also feature Auto Tuned Control Loops that "reduce commissioning time, eliminate change-of-season re-commissioning, and reduce wear and tear on mechanical devices." [xxxix]

Variable Speed Drives – Variable Speed (or Frequency) Drives (VSDs or VFDs) allow for precise electrical motor control. Rather than having the motor run at a constant speed, a VSD can be ramped up and down, and maintained, at the actual speed required. This adjustment allows the motor, which consumes a majority of the energy produced, to utilize only the energy required. JCI's VFDs provide closed loop control capabilities with their Metasys® and Facility Explorer digital field controllers. Furthermore, their Series II Open Drives "feature an ultra-efficient DC capacitor and a power structure that allows the drives to consume less energy, lowering greenhouse gases and saving you money.” [xl]

LEAN Energy Analysis

Johnson Controls has begun using the LEAN Energy Analysis methodology for an initial building energy analysis when approaching potential clients. This regression analysis provides building managers with a model of the performance of their buildings based on previous years' utility data, and can be used “to predict energy use, to estimate savings, and to assess building energy performance trends”.[xli] The energy use of each building is weather-normalized and benchmarked against buildings of similar type to compare the building's energy performance to buildings of similar use across the globe. For example, a typical office building's utility data can be run through LEAN Analysis and the energy performance of that building is compared with a dataset of similar office buildings. In addition to ranking the building's energy performance, the tool also offers a high-level overview of potential energy efficiency opportunities.

LEAN Methodology

LEAN Energy Analysis, as is illustrated in Figure 6, uses a four-step process. In the first step, two or more years of monthly utility bills are analyzed to calculate the energy use intensity (EUI) of the building, which is normalized by the gross or conditioned area of the building by dividing by the building square footage. Additional data requirements include primary building use and occupancy schedules to allow for benchmarking against similar building types. The analysis regresses the normalized EUI data against local weather data to fit an energy performance model to the building, relating consumption to outside temperature. The model and corresponding model coefficients reflect the current performance of the building, and can be benchmarked against similar buildings across the world as the resulting statistical model is weather normalized. Additionally, the regression analysis can be run on older utility data for a historical trend analysis, where a baseline model is developed and the performance of the building is investigated over time. The final step, then, is to undergo a preliminary opportunity assessment, which predicts which energy efficiency opportunities and recommendations may be considered for that particular building.

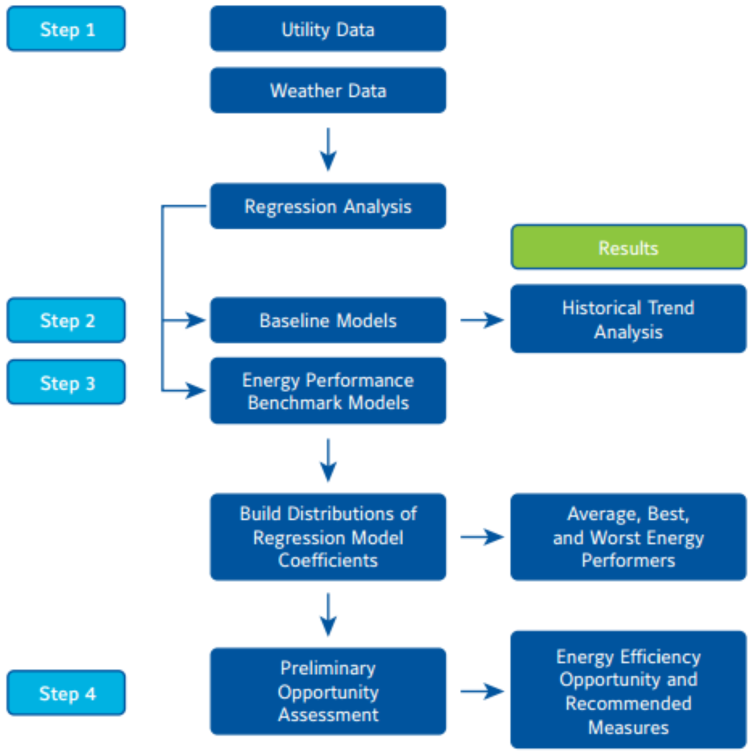


Figure 6: LEAN Process Diagram.[xlii]

The regression analysis fits a model to the relationship between average monthly temperature and monthly energy consumption data. Separate models are created for electricity and fossil fuel consumption. Each model is able to identify weather-independent energy use (base load, β_0), weather-dependent energy use or "weather sensitivity" (heating and cooling, β_1), and change point temperatures (break-even temperatures, β_3). The base load is represented by the horizontal segment of the model, where consumption does not vary with temperature and includes consistent building consumption such as lights, plug loads, and process loads. Weather-dependent energy use is defined by regression coefficients (cooling and heating sensitivity) that are linear relationships between outdoor air temperature and consumption. The slope coefficients for heating and cooling are functions of building properties such as the building envelope, ventilation air and the efficiency of cooling or heating[xliii]. The break-even temperature is affected by internal heat loads of the building and heating and cooling temperature set-points. An advantage of the LEAN Energy Analysis is that identified model coefficients (β) directly characterize the performance and properties of the building's envelope and operation, eliminating estimation uncertainty inherent in calibrating simulation models.[xliv]

By benchmarking these coefficients against those from buildings of a similar type, the building performance can be analyzed for energy savings opportunities. Figure 7 shows an example of a three-parameter cooling model, described by Equation 1. The superscript "+" denotes that the sensitivity term only applies when the calculated parenthetic quantity is positive.

Equation 1: Three-parameter cooling model.

$$Energy = Baseload\ (\beta_0) + Cooling\ Sensitivity\ (\beta_1) \times \{Outside\ Air\ Temperature\ (T_{oa,1}) - Cooling\ Breakeven\ Temperature\ (\beta_2)\}^+$$

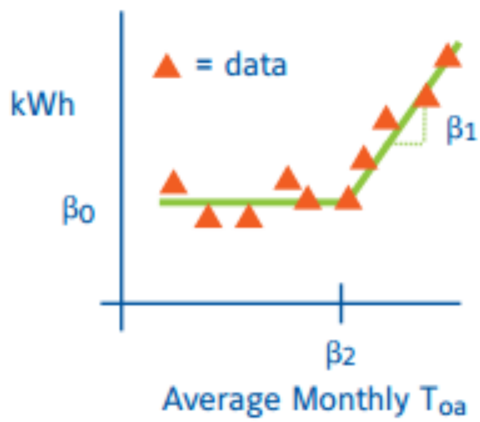


Figure 7: Cooling Energy Use Sensitivity.

University of Michigan Previous and Current Energy Initiatives

The University of Michigan is a leading higher education institution. The *U.S. News & World Report* named the University as one of the top five U.S. Public Universities, and ranked over 100 graduate programs in the top 10 nation-wide. Additionally, the University was ranked as the best public research university in the nation.[xlv]

Given their position as a leader in academia and research, the University acknowledges their responsibility to become a model for other institutions—and not just in academics. University leaders are aware of the need for increased sustainability initiatives and acknowledge their role in conveying the importance of sustainability to students, the broader community and competitors by making it a priority. As such, the University continuously strives to decrease environmental impact, increase awareness and achieve bold sustainability goals.

History of Demand-Side Sustainability Efforts at the U-M

The University of Michigan has a long history of sustainability efforts. The earliest mentioned initiative dates back to 1970 when the University received grants funded by the United States Department of Energy (U.S. DOE) to conduct energy audits and energy related projects.[xlvi] Since the late 1970s, the University has been actively involved in energy audits on campus and in making the necessary investments to ensure that sustainability would become an ingrained priority for the campus long-term. During this time (and through the early 1990s), the U.S. DOE funded several energy audits through energy project grants at the University of Michigan.[xlvii] A list of the main sustainability initiatives that followed these projects is detailed in the following sections.

Energy Conservation Account (1987)

The first institutional and financial change that drove energy conservation efforts arrived in 1987 with the Energy Conservation Account (ECA). This account was "the funding vehicle for capital measures to reduce energy consumption in General Fund[3] buildings."[xlviii] With this account, energy and lighting engineers identified projects that were consuming a lot of energy and proposed methods to both increase efficiency and decrease energy consumption. Projects that were accepted fell within a five-year payback period, which was later extended to eight years. The current annual budget is $1.5 million and is generally distributed to an average of 50 Energy Conservation Measures (ECM's) each year.[xlix] The money realized in savings from these ECMs is put back into the Energy Conservation Account for future projects. Although this is a standard practice for financing energy improvements today, this was considered revolutionary at the time.

Energy Star Program (1997)

On June 19 of 1997, the University of Michigan signed a Memorandum of Understanding (MOU) with the U.S. Environmental Protection Agency (U.S. EPA). In this agreement, the University formally committed to the Energy Star program for all General fund facilities, which included a five-step program over a six-year period. At the time, the General fund facilities consisted of 119 buildings with a floor area of 12 million square feet and a combined energy budget of $38 million.[l]

In alignment with the commitment, the University completed a "tune-up, engineering analysis, and capital improvement phase" as outlined by Energy Star. During these improvements, the consumption data for electricity, steam and natural gas were recorded. Each year, the efforts of this program were assessed through energy metering. The reduction for both heating and electricity use decreased by approximately 10-13 percent annually over the course of the six-year commitment, equivalent to a savings of $5.4 million each year.[li]

Energy Conservation & Outreach Program (2004)

In 2004, the Energy Conservation & Outreach (ECO) Program was established. This five-year program focused on General fund buildings and was designed to build upon the success of the Energy Star program completed in the previous fiscal year. ECO was described as a "second cycle" of the Energy Star program. Starting in 2004, ECO focused on addressing building mechanical upgrades including: lighting, HVAC fan systems, and water conservation measures. Specific effort was placed on increasing coordination between automated building services and facility managers in order to better control and manage the building's energy use to match activity and need.

ECO worked to expand the range of acceptable ECM projects by implementing demonstration projects and conducting feasibility studies.[lii] The successful demonstration projects were then implemented across all General fund buildings including: cogged belts to reduce slippage and increase efficiency in HVAC systems; Cimetrics, a study that focused on monitoring and improving

[3] The campus is divided into ten funds. These funds are used to manage campus finances and are as follows: Athletic Buildings, Auxiliary Units, General Fund, Housing, Leased Property, Miscellaneous Buildings off Campus

building inefficiencies; and Vending Mizer, which combined occupancy sensors with vending machines to shut down power when there was no activity nearby.[liii]

At this point, the payback period was extended from a five-year period to an eight-year period, which is still in use today. Each project, in addition to fitting the payback criteria, was expected to have a service life of 20 years or more. ECO was also used to pilot additional ECMs that were not previously considered through demonstration projects. Of the 102 potential ECMs identified, 27 were "deemed feasible" and presented to the Energy Conservation Committee for approval and funding.

Planet Blue (2008)

With systems in place to attack energy conservation on campus, there was an increased effort to build upon the "culture around conservation" that ECO initiated. A campus-wide educational and outreach campaign, Planet Blue, was established in 2008 to push behavioral and social sustainability initiatives forward.

Planet Blue was part of the Environmental and Energy Initiative (EEI), an initiative that came out of the President's Environmental Task Force. This initiative includes six elements: an annual sustainability report, alternative energy, alternative transportation, green purchasing, sustainable new construction, and planet blue teams.[liv]

Planet Blue was housed under Plant Operation and worked closely with the Office of Campus Sustainability (OCS). The program had three teams that conducted audits on 10 General fund buildings each year and was in place from 2008 to 2012.[lv] These audits included energy assessments and resulted in an annual reduction of 8% in energy use over the program.[lvi] In 2012, four energy managers were assigned a cluster of buildings and continued to make improvements.

In 2015, the Planet Blue team was renamed as the Energy Management Team, but their general structure and purpose remains the same. There are now five energy managers throughout the General fund campus and they are continuing to rotate through their specific buildings to conduct building audits with the aim of increasing efficiency and decreasing consumption.

Current Demand-Side Sustainability Initiatives

To continue the momentum that the University initiated in the early 1970s, former President of the University, Mary Sue Coleman, committed to achieving several campus-wide sustainability goals. She announced these goals at EarthFest in 2011, where she broadcast six measurable goals in the following categories: Climate Action, Waste Prevention, Healthy Environments, and Community Awareness (Figure 8).[lvii] Each of these goals uses fiscal year 2006 as a baseline and are meant to be accomplished by 2025.[lviii]

Climate Action

- Reduce greenhouse gas emissions by 25% below 2006 levels
- Decrease the carbon intensity of passenger trips on U-M transportation options by 30% below 2006 levels

Waste Prevention

- Reduce waste tonnage diverted to disposal facilities by 40% below 2006 levels

Healthy Environments

- Purchase 20% of U-M food in accordance with U-M Sustainable Food Purchasing Guidelines by 2025
- Protect Huron River water quality by minimizing runoff from impervious surfaces and reducing the volume of land management chemicals used on campus by 40%

Community Awareness

- Invest in sustainability culture programs to educate our community, track behavior, and report on progress over time

Figure 8: University of Michigan Sustainability goals to be met by 2025 using 2006 as baseline.

Since these goals were announced, sustainability stakeholders across campus have worked hard to meet them. In terms of the goal to reduce greenhouse gas emissions by 25%, which is the most pertinent goal for this report, several campus-wide initiatives have been established. For example, all new buildings on campus are required to meet at least LEED[4] Silver certification requirements and must be 20% beyond ASHRAE[5] 90.1 standards.

Each group of buildings is separated by their funding source (discussed further in the section titled "Funding Structure") and are therefore required to finance their own sustainability initiatives. The following sections give a general description of how each fund has pursued (or expanded on) the campus-wide sustainability goals from their respective areas.

General Fund

In all existing General fund buildings, the Energy Management Team reviews each General fund building every few years by conducting an in-depth building audit with a checklist of over 100 energy conservation measures (ECMs). All projects with a payback period of under eight years are put into effect and the energy savings/GHG reduction savings are reported. The Energy Management team consistently achieves an 8% energy reduction each year in all the General fund buildings through these projects, and make a number of improvements to building efficiency and comfort.

Athletics

Each year, the Athletics Department creates and updates a "Michigan Athletics Sustainability Game Plan," which details the long-term goals, strategic initiatives and SMAC (specific, measurable, achievable and compatible) objectives that they focus on throughout that fiscal year (Appendix C). These items are categorized based on the University's sustainability goals: Waste Reduction and Recycling; Energy Efficiency and Sustainable Building Infrastructure; Water Conservation, Chemical

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[4] Leadership in Energy and Environmental Design

[5] American Society of Heating, Refrigerating, and Air-Conditioning Engineers

Usage and Sustainable Cleaning; and Education and Awareness. Some examples of the overarching, long-term goals include the following:

- Achieve an average annual waste diversion rate that exceeds the campus average.
- Operate all facilities at maximum levels of energy efficiency.
- Protect streams and rivers by controlling use of synthetic land management chemicals.
- Prioritize sustainability in decision-making processes.

Additionally, a student organization, M-SAS (Michigan Student Athletes for Sustainability) is actively working to make both institutional changes and behavior changes that increase sustainability efforts. For example, M-SAS is currently piloting a food waste program in the athletics' dining halls, where they hope to incorporate a competition surrounding waste management. Their goal is to encourage team members to avoid taking too much food on their food tray. Student M-SAS leaders have observed the massive amount of food waste in their dining halls and feel confident that several pounds of waste will be prevented because of this competition.

Student M-SAS leaders are also working on a pilot program in one building that will focus on positive student sustainability behavior. They hope to post sustainability-related signage around this pilot building and measure the savings based on previous years' utility and inventory data. This signage includes—but is not limited to—signs on light switches reminding the students to turn them off, and signs on the paper towel dispensers reminding students that the paper has an environmental cost.

Hospitals

In total, there are 67 buildings in the hospital fund, accounting for 6.5 million square feet of campus and $26 million in utilities in fiscal year 2013. Given the amount of energy consumed in the hospital systems and their prioritization of sustainability initiatives, the administration has identified opportunities for energy savings and has expanded on the aforementioned campus-wide sustainability goals.[lix]

The University of Michigan Hospitals and Health Centers (UMHHC) have set the following additional sustainability goals:[lx]

- At least $100 thousand per year in new savings from ECM projects each year.
- Energy Star rating of 50 or higher.
- Achieve HHI Level 3 Leaner Energy Challenge of 10% normalized energy improvements in hospital buildings.

The UMHHC have been widely recognized for their accomplishments. In 2015, they received the Emerald Award from Practice Greenhealth, a national membership organization of healthcare facilities committed to environmentally responsible organizations, for the twelfth consecutive year.[lxi] Additionally, in 2013, UMHHC was recognized by "Becker's Hospital Review" as one of the 50 greenest hospitals in the country.[lxii]

Student Life

The student life administrators have developed several sustainability initiatives and separated them into two categories—Student Life and Michigan Dining Projects—discussed in further detail in the following sections.

Student Life Projects

The Student Life projects are categorized into the following nine categories: purchasing, energy/water, waste reduction, student initiatives, sustainability education, communications/marketing, regional/community engagement, health/wellness and new construction/renovation. These categories, and some example projects from each, are given in Table 4.

The student life & housing fund has created (or supported) several student-initiated sustainability projects. In winter semester of 2015 alone, Student Life administration met and worked with over 55 student groups focused on increasing sustainability efforts on their campus.

Table 4 Student Life Sustainability Categories and Project Examples from FY 2015-16.

Category	Project Examples (2015-2016)
Purchasing	Energy star appliances; LED lights in the Unions; LED lights in Northwood 3
Energy/Water	Lighting sensors; water refill stations; water bottle distribution; energy use reporting
Waste Reduction	Move-out-Move-in procedures; single stream recycling; UHS "rethink recycle"; recycle of batteries, toner cartridges and pens; laundry report
Student Initiatives	Greening of alternative spring break; Recycle Mania; Ginsberg Center Involvement; ENV 391 (undergraduate course)
Sustainability Education	Planet Blue Sustainable Workplace Certification; Plant Blue Ambassador program; Beyond the Diag
Communications/ Marketing	Develop sustainable website education, Composting pamphlet
Regional/ Community Engagement	Ginsberg Project Outreach; Read a book related to food
Health/Wellness	Fitness group classes; food options; UHS's webpage to display nutritional information
New Construction/ Renovation	Renovation: South Quad, East Quad, West Quad, Michigan Union Ground New Construction: North Quad, Munger

Michigan Dining Projects

Similar to the Student Life Projects, the Michigan Dining projects are listed in eight categories: purchasing, energy/water, waste reduction, student initiatives, sustainability education, sustainable catering, communication/marketing, and regional/community engagement. These project categories, and some examples from each, are listed in Table 5.

Table 5 Michigan Dining Sustainability Categories and Project Examples from FY 2015-16.

Category	Project Examples (2015-2016)
Purchasing	Expand options for non-produce local sourcing; tracking local and sustainable purchases (20% target); Sea to Table program; Farmer's market on campus
Energy/Water	Water refill stations; Safe Temp programs for coolers; lighting sensors; equipment preventative maintenance schedules
Waste Reduction	Pre-consumer composting program; post-consumer composting program; Tray less dining; Local waste oil recovery; Investigate packaging options with vendors; Reusable container/mug program; Green Restaurant Association certification
Student Initiatives	Student internship program; Sustainable food student groups
Sustainability Education	Training for catering staff; Sustainability intern; Develop videos to educate; New hire and annual training around sustainability; Zero waste events
Sustainable Catering	Develop sustainable framework to events with local seasonal menus; promotion of sustainable catering; post-consumer composting
Communication/ Marketing	Develop sustainable website education; Partnership with Office of Campus Sustainability; Develop focused sustainability messaging for dining ambassadors and dining halls; social media; Michigan Meal to be served in Dining Halls
Regional/ Community Engagement	Collaborate with Washtenaw Food Hub; Huron High School outreach; Agrarian Adventures; Local Food Summit; A2 Public Library; Culture Committee; Collaboration on Sustainability events on Campus (Earthfest, Earth Day, Harvestfest)

Supply-Side Sustainability Initiatives

Approximately two-thirds of the electricity generated on campus comes from the University Central Power Plant (CPP), which provides electrical services to 130 University buildings and heat/hot water services to nearly 100 buildings on campus. The fuel efficiency of the CPP is extensively higher when compared to private utility plants, 86 percent vs. 40 percent, respectively.

The CPP was awarded the Energy Star Combined Heat and Power Award for significant fuel energy savings associated with overall plant efficiency from the U.S. EPA in 2002, and was recognized by the EPA's Combined Heat and Power (CHP) Partnership for their emissions reductions in 2006 and 2007. Currently, the University is looking to purchase a third steam turbine, which will allow a larger percentage of campus electricity to be served by the CPP rather than our local utility, DTE Energy. In lowering the University's reliance on DTE Energy, the University would significantly increase energy efficiency and decrease GHG emissions on campus (discussed more in the section titled "Understand Where the Energy Goes").

Funding Structure

UM is subdivided by both funding source and purpose. The campus is generally divided into two categories: General fund and auxiliary funds (which include the hospitals, athletics and student life, among others).[lxiii]

The General fund buildings make up approximately half of the campus and rely mostly on student tuition and fees, but also some state appropriations for income as indicated in Figure 9. The majority of the funding goes towards the capital renewal fund, which was established to renovate and reprogram existing buildings and their infrastructure needs.[lxiv] The remaining budget pays for teaching, research, library services, student scholarships, fellowships and maintenance, operation of physical properties, and other services indicated in Figure 10.[lxv] Essentially, the General fund houses most of the academic, research and operations buildings on campus.

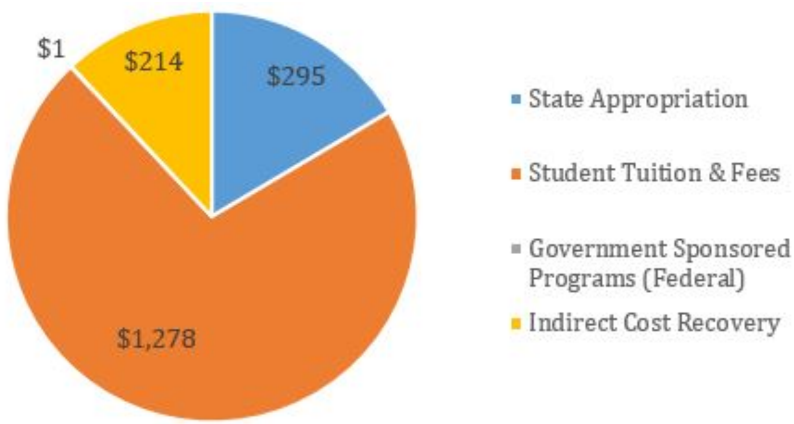

Figure 9: Sources of General Fund Revenue in millions of dollars: Fiscal Year 2015.

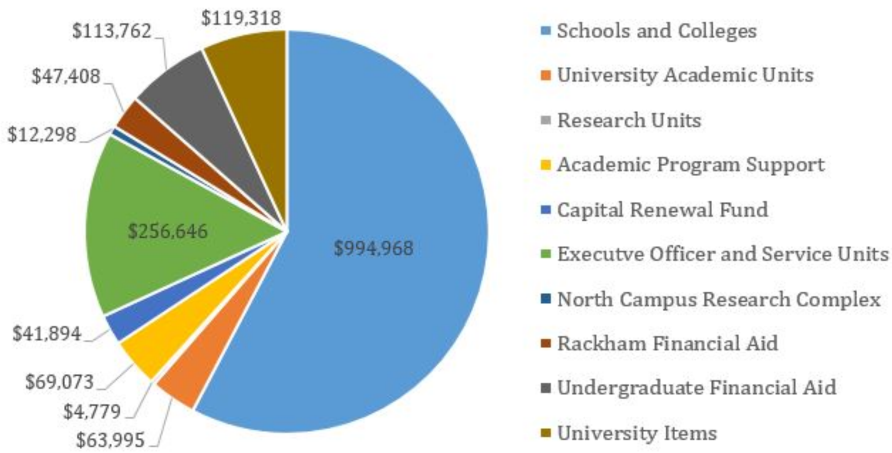

Figure 10: General Fund Expenditures: Fiscal Year 2014.

All of the other departments in the auxiliary fund are considered separate because, unlike the General fund, they finance themselves.[lxvi] For example, the University Hospital system is funded by the revenues from services they render (from check-ups, surgeries, etc.), and are therefore responsible for their own budget and operations.

The source of a fund's budget is an important distinction when we consider how the University proceeds with energy management. For example, any sustainability initiatives created and enforced by the General fund can only be implemented in buildings within their funding source. As a result, each fund largely pursues their own sustainability initiatives, even though they are all responsible for attaining the campus-wide sustainability goals discussed in the Current Demand-Side Sustainability Initiatives Section.

Energy Types by Fund and by Expense

The University of Michigan purchases several different types of energy to power the entire campus: natural gas, electricity, rechargeable bulk gas, and steam. Figure 11 shows the complexity of the financial side of energy procurement, broken down by funding source on the far right side.

Energy costs flow of University of Michigan

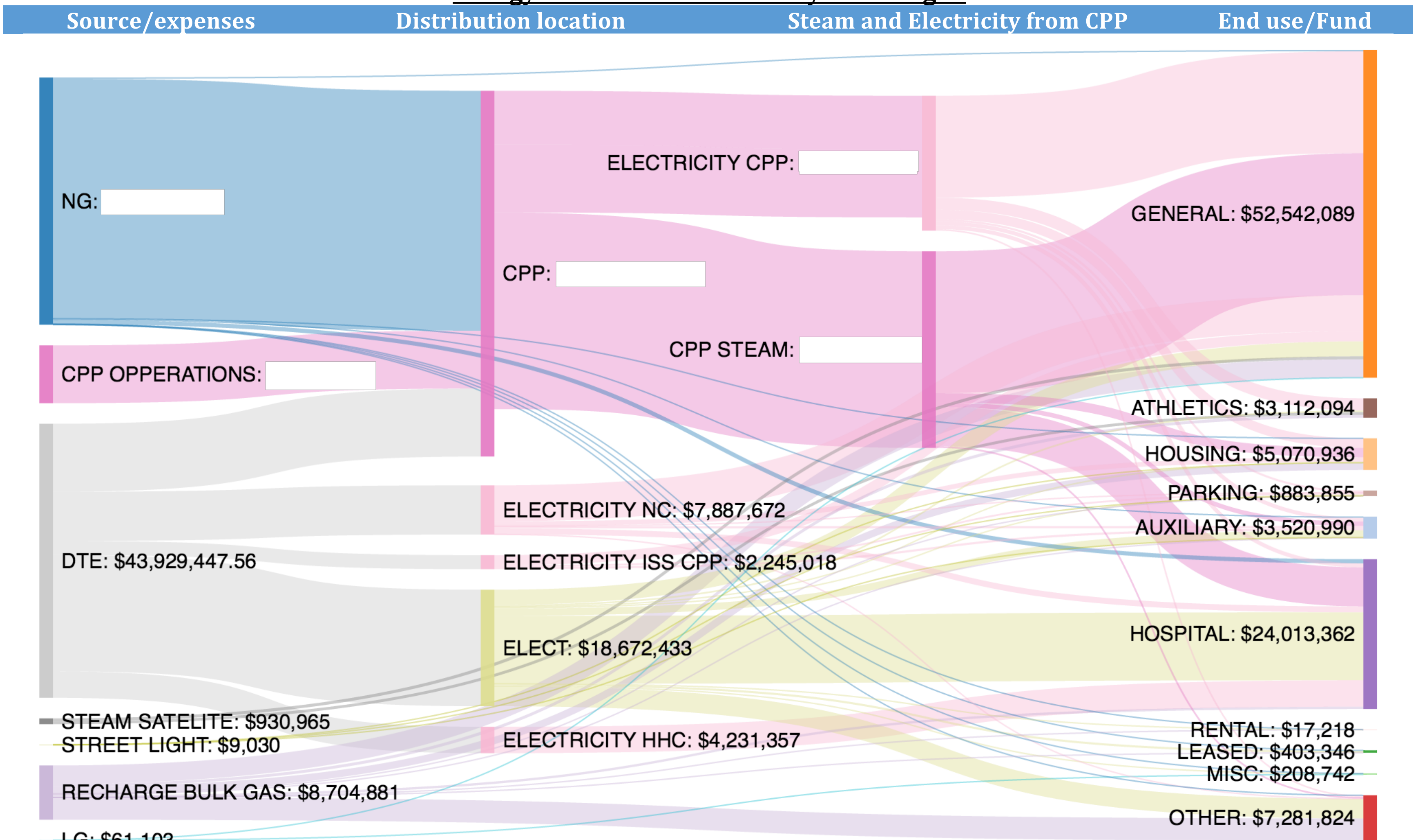

Figure 11 Flow diagram of energy costs for FY 2014. [lxvii] The far left side of the diagram breaks down the cost by the fuel source and the middle-left band represents how much energy is purchased by each substation before it is distributed to campus. The center right band illustrates the breakdown of steam costs and electricity generated by the CPP. The far right band breaks down energy cost by fund. As illustrated in this flow chart, the General Fund spends the most on energy, followed by the Hospital Fund and then the Other Fund. The Hospital and General fund use most of the steam generated by the CPP. The colors in the diagram are for guidance in following the financial flow of energy expenses. [lxviii] Some data has ben removed for proprietary data protection.

Energy Stakeholder Organization Charts at the University of Michigan

With the intense focus on sustainability initiatives at the University, it is important to know how projects are structured and who is in charge of implementing the necessary changes to reach the campus-wide sustainability goals.

Throughout the past several years, the energy-stakeholder structures have changed frequently. To learn how the campus is currently structured, interviews with several campus energy-stakeholders were conducted (Appendix D). From these interviews, as well as from utilizing pre-existing organization charts, a hierarchy of individuals associated with sustainability energy goals was created for the general, athletics, hospital and student life funds. Since each fund has varying plans on energy-saving implementations due to their differing funding sources as discussed in the Funding Structure section, the organization of energy-stakeholders for each fund differs greatly.

To provide additional information on each fund's organization and hierarchy for energy management decision-making, the master's project team completed a fund-by-fund analysis of strengths, weaknesses, opportunities, and takeaways (i.e. a "SWOT" analysis). Refer to Figure 14, Figure 16, Figure 18, and Figure 20 for the SWOT's performed on behalf of the General, Athletics, Hospital, and Student & Residential Life Funds, respectively.

Overview

Two branches report to President Schlissel on sustainability initiatives: Facilities & Operations and Office of the Provost. The Office of the Provost oversees mostly the academic-side of the University's sustainability goals, indicated in green in Figure 12. This study, however, focuses on demand-side energy consumption, which falls under Facilities & Operations (indicated in blue).

Four departments are encompassed in Facilities & Operations: 1) Architecture, Engineering & Construction (AEC); 2) Parking and Transportation Services; 3) Plant Operations; and 4) Occupational Safety & Environmental Health (OSEH). Housed within OSEH is the Office of Campus Sustainability (OCS), which is the reporting arm for the University's progress towards their campus-wide sustainability goals.

In order to accurately report the University's progress, each of the funds share their information and sustainability initiatives with OCS. This, in conjunction with the campus utility reports, comprises the majority of the content for the OCS's most notable publication—the Annual Sustainability Report.

From this overview in Figure 12, there are two main things to note. First, each department and fund is striving to meet certain sustainability goals, as dictated by the colored dots. The goal that most closely aligns with this project's goal of doubling energy efficiency is the goal to reduce GHG emissions by 25%, which is the green dot. Interestingly enough, this organization chart shows that Student Life is not required to work towards the GHG reduction goal. This could significantly influence how Student Life approaches energy initiatives. Second, the Plant Operations sector (that houses the Energy Management Team) only serves the General fund buildings and no other buildings. This is discussed further in the next section.

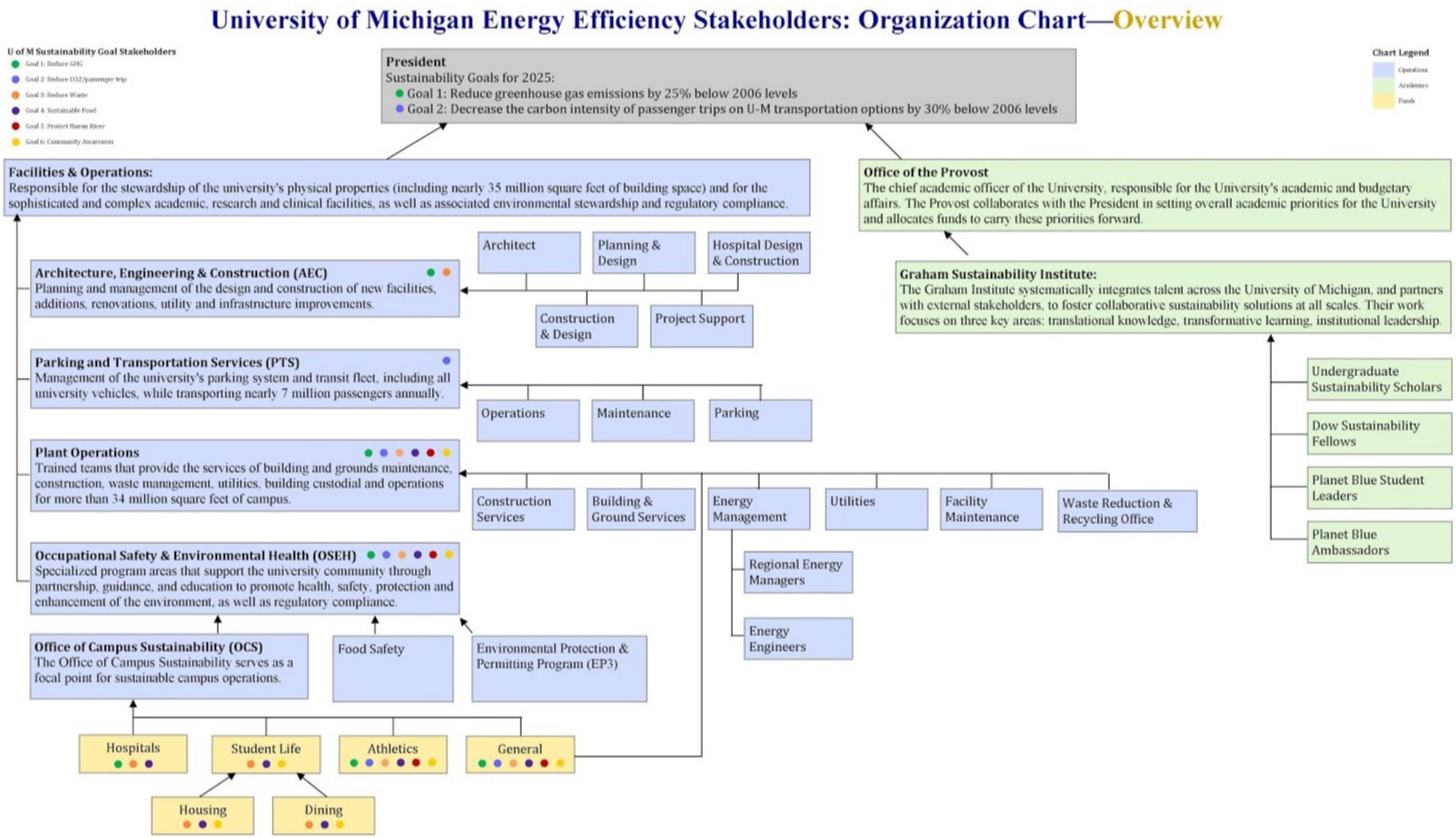

Figure 12 Organizational Chart Overview.

General Fund

As previously mentioned, the General fund comprises approximately half of the University's buildings and their budget mainly comes from student tuition and state appropriations—not their own revenue stream. As a result of this, and the fact that building audits have been performed in the General fund since the early 1970s, the energy-stakeholder organization chart is both expansive and well structured (Figure 12).

The main wheelhouse for energy conservation in the General fund is the energy management team, which includes five regional energy managers that are responsible for a specific set of buildings and report to Kevin Morgan, the Manager of Energy Management. These regional energy managers conduct a thorough building audit of each building in the General fund every few years. In Figure 13, the General fund organization chart illustrates the large number of players addressing sustainability efforts. They check over 100 ECMs for potential efficiency upgrades and analyze the building automation system (BAS) for potential improvements to equipment schedules.

Once an ECM is identified in the audit, the energy manager formulates a report that details the upgrade, calculates the payback period and estimates the GHG emissions mitigated through implementation (example in Appendix E). If the ECM is under an 8-year payback period, the ECM will be suggested to the building manager and then implemented if the project is accepted.

The SWOT analysis for the General fund is illustrated in Figure 14.

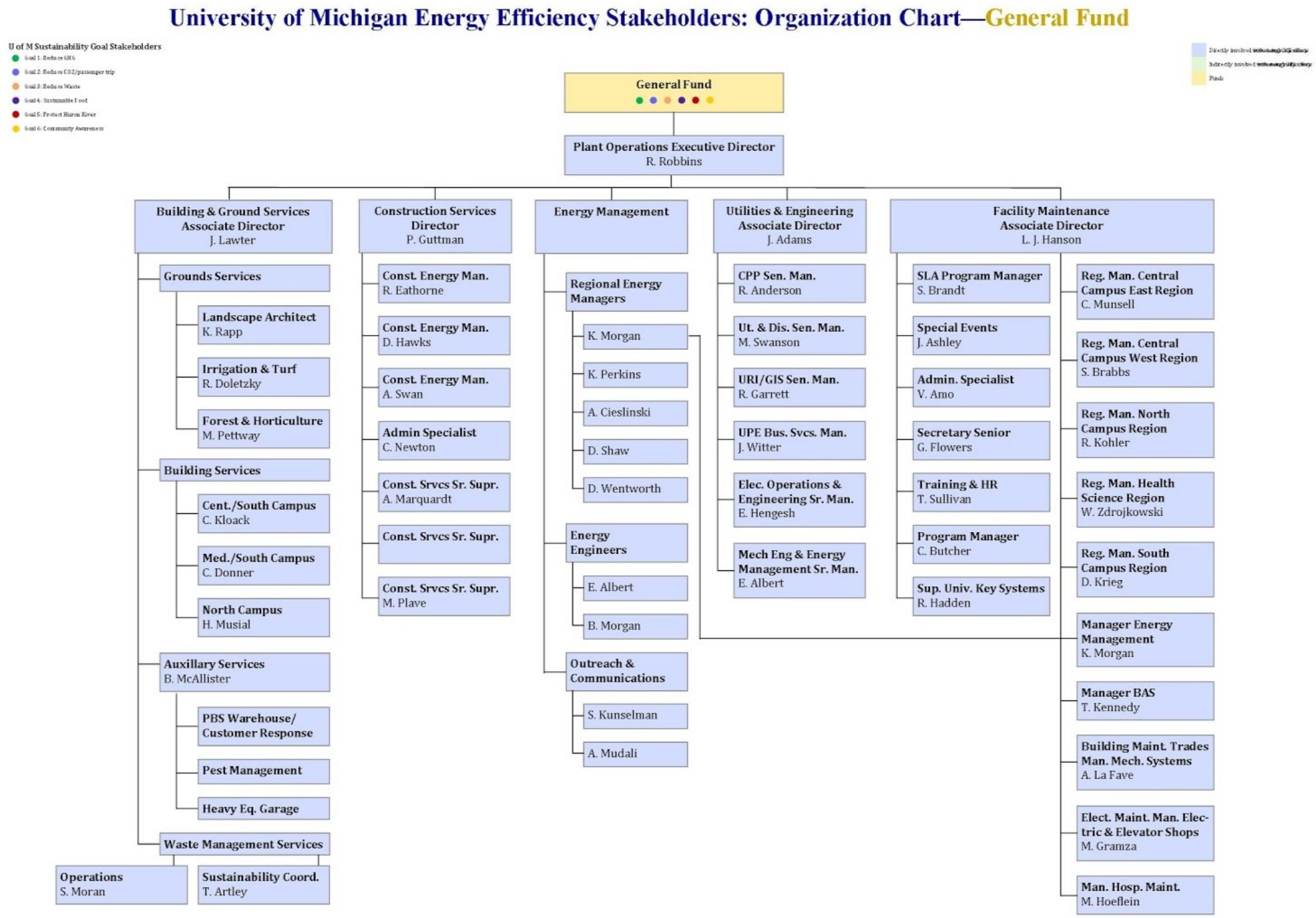

Figure 13: Organizational Chart of the General fund.

SWOT Analysis: General Fund			
Strength:	**Facilities Mgmt:** Access to all buildings' energy data & centralized campus role **Utilities & Plant:** Technical guidance implies a significant opinion for feasibility of projects on campus **OSEH:** Owner of data and statistics supporting the sustainability of energy efficiency projects on campus	**Weakness:**	**Facilities Mgmt:** Process of several reorganizations and ID'ing role/identity **Utilities & Plant:** Focus on reliability versus innovation and development **OSEH:** Owner of data and sustainability initiatives, but level of influence with funds for energy management decisions
Opportunity:	**Facilities Mgmt:** Clear JC value proposition with goals for "Ops Center" and increased centralization of UM **Utilities & Plant:** Can best identify alignment of JC tech and building needs **OSEH:** Provide influence in decision-making for energy management and managing GHG emissions goals	**Takeaway:**	**Facilities Mgmt:** Must ensure the best option (including choice of technology) to ensure proper energy mgmt. on campus **Utilities & Plant:** Conservative nature, but credibility is key to influencing leaders **OSEH:** Important to have on board to ensure endorsement; alignment with campus goals but must integrate $ saving

Figure 14: SWOT Analysis for the General Fund.

Athletics

Unlike the General fund, the Athletics department does not have the resources necessary to conduct building audits on a regular basis, as is illustrated in Figure 15. In fact, in winter of 2015, administrators in the department were seeking quotes on how much a building audit would cost from both the Energy Management team and external companies, knowing how crucial audits are to increasing efficiency in their buildings.

Although there is no position that is solely dedicated to sustainability initiatives, the Athletics department does have a Sustainability Chair and a Sustainability Committee that works closely with M-SAS to create and advance sustainability initiatives. Currently, Corbin Todd is the Sustainability Chair and oversees the Sustainability Gameplan (Appendix C), but his main job is Director of University of Michigan Golf Courses.

In discussions with Mr. Todd and his predecessor, Paul Dunlop, Senior Facility Manager for Michigan Stadium-Crisler Center, Athletics currently implements energy efficiency upgrades through their maintenance team, under the management of Joe Hepler. Once a piece of equipment has reached end of life (EoL), it is replaced with a more efficient version. For larger efficiency upgrades though, proposed projects are contracted out to the University's AEC for review and/or recommendations prior to implementation.

The SWOT analysis for the Athletics fund is illustrated in Figure 16.

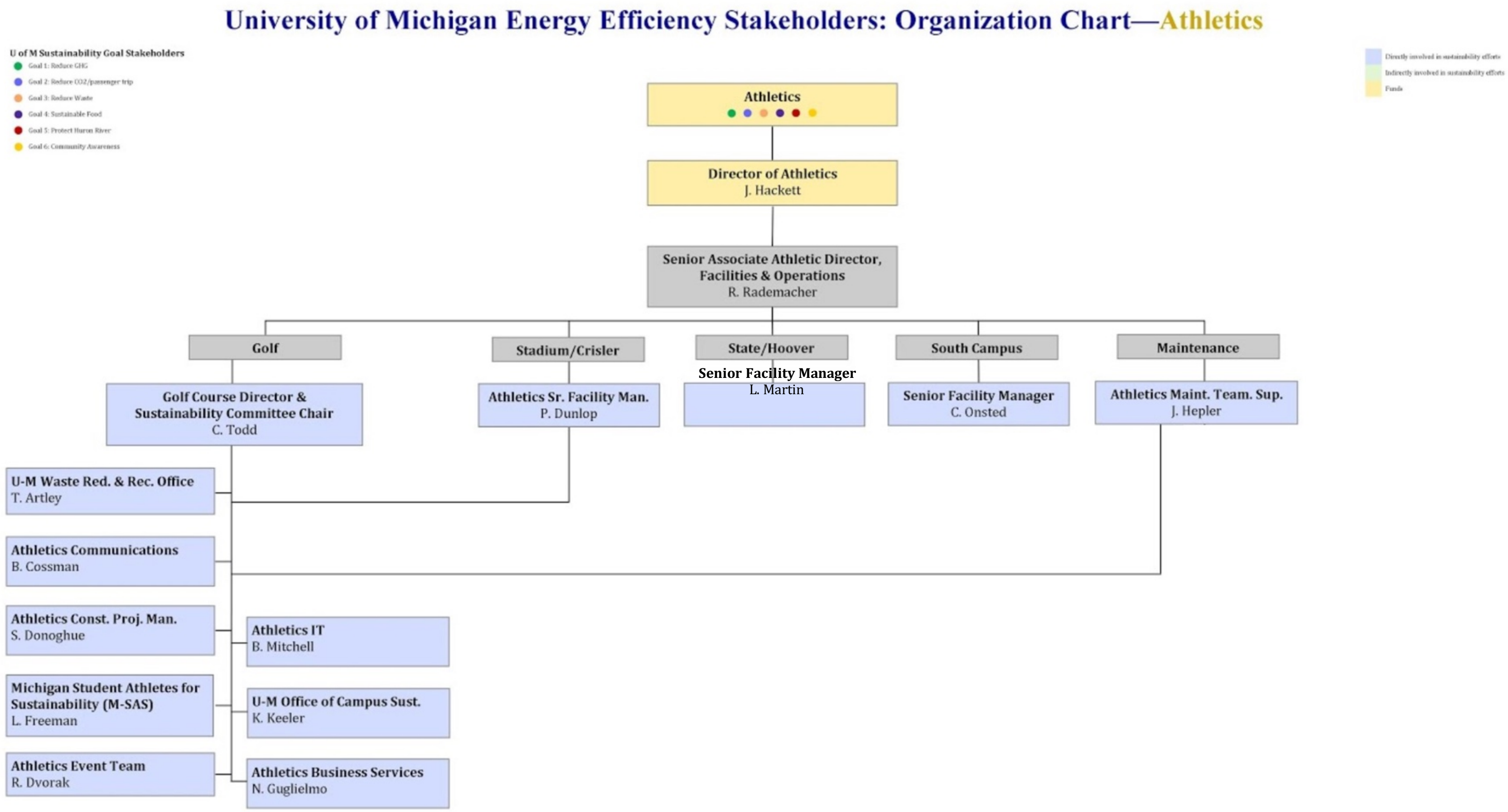

Figure 15: Organization chart for Athletics.

SWOT Analysis: Athletics Fund			
Strength:	1) Committee of representatives involved on department's sustainability initiatives 2) Very independent and profit-seeking relative to other funds; likely clearer decision-making (based on economics) 3) Very specific and intensive use of buildings provides clear opportunities for use and measure	**Weakness:**	1) Rotating sustainability chair leaves no true hierarchy or clear involvement 2) Comparability of fund's buildings relative to campus due to intensive and seasonal usage patterns may limit increased adoption by campus from exhibition
Opportunity:	1) High visibility of buildings to students, local, and (potentially) national audience 2) Leadership wants building energy audits 3) Foresee a pipeline of modernization and retrofits (including the Big House) which can lead to extended relationship and opportunities for enterprise development	**Takeaway:**	- Current University policy prevents desired energy audits at a competitive rate - Along with already "business" approach to managing the fund, leadership seems very inclined to working with third parties - Value proposition of technology and services is key to establishing a high-Potential relationship

Figure 16: SWOT Analysis of the Athletics Fund.

Hospitals

The organizational structure for energy-stakeholders in the UMHHC is very similar to the Athletics department and is shown in Figure 17. An Environmental Stewardship Committee oversees both the campus-wide and hospital-specific sustainability goals. The main difference is that the UMHHC does have one person whose sole job is dedicated to energy conservation.

Colin Murphy is the Building Systems and Energy Manager for the hospitals. He previously worked as a regional energy engineer for Planet Blue, and is therefore well versed in the processes that the General fund implements to increase efficiency on campus in the General fund buildings.

Mr. Murphy receives an annual budget to make energy efficiency improvements and upgrades, unlike the General fund, which has the EAC. With his budget, Mr. Murphy identifies opportunities for energy savings and implements as many opportunities as possible with the finances available. Although he does not have a staff to conduct regular building audits, Mr. Murphy's familiarity with the building audit process and his expertise in identifying impactful projects has enabled him to make drastic improvements throughout the UMHHC.

The SWOT analysis for the Hospitals fund is illustrated in Figure 18.

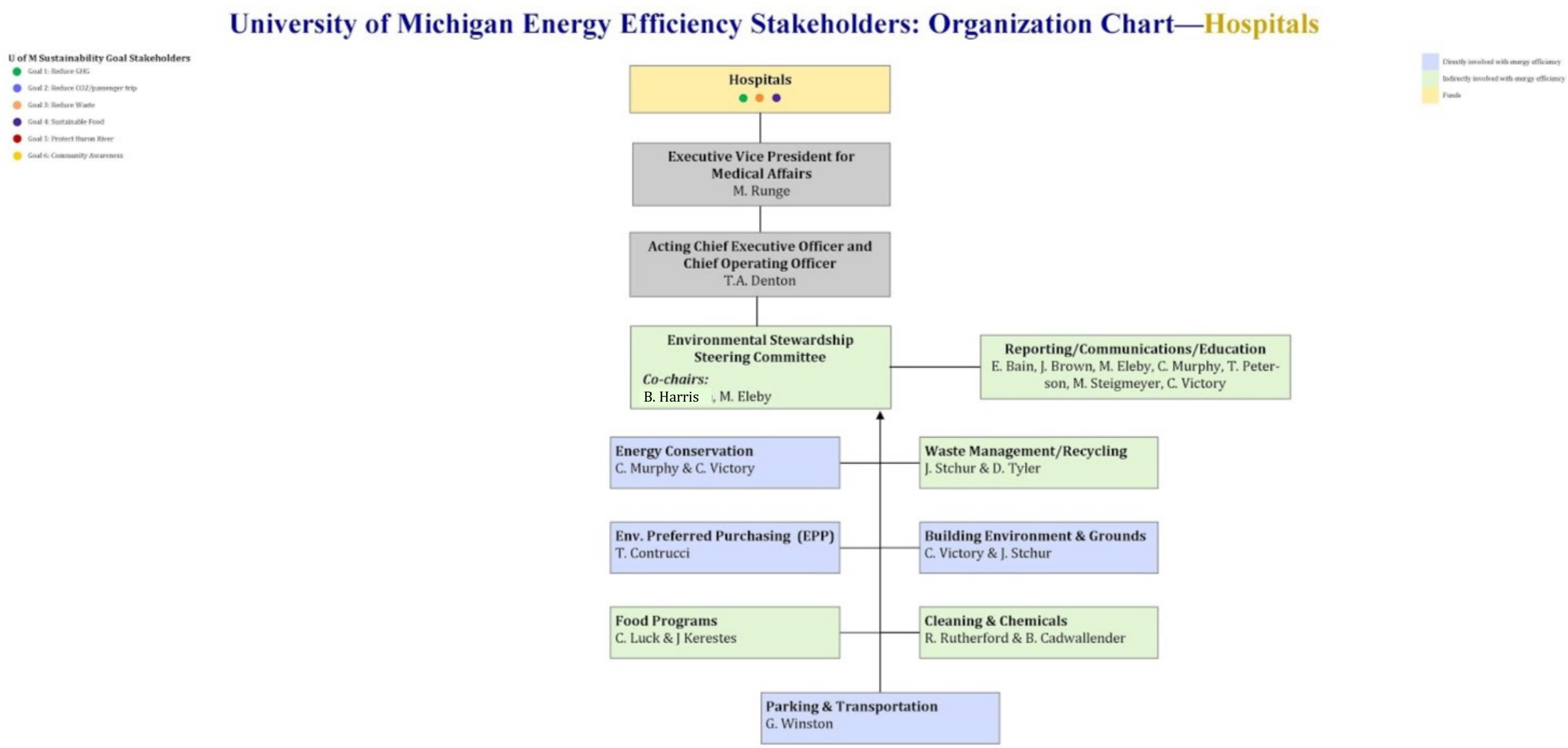

Figure 17: Organization Chart Hospital.

SWOT Analysis: Hospitals Fund			
Strength:	1) Have set goals for energy management beyond the University's mandates for sustainability 2) Current approach has targeted "low hanging fruit" and can benefit from professional/technical direction 3) Leadership is self-motivated, experienced, and cooperative	**Weakness:**	1) No audits or formal doctrine for determining energy efficiency projects 2) Comparability of available budget (and payback) for energy projects; currently set aside $0.5-1.0M annually 3) Lack of continuity and expectations for role and performance in light of gains through increased energy management
Opportunity:	1) ~$6M in planned renovation at main hospital to decrease energy use by 20% 2) Energy management crucial to fund's building and operations because of patients and research. High priority. 3) Several different BAS systems employed and a likely strong fit for LEAN and future proposed projects	**Takeaway:**	- Potential for funding and projects focused on energy management a clear priority for the future of the fund and its buildings - Currently there's a low-bar for energy savings initiatives that leave opportunity for a host of projects that can be proposed - Room for influence since management structure & direction is still developing

Figure 18: SWOT Analysis of the Hospitals Fund.

Student Life

The Student Life organization chart, as you can see from Figure 19, also does not have many key players in energy efficiency measures. This fund is particularly difficult to create a dedicated energy-stakeholder structure for because it encompasses so many seemingly distillate buildings. For example, each of the residence halls falls within this fund, but each building manager may prioritize energy efficiency differently. There is currently no structure for buildings to reach energy reduction targets. However, each of these residence halls houses a Planet Blue Ambassador, whose purpose is to encourage their fellow classmates to practice good sustainability behaviors and to encourage participation in sustainability events on campus.

A new position was created under the Director of Dining in fall of 2014 that will assist with unifying these aforementioned sustainability efforts. Keith Soster, previously Director of Food Service, is now Director of Student Engagement, where a large portion of his job description is dedicated to making institutional sustainability initiatives and to fostering a student culture around sustainability. He is in charge of the Planet Blue Ambassadors and has made significant strides in the campus-wide sustainability goals—particularly in terms of pre- and post-consumer composting in the dining halls.

Although Mr. Soster does not have energy managers to conduct building audits, he asked OCS to perform an audit in the Unions (and several offices), and is proud to say that all dining halls are certified by OCS. Although these audits are not as in-depth as those conducted by the Energy Management team, several suggestions and improvements were made because of them.

In general, Mr. Soster explains that, outside of large projects like renovations, efficiency upgrades typically come from the maintenance staff first, as is the case with the Athletics Department. The maintenance staff's recommendations are considered and, if the budget allows, implemented. However, there is no process within the fund to measure how much energy is conserved by each project, nor is there a method by which to calculate the GHG mitigated by that project.

The SWOT analysis for the Student Life fund is illustrated in Figure 20.

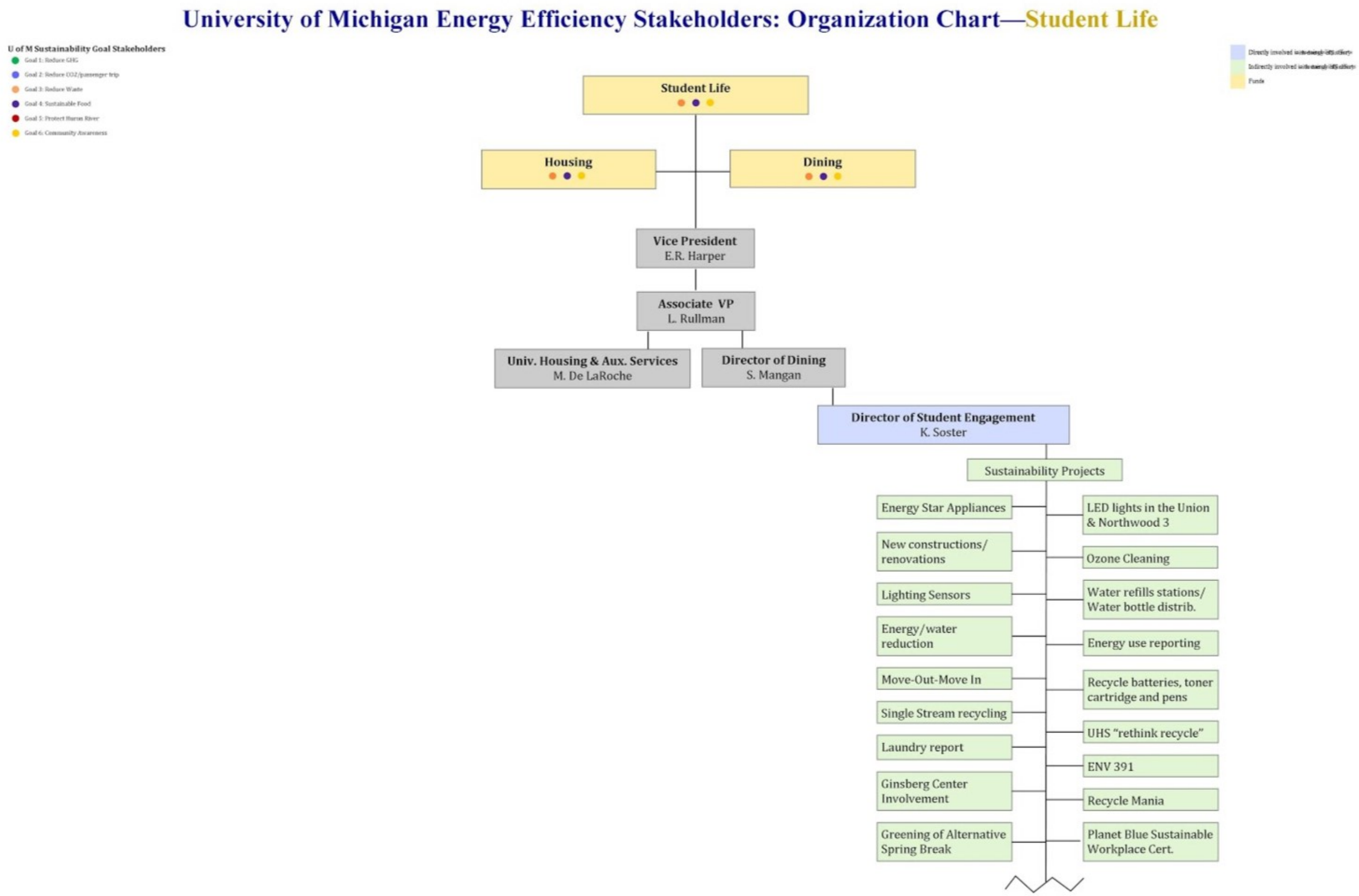

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Figure 19: Origination chart Student Life.

SWOT Analysis: Student & Residential Life Fund			
Strength:	1) Huge network and outreach capable with inclusion of students, faculty, and administration across campus 2) Buildings are highly visible & utilized 3) Leadership's personal motivation for sustainability makes for a potential strong partnership and willingness to collaborate	**Weakness:**	1) Distributed leadership on energy management issues and decisions 2) Comparability to other funds' operations and building demands may prevent opportunities for cross-over 3) Leadership focus is primarily on food and waste with energy management not as effectively scoped into responsibilities
Opportunity:	1) Exposure: students represent the largest population base and voice on campus 2) High motivation/interest from leadership is open to influence/guidance 3) Pipeline of projects due to the importance of maintaining/retrofitting buildings designated for student use and safety	**Takeaway:**	- Clear intent for impact on campus and on behalf of all E16; mission is strong - While there's a clear dedication however, must balance initiatives from potentially higher-competing priorities - As a value proposition, weigh benefits of economics, social, or combination of impact

Figure 20: SWOT Analysis of Student Life Fund.

Summary of Organization Charts

In summary, although all of campus is responsible for meeting the same sustainability goals, each of the funds operates in very different ways.

As is evidenced by the organization charts, the General fund clearly has a well-defined process by which they both identify and implement energy conservation measures. Although the Athletics, Hospital, and Student Life funds are working towards sustainability initiatives, they each have only one person who is primarily responsible for their efforts.

In addition to the organizational structure, each of these four funds implements energy improvements in different ways, which is illustrated in
Figure 21. The steps that lead to energy project implementation in each of these funds is a direct result of the human capacity that is dedicated to energy efficiency. The Energy Management team's process is similar to Johnson Controls process (as discussed in the Section titled "JCI in the Campus Energy Industry") and is the industry standard, because they have a team dedicated to—and trained in—conducting building audits. The Athletics, Hospitals and Student Life funds do not have that expertise readily available to them. As a result, many of their ECMs are reactionary and are responses from either budget availability or the equipment life and maintenance observations.

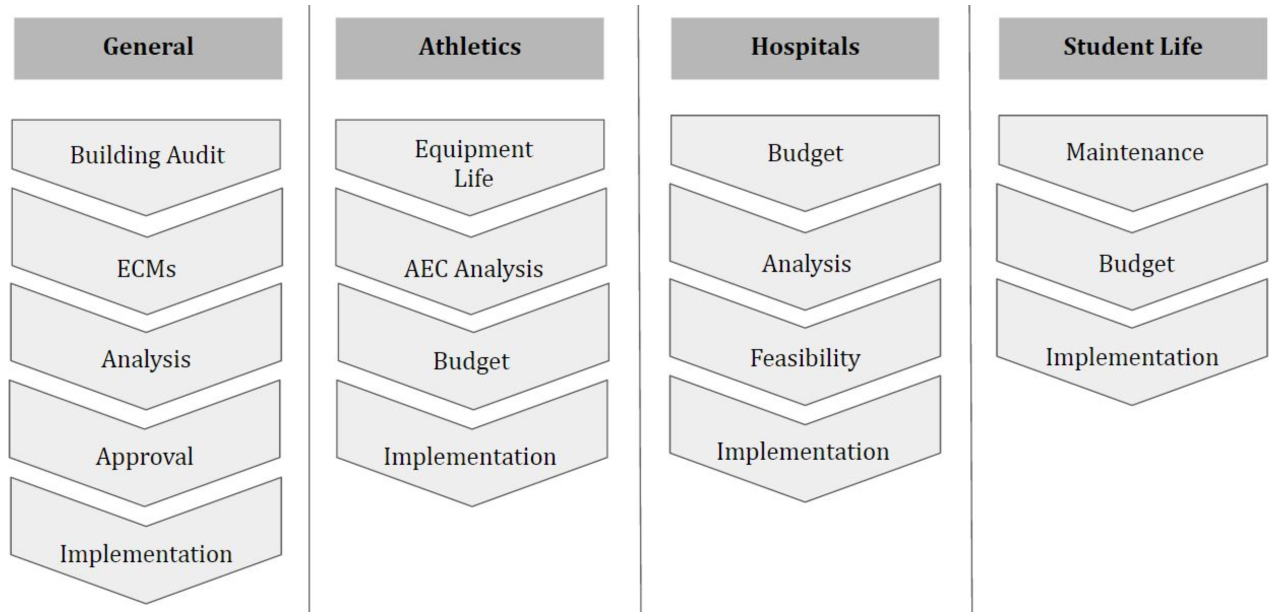


Figure 21: ECM process for the General, Athletics, Hospitals and Student life funds.

Current and Past energy consumption

As mentioned in the section titled "University of Michigan Previous and Current Energy Initiatives," the University underwent several years of major updates and progress in energy conservation through the Energy Star program and EOC initiatives. As a result, most of the high impact ECMs have already been implemented in the General Fund, which makes the goal of reducing GHG emissions by 25% and this project goal of doubling energy efficiency, very aggressive.

Understanding how the energy is distributed:

The University purchases resources such as electricity, water and natural gas from the utilities on a contract basis with an agreement of 10 years or beyond. The University buys more than 60% of the electricity, while the rest is produced from an on-campus cogeneration power plant.

Due to the spatial distribution of campus buildings, the electricity purchased feeds into several sub-stations including, the Central Power Plant, North and Ingalls, as shown in the yellow box of Figure 22. In addition to the purchased electricity, the University of Michigan also has a co-generation power plant, the Central Power Plant (CPP), which generates electricity and steam, illustrated in the blue box in Figure 22.

U-M currently purchases the RECs associated with 100% of the output from two 2.5-megawatt (MW) wind turbines in Michigan operated by Heritage Sustainable Energy, as shown in the green box of Figure 22. This represents an offset of our GHG emissions of about 10,000 $MTCO_2e$ (million metric tons of carbon dioxide equivalent) each year at a cost of $20 per megawatt-hour (MWh)[lxix].

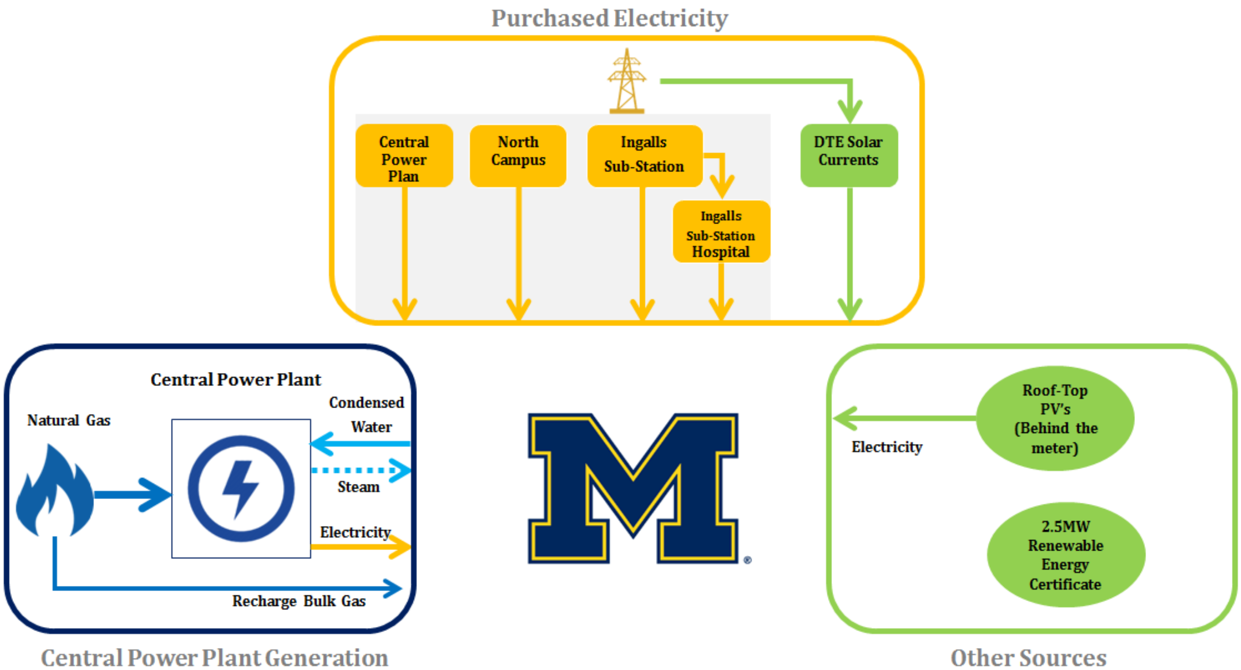


Figure 22: Schematic Diagram explaining the Energy supply across the campus.

Understanding where the energy comes from and where it goes:

The University of Michigan's utilities are managed through 10 different funds: the General, Athletics, Student Life, Parking, Auxiliary, Other, Hospital, Leased, Miscellaneous and Rental funds. Distinguishing by funding source helps the University organize budget allocations and billings across the various units on campus.

So far, the University's efforts to reduce energy use have focused mainly on the General fund, which makes up a majority of the academic buildings. However, only about half of the energy demand is from the General fund, while the rest is distributed between the Hospital, Student Life, Athletics, and other funds. The Sankey diagram in Figure 23 illustrates where the electricity is coming from and which fund consumes it. The flow diagram can be understood from left to right with the left representing how many kWh (kilowatt-hours) are generated by a particular fuel source. The numbers for gas are exact as the central power plant reports how much natural gas it consumes over one year. The kWh numbers from coal, nuclear, oil hydroelectric, and renewable are approximate and are calculated from percentages advertised on DTE's website. In the second column from the left, CPP splits into two flows "STEAM TRUBINE CPP" and "GAS TURBINE CPP". These flows illustrate how much electricity the steam turbines generate as compared with the gas turbines. See the image description for more information.

Electricity flow of University of Michigan

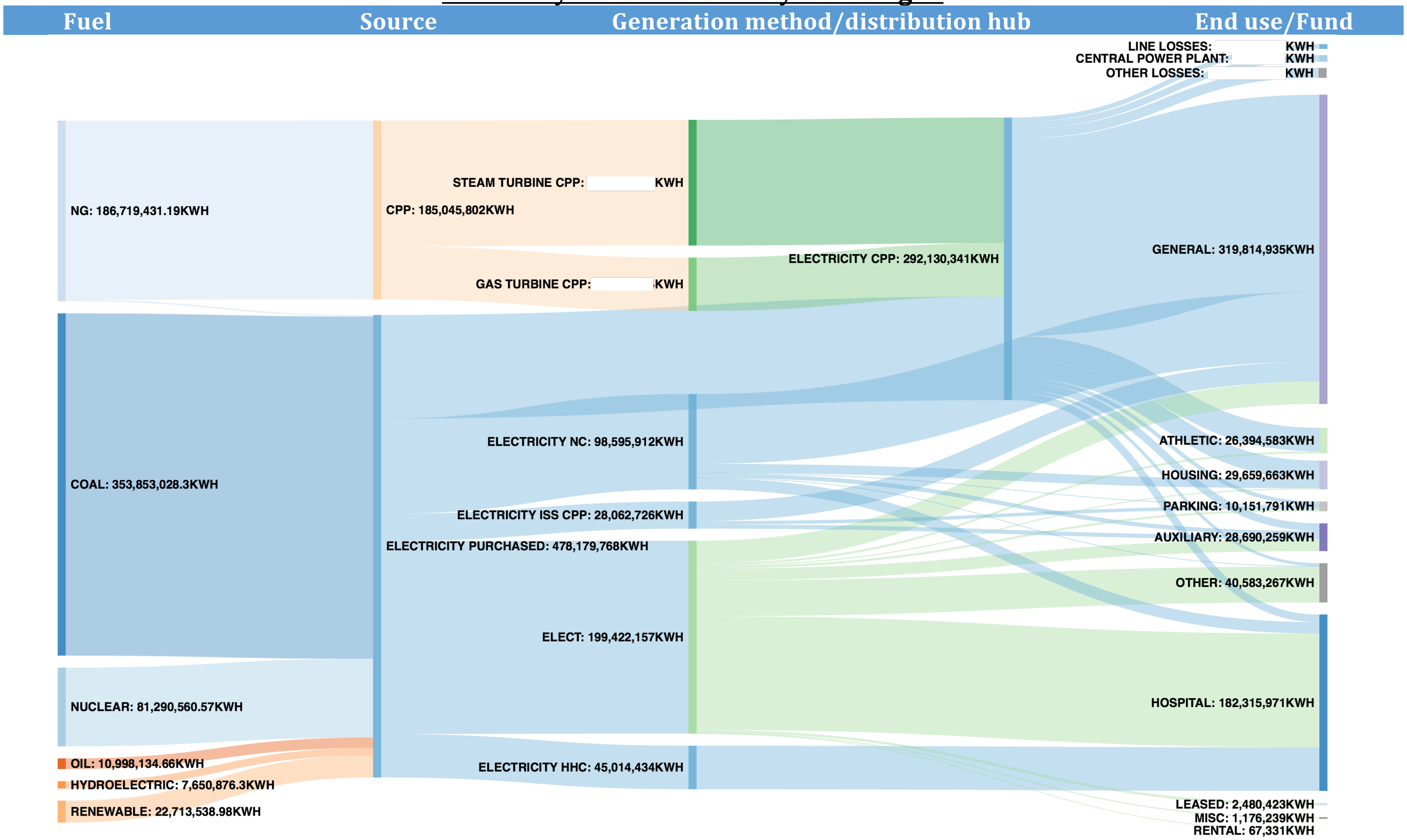


Figure 23: Flow diagram of electricity purchased, generated and consumed, by fund. Data is from UM annual report FY 2014. This diagram shows that the CPP supplies about 75% of the general fund, while the rest is purchased from DTE Energy. The far left side of the diagram breaks down the kWh by the energy generation source from DTE Energy, which is approximately 75% coal-based.[lxx] The middle-left band represents the total amount of electricity purchased by the University. The center band illustrates the five substations where electricity enters the campus and the additional electricity that is generated by the CPP. The far right band breaks the electricity consumption down by fund. As is illustrated in this flow chart, the General fund consumes the most electricity, followed by the Hospital fund. The Housing fund represents the "Student Life" fund. Some data has ben removed for proprietary data protection.

Although the General fund is mostly serviced by the CPP, nearly all of the remaining fund buildings are powered by DTE. This is a major concern when we consider GHG emissions. As previously mentioned, 75% of DTE's energy is generated with coal, which is a much higher carbon-emitting fuel. Consequently, the electricity composite mix consumed by the University remains mostly coal-based, even though the CPP is fueled by natural gas. This imported coal-generated electricity has significant implications when considering the University's goal to reduce GHG emissions by 25% by 2025 (Figure 24).

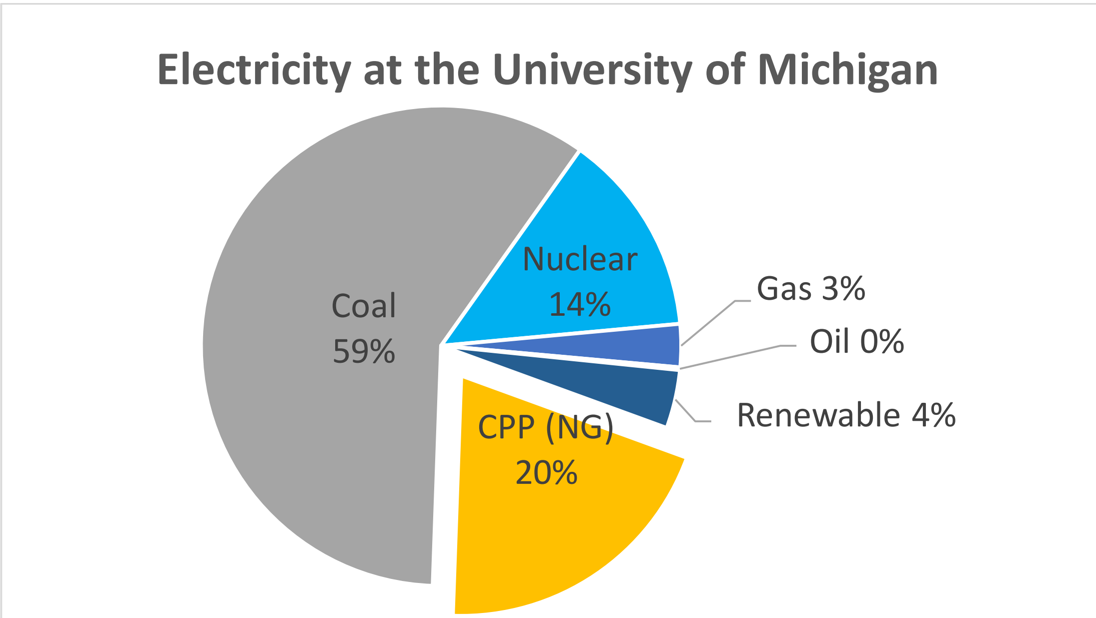


Figure 24: Source and fuel type of electricity consumed at the University of Michigan from FY 2014.

Building Energy Assessment by type:

In the year 2014, the University's building footprint of about 35 million square-feet paid more than $108 million for its energy consumption - spending just over $3.0 for each square foot.[lxxi] The campus has 188 buildings across campus (excluding Auxiliary and Parking Structures), which consumed a total of 7,636,595 MMBtus in 2014, which is 418,498 MMBtus more than levels in 2013, and 781,388 MMBtus more when compared with 2006 levels. Each of the buildings were first categorized by building type, and later arranged in a decreasing order of the EUI, as shown in

Although most of the campus-buildings – typically comprising of classrooms, labs, offices and common spaces etc. - will fall under mixed-use building type, buildings are categorized per the University of Michigan's campus information into seven groups: Academic, Administrative, Athletics, Housing, Library & Museum, Medical and Student life/Activities building. All 188 buildings across the Ann Arbor campus were studied. Forty-five Academic buildings are above EPA's national college energy consumption median of 130.47 kBtu/sqft/yr. The median for the UM campus is above the national average. The median for the campus is 136.3 and the overall EUI for the campus (total building energy consumption/total square feet) is 209.44 KBtu/sqft. Appendix E: University of Michigan Building Size provides a graph of all University buildings, organized by square footage.

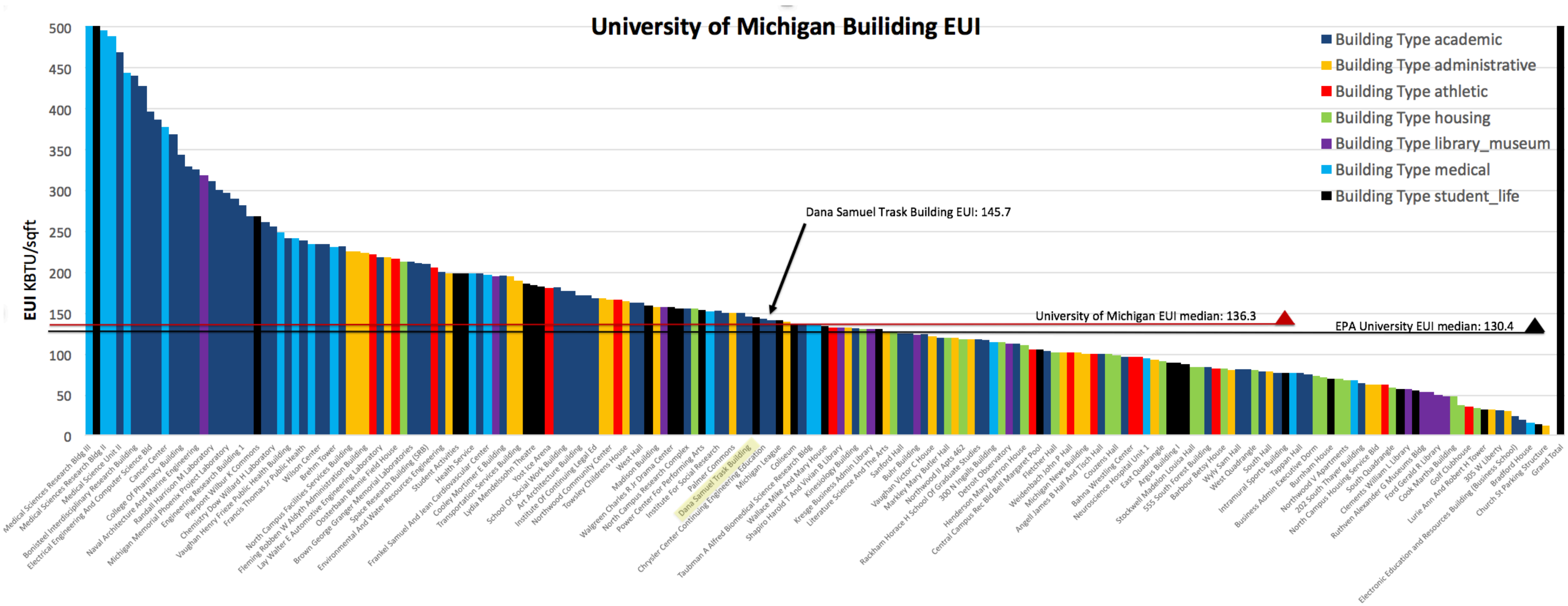


Figure 25: University of Michigan's Energy Use Intensity by building type, for the year 2014.

Given the climatic conditions in the city of Ann Arbor, which comes under Climate Zone 5a (indicating moist and cold climate type), the energy intensity is expected to be much higher than the national median for campus buildings. However, the EPA does not provide any benchmark for each of the climate zones.

Figure 26 compares the median EUI of buildings by type with the total number of buildings (on x-axis) and total energy consumption represented as the size of the bubble.

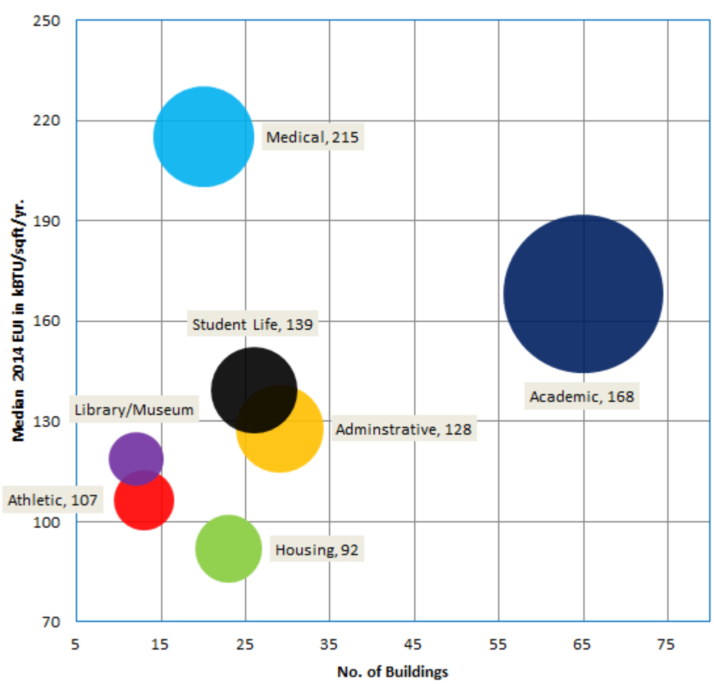


Figure 26: Bubble diagram – Explaining the total energy consumption and median EUI by building type for the year 2014.

The median energy consumption of 65 Academic building in Ann Arbor campus is 168 kBtu/sqft/yr and 215 kBtu/sqft/yr for just 20 Medical buildings. Differences in EUI were observed because of different functionality of spaces for each of the buildings. For example, the Academic buildings consist mostly of classrooms, offices, meeting rooms and common study spaces, whereas, the majority of Medical buildings have research labs, extensive equipment and supporting service rooms which have a higher energy intensity.

Along with different functionality of the spaces, the time of use of buildings also differ. The Medical building spaces are running throughout the year, whereas much of the academic buildings are not fully functional during the summer months and student vacation times. Additionally, the time of building usage (or the operating hours) of the Medical building category not only contrasts with the Academic buildings, but also with Athletics buildings, Student activities and Public buildings. There are only 12 Athletic buildings with median EUI of 107 kBtu/sqft/yr, as shown in Figure 26, representing only 3% of the UM's building footprint, but some buildings' activities are visible only during game days. On the other hand, the Housing buildings with the lowest EUI (92 kBtu/sqft/yr) exceeds the EPA's national median site energy for Residential Hall/Dormitory category (78.8 kBtu/sqft/yr). [lxxii]

The differences in EUI is not only evident amongst each of the building categories – the Medical building type being the highest and the Housing with lowest EUI – but a wide range of EUI is also observed within buildings under the same building type, as shown below in Figure 27. Each of the box plots are arranged in decreasing order with a circular marker representing the buildings falling in a particular building type. The color blue represents the second Quadrantile and Maize represents the third. The highest values, or outliers, are marked on each of the building types on the box plot. The building spaces of these outlier buildings predominantly falls under mixed-use building, for example, the Medical Science Research Building (MSRB) has more than 70% space allotted for research purpose only.

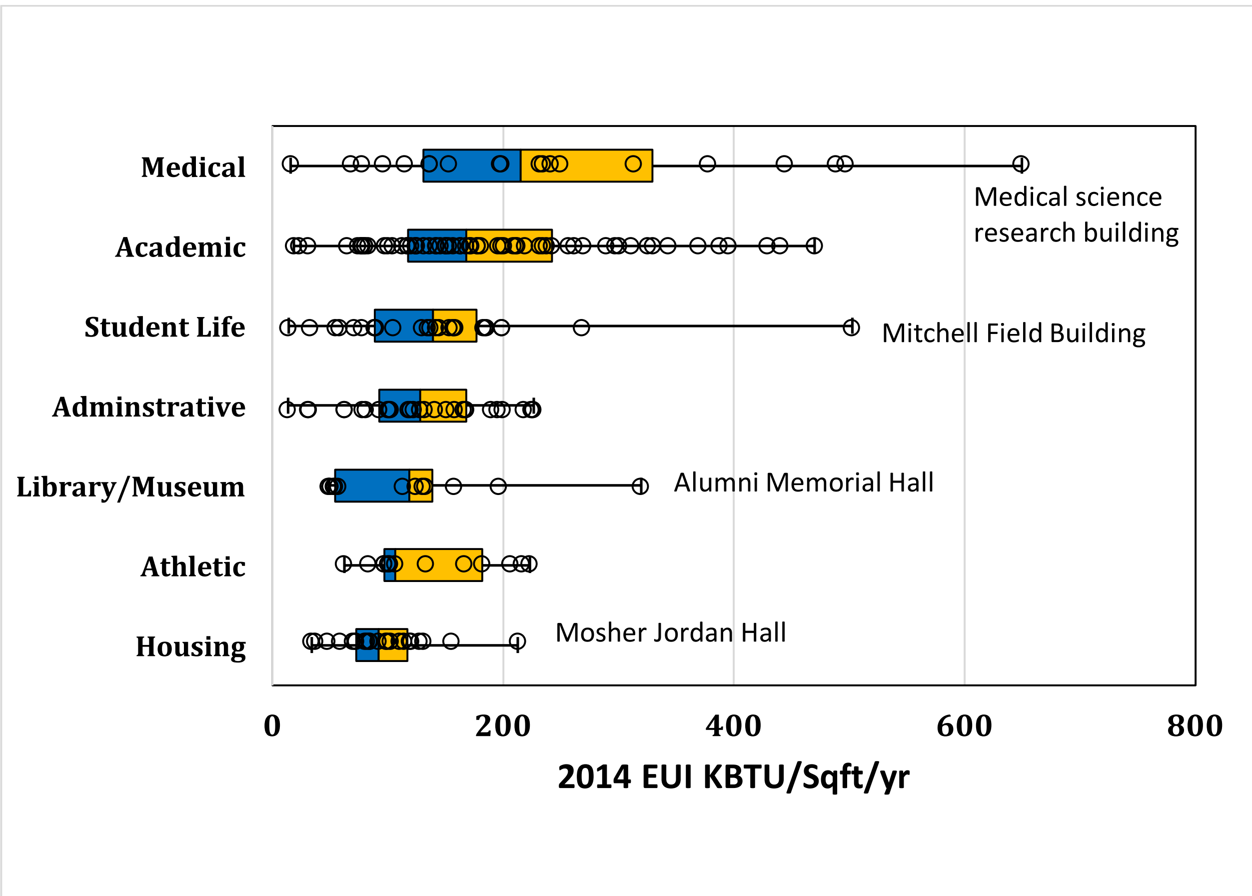


Figure 27: Box Plot – Explaining the total energy consumption and median EUI by building type for the year 2014. A total of 188 buildings are represented in this box plot.

A correlation between each of the buildings with building type wasn't found. Hence, categorizing building by 'building type' is not that useful. The study to understand campus buildings at UM is categorized by its budget, as mentioned in the Funding Structure section.

The percentage of change in energy and building footprint growth by funds over the course of a decade (2004-2014) is indicated in Table 6.

Table 6: Change in Energy consumption and spaces by funds between 2004 and 2014.[lxxiii]

Budget Unit	**FY14 energy consumption (billion Btus)**	**% Change in Energy consumption, FY04-FY14**	**% Change in space FY04 to FY14**
General Fund	3230	-3.5	+ 22.2
University Hospital	1200	+ 45	+ 81
NCRC	800	+ 9.5 FY10- FY14	n/a
Student Life	415	-5.8	+ 1.2
Auxiliary units/ others	270	-15.6	+ 35.7
Athletics	200	+ 93.6	+ 56

The space growth of buildings under the General fund, Student Life and Auxiliary units have increased over the decade, but a significant energy depreciation is observed – suggesting aggressive end-use energy reduction strategies have already been adapted to those funding categories. On the contrary, the energy consumption for the buildings under Athletics fund – which has highest energy impacts only during game days - were almost doubled for the space growth of just 56% over the decade. Hence, for the buildings falling under Hospital, Auxiliary units and Athletics, there needs to be specialized attention for reducing building energy consumption.

Looking at the amount of Btus/person, the overall energy consumption has decreased slightly since 2006; however, there is no distinct downward trend in energy consumption in the last nine years shown in Figure 28. When comparing the energy consumption of persons per square foot, though, it is clear that there have been several energy conservation accomplishments, and the downward trend looks as though it will continue towards increased efficiency as shown in Figure 29.

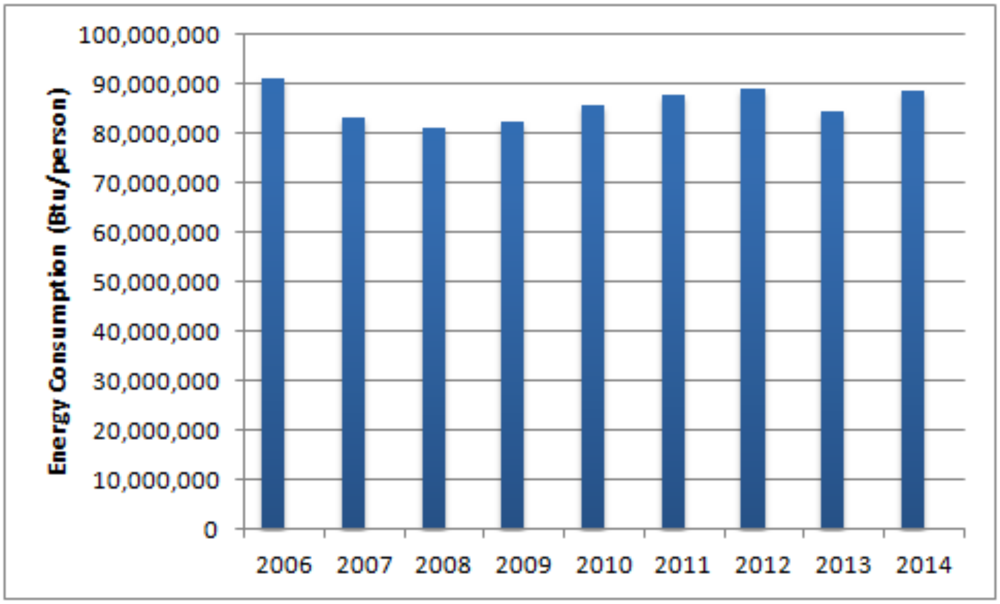


Figure 28: Total Energy Consumption in Btu/person at the University of Michigan from 2006-2014.

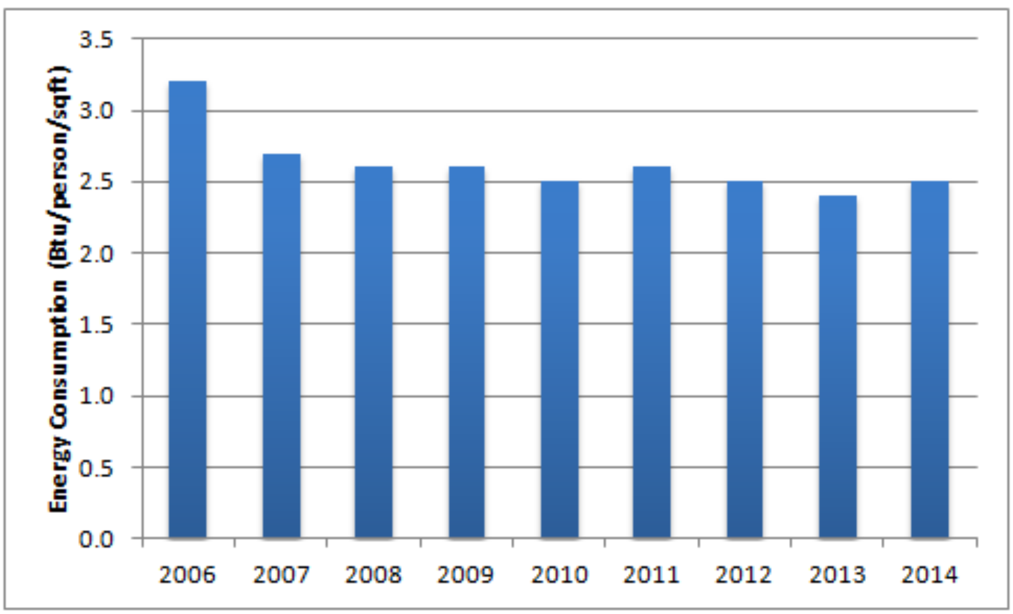


Figure 29 Total Energy Consumption in Btu/person/sqft at the University of Michigan from 2006-2014.

Progress has been made in decreasing energy consumption per person per square foot on campus, but the University's goal of reducing carbon emissions by 25% by 2025 has not seen much progress since 2006 levels illustrated by Figure 30. With only ten years remaining to reach the University's GHG emission goal, energy efficiency efforts must be prioritized.

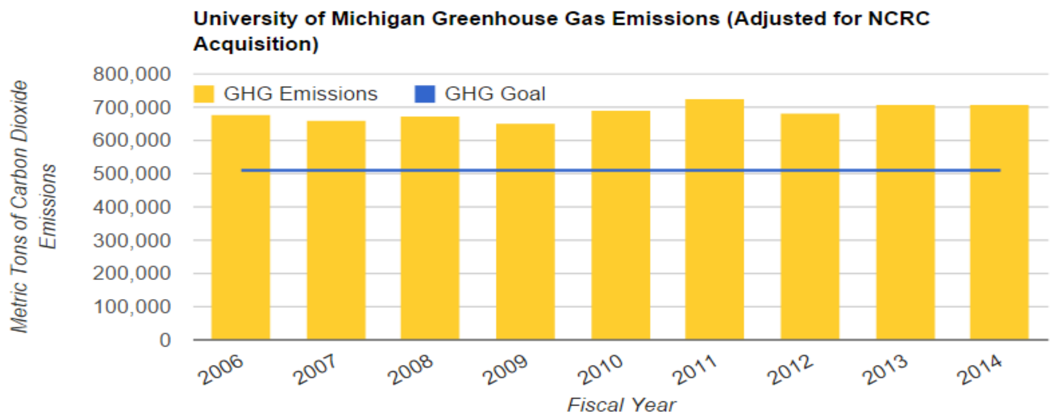


Figure 30 University of Michigan Greenhouse Gas Emissions (Adjusted for NCRC Acquisition).

As a result of the lack of progress in meeting the emissions goal, current University President, Mark Schlissel, announced on November 4, 2015, several key changes that will further assist the school in meeting these initiatives, including a dedicated $100 million towards campus sustainability initiatives. The two biggest suggested changes are to expand the energy management team's energy audits across campus (previously only performed in General fund buildings) and the addition of a 15 MW natural gas combined cycle turbine to the Central Power Plant.[lxxiv]

LEAN Energy Analysis on University of Michigan Buildings

To further assess the energy consumption and energy efficiency potential on campus, the Master's project team used JCI's LEAN Energy Analysis to conduct a preliminary benchmarking analysis on how the University of Michigan is currently performing, and to identify key buildings that have high potential savings and opportunities for energy conservation measures. The LEAN Energy Analysis was a low investment process for the University as it is unobtrusive, uses publicly available utility data, and is able to provide a high-level estimation of the magnitude of savings.[lxxv]

As previously mentioned in the LEAN Energy Analysis section, the tool compares buildings' energy performance against those of similar operational use across the globe. Although Johnson Controls has collaborated with college campuses to optimize their energy use, the LEAN analysis tool itself has not been used extensively on campus-specific buildings. JCI has a robust dataset from previous customers on office buildings, which allows for accurate benchmarking and comparison, but a similar dataset has not yet been compiled for college campus-specific building types (labs, classrooms, schools operating hours and mixed-use).

Energy stakeholders in each fund (general, athletics, hospitals and student life) identified an initial list of buildings in which to apply the LEAN Energy Analysis. Ultimately, twenty University of Michigan buildings of various functions and size were selected for analysis, with eight mixed-use lab buildings shown in Table 7 and twelve single-use buildings shown in Table 6.

Table 7: University of Michigan Mixed-Use Lab Buildings.

Building	Primary Function	Square Footage
Biomedical Science Research Building	Labs and Offices	593,719
Chemistry Building	Lab, Classrooms	544,628
Dana Building	Classrooms, Offices, Labs	117,148
Electrical Engineering and Computer Science Building	Labs, Classrooms, Offices	305,021
Institute for Social Research	Labs	225,766
Life Sciences Institute	Labs	295,882
Medical Sciences Research Building III	Labs	217,897
Randall Lab	Labs, Classrooms	217,169

Table 8: University of Michigan Single-Use Buildings.

Building	Primary Function	Square Footage
Alumni Center	Administrative	34,447
Canham Donald B Natatorium	8-lane, 50 m pool, diving well	77,639
Crisler Arena	Indoor Arena	201,311
Duderstadt Center	Library and Multipurpose	240,255
East Quad	Residence Halls, Dining	333,036
Michigan Stadium	Football Stadium	576,993
Michigan Union	Common Areas, Dining	316,142
South Quad	Residence Halls, Dining	371,520
Trotter WM Monroe House	Event and Office Space	13,799
University Hospital	Medical Center	1,721,523
Wolverine Tower	Administrative/Offices	224,966
Yost Ice Arena	Indoor Hockey Arena	113,972

For typical buildings, the LEAN Analysis computes coefficients from the building model and benchmarks them against the coefficients from a population of similar buildings. However, many of the mixed-use buildings selected for the UM campus represent combinations of two distinctly different space types when energy use is considered. This was especially important in mixed-use lab and classroom buildings, where the energy consumption of these uses is significantly different. Steve Snyder at JCI used a Mixed-Use Lab Methodology to split these buildings into lab and non-lab components, where he benchmarked them as separate buildings.

The University buildings chosen for analysis were not sub-metered for utility data, which made it difficult to separate the energy usage from specific areas of each building. Instead, the buildings were divided by using space area percentages and an assumed lab factor relating the lab energy intensity to office energy intensity. Equation 2 relates the energy consumption of a mixed-use building to the relative contributions by type of an office and lab mixed-use building.

Equation 2: Mixed-Use Lab Methodology.

$$Total\frac{kWh}{ft^2} = [(Office\frac{kWh}{ft^2} * (1 - \%\,Lab)] + [Office\frac{kWh}{ft^2} * \%\,Lab) * Lab\,Factor]$$

The Lab Factor is determined using laboratory benchmarking data from Labs21, which contains energy use data for labs as well as lab area percentages.[lxxvi] Lab factors for electricity and fossil fuel are solved for iteratively by minimizing the deviations between the Labs21 office energy/ft^2 distributions (mean and standard deviation) and the office energy/ft^2 distributions from the LEAN database of office buildings. The lab factor is then combined with lab area percentages provided by the University of Michigan to divide the overall EUI (for electric and fossil fuel) into a lab component EUI and other use EUI.

LEAN Energy Analysis Results

The LEAN Energy Analysis of the twenty selected University of Michigan buildings estimated a total savings potential of $4,414,300, which represents 16.6% of the current total energy budget for these buildings.[lxxvii] The analysis identified the total savings of Low Cost Measures of $1,760,400, which represent easily implementable and viable projects. The highest identified savings opportunity was the University Hospital, with a total potential savings of $700,000 (9% savings). The campus savings for traditional single use and mixed-use building types is shown in Figure 31 and Figure 32, respectively. In the pie charts below, the green represents the target energy budget while blue and red represent savings from no or low cost measures and comprehensive (potentially capital intensive) measures, respectively.

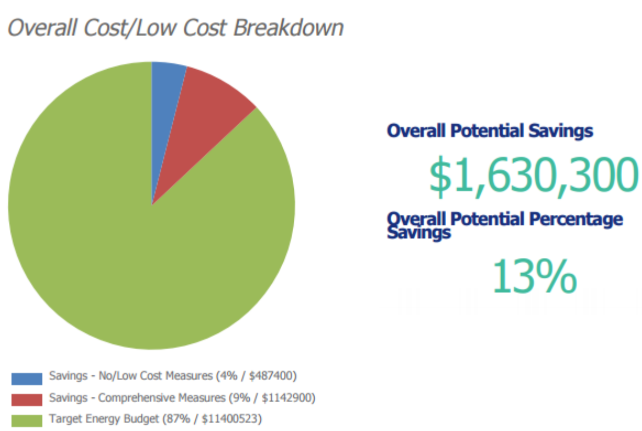


Figure 31: Cost Savings for Single-Use Buildings.

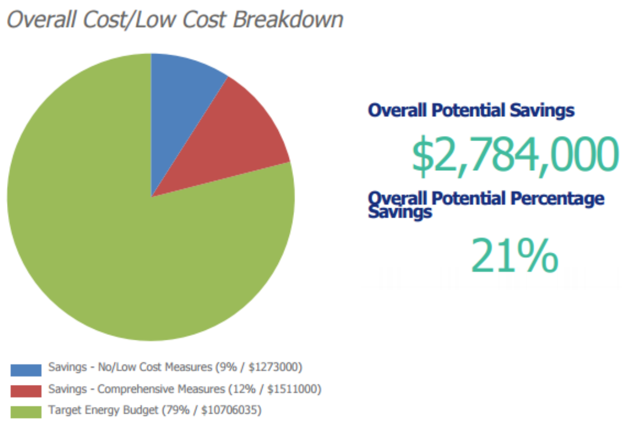


Figure 32: Cost Savings for Mixed-Use Lab Buildings.

The Energy Use Intensity (EUI) for the tested single use and mixed-use lab buildings is shown in Figure 33 and Figure 34. Buildings with relatively high EUI for both electric and fossil fuel (University Hospital, Electrical Engineering and Computer Science Building Labs) also have high potential cost savings. In the figures below, the blue and teal columns represent electric and fossil fuel use for each building. The circles below the columns identify the building's performance as either typical (grey), good (green), or poor (red). These charts can be used to identify areas where each building is underperforming and follow-up audits can be performed to isolate areas and projects to improve. It is important to note that buildings with relatively low EUI may still have parameters in which the building is performing poorly, which indicate that they also have opportunities for improvement. These opportunities would be missed by traditional benchmarking approaches, which only look at EUI and would pass over low EUI buildings.

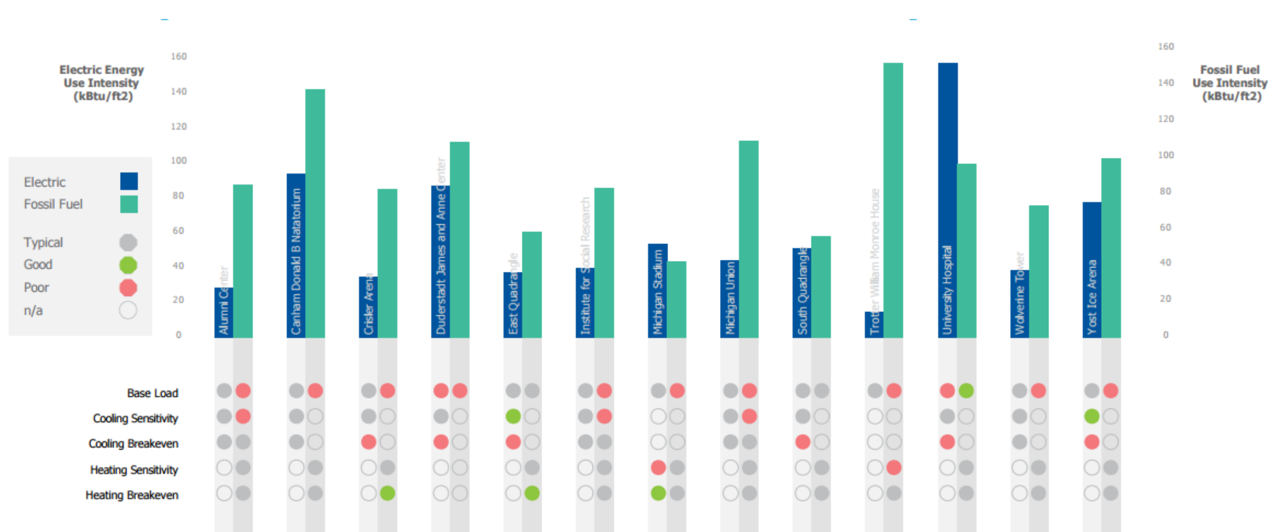


Figure 33: Energy Use Intensity for Single-Use Buildings.

Figure 34: Energy Use Intensity for Mixed-Use Buildings.

The LEAN Analysis provides a high-level estimate of the potential savings in buildings, and requires further investigation and verification with a series of on-site audits. The results indicate that there could be a large potential for energy conservation measures within these 20 buildings. However, it is important to note that the majority of the buildings with a high magnitude of savings are lab buildings and the University Hospital, which have relatively strict control guidelines for air handling. For example, the Electrical Engineering and Computer Science Building houses labs such as the Lurie Nanofabrication Facility, which requires high-efficiency particulate arrestance-filtered clean space for the fabrication of devices and microsystems. The LEAN Analysis recommendations for this space include changing the heating and cooling set-points and reducing the equipment schedules and ventilation. The current LEAN database does not include a large population of lab and mixed-use buildings, and may not have a set of equivalent buildings to fairly benchmark these buildings. The follow-up audits will be able to identify if the recommendations are feasible for the specific space-condition and air handling requirements.

Dana Building Spotlight

After broadly analyzing the University's energy consumption, including sampling the 20 buildings analyzed with the LEAN tool, the master's project team chose to focus on the Samuel T. Dana Building for a case study to identify potential energy conservation improvements with the help of the University and JCI experts.

The Dana building was chosen for several reasons. First, since the building houses the School of Natural Resources and Environment (SNRE), there was a general consensus that this building should be a campus leader in building energy efficiency performance. Second, the building manager, Sucila Fernandes, is actively seeking energy efficiency upgrades and opportunities to increase operational efficiency. The team knew that Ms. Fernandes not only would welcome the prospect of recommendations, but also had the motivation to implement them. Lastly, all of the team members are enrolled in SNRE and wanted to both learn more about the building and take advantage of the opportunity to make some energy-savings improvements that can benefit their school.

Heating Degree Days (HDD)

Prior to looking at the energy use in the Dana building, it is necessary to compare how the energy demand can change year to year. The most dramatic change that is outside of a building manager's control is the weather. Each year, the number of heating degree-days differs, which significantly contributes to the amount of energy necessary to heat buildings across the University of Michigan campus. Figure 35 illustrates the HDD in Ann Arbor by month from 2006 to 2015.

While the number of HDD in Ann Arbor follow the same trend, there are several years where the number differed greatly. The month of February in 2012, for example, is significantly lower than February 2015. This should be considered before comparing energy consumption between these two periods.

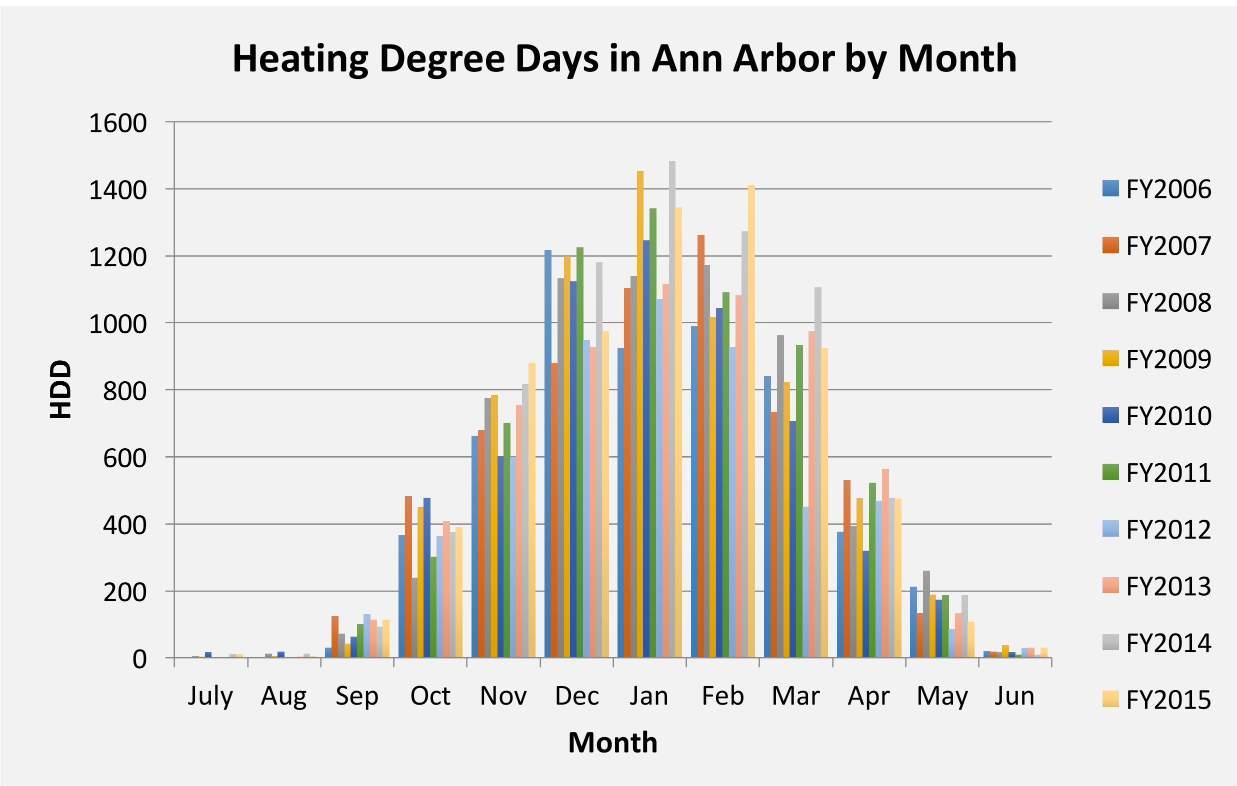


Figure 35: Heating Degree Days for a base temperature of 65.[6] [lxxviii]

[6] Station: ANN ARBOR MUNICIPAL AIRPORT, MI, US (83.74W,42.22N) KARB

Dana Building Energy Consumption:

To understand the current state of energy use at the Dana building, it is important to review past energy consumption. The following sections document the history of steam and electricity consumption over time and by month. In Figure 36, a list of ECM's and their execution date helps shed light on how the energy consumption at the Dana building has transformed over time.

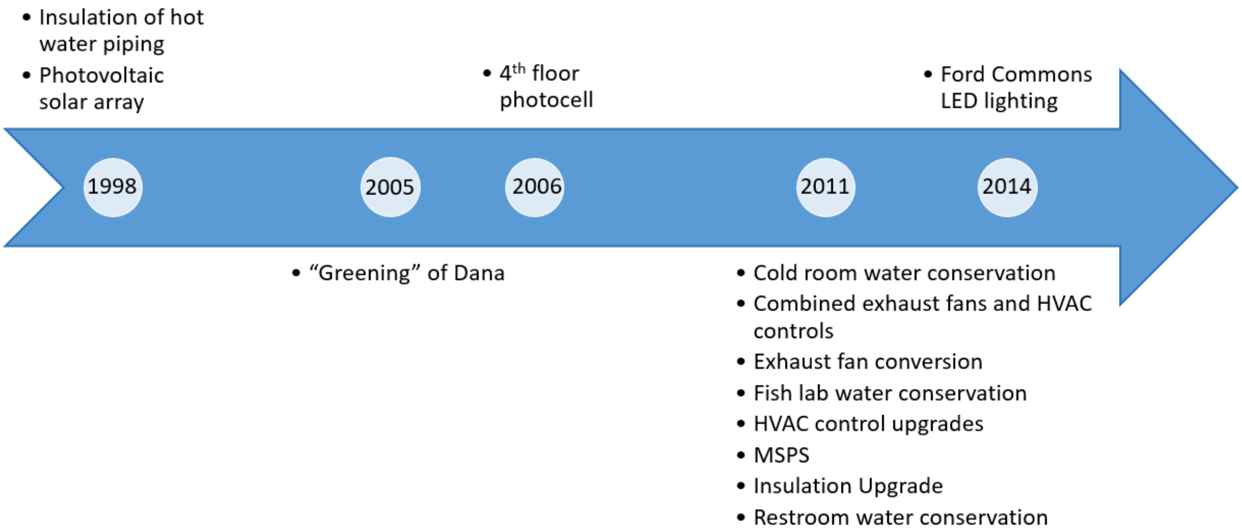


Figure 36: History of ECMs completed at the Dana building.

Steam consumption

The Dana building, along with many other buildings on Central campus, use steam energy from the CPP for both the hot water and for heating shown in Figure 37. This bar graph is slightly deceiving, because of a billing error in 2007, where the Dana building was over-billed and then the error was corrected, making the month of August appear to have consumed almost twice as much as other months.

Figure 38 presents annual steam consumption from 2005 to 2015. When compared to 2006 levels, the current steam consumption is significantly lower. This could be due to better building management and/or new energy conservations measures.

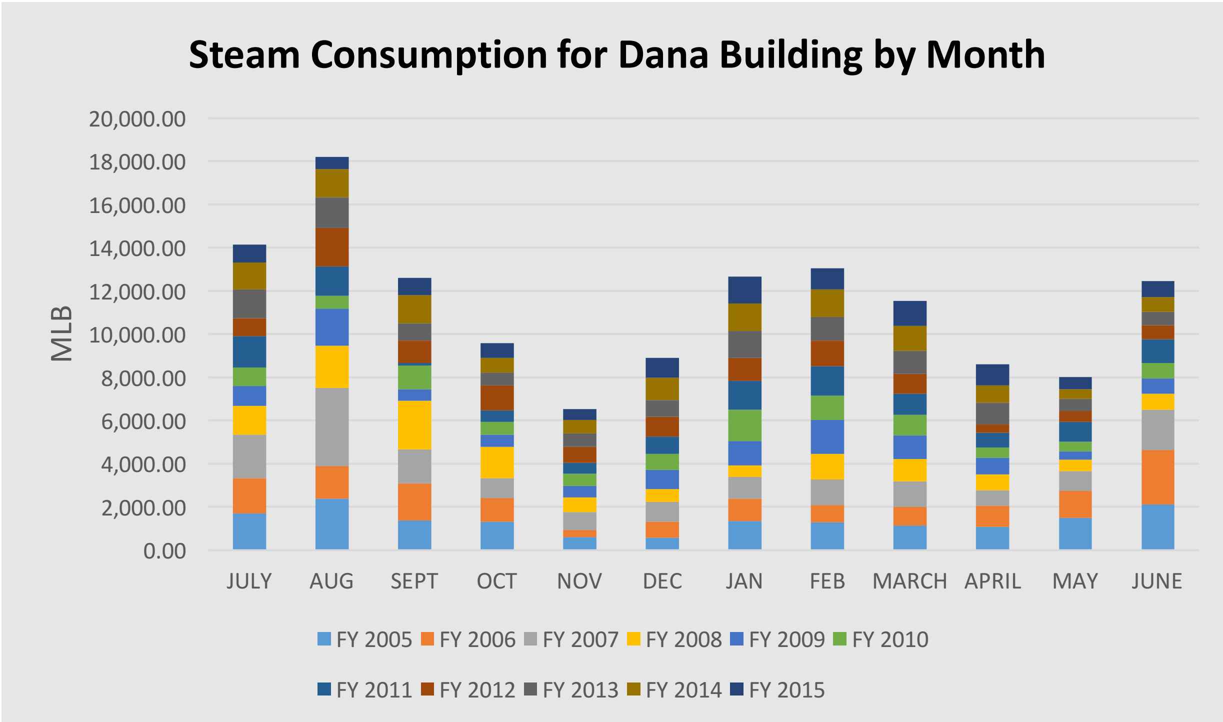


Figure 37: Steam Consumption for Dana Building AER Data.

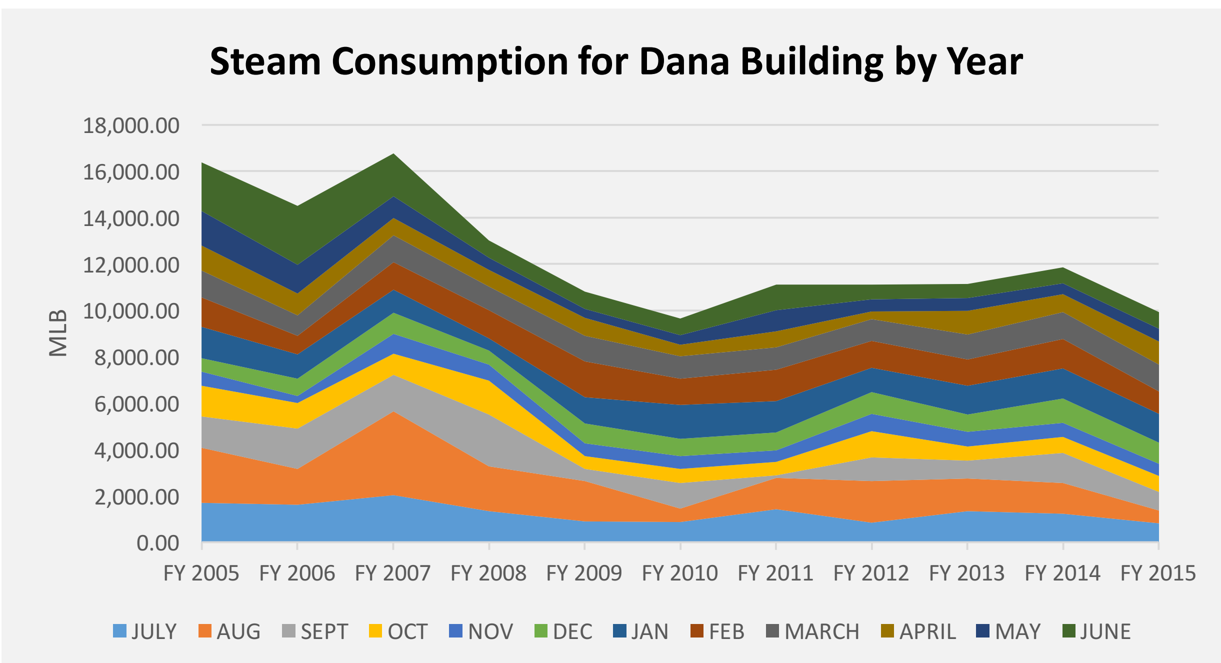


Figure 38: Steam Consumption for Dana Building.

Electricity Consumption

Similar to steam consumption, electricity consumption in the Dana building is the highest in August. The months of June, July and August have the most electric demand, as illustrated in Figure 39. While higher energy use is common for most buildings during the summer due to cooling intensive activity, the majority of the Dana building is cooled with the use of cooling panels that use steam energy. Steam energy is used to cool the Dana building through adsorption chillers. Reduced occupancy during the summer months also suggests that this could be an opportunity to find more savings at the Dana building.

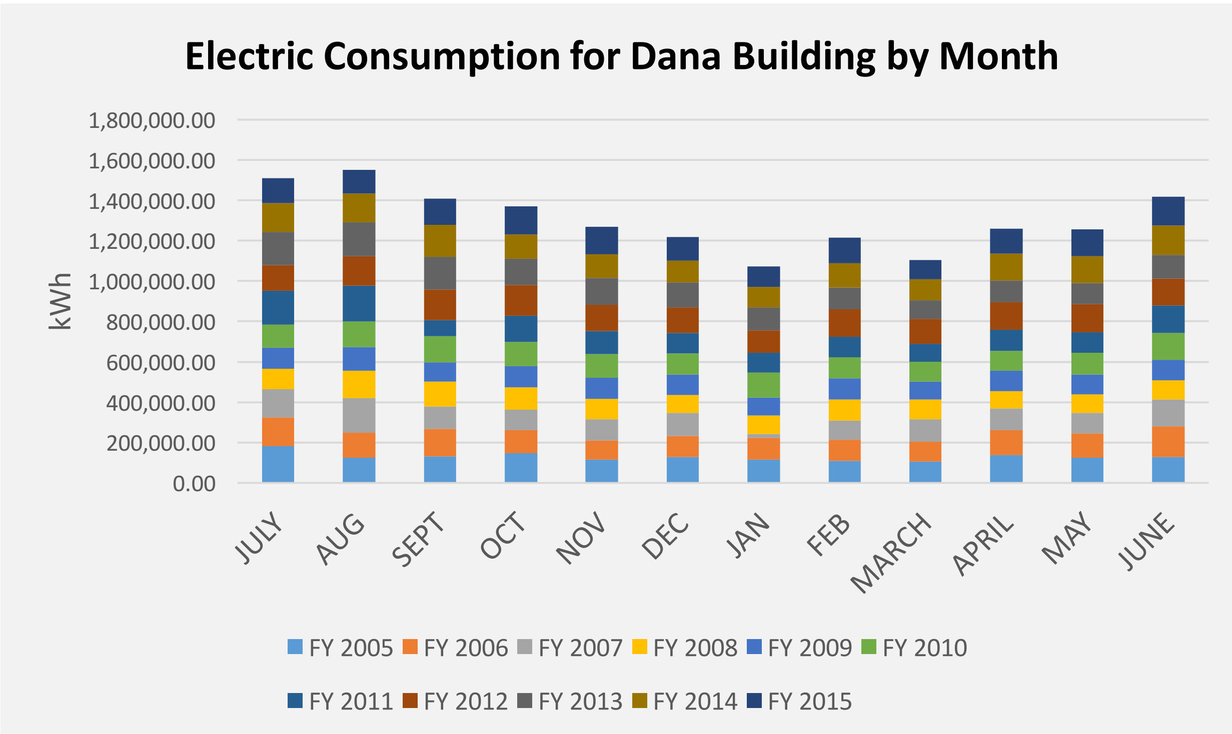


Figure 39: Electric Consumption for Dana Building by month.

Although the electricity consumption by month is similar to steam consumption, the electricity consumption over time is quite different. Figure 40 shows that, although electricity consumption was at its lowest in 2009, peaked in 2012, and now currently is about the same as in 2005. The increase from 2009 to 2012 is likely due to the increase in electronic equipment at the Dana building, including adding new energy intensive labs.

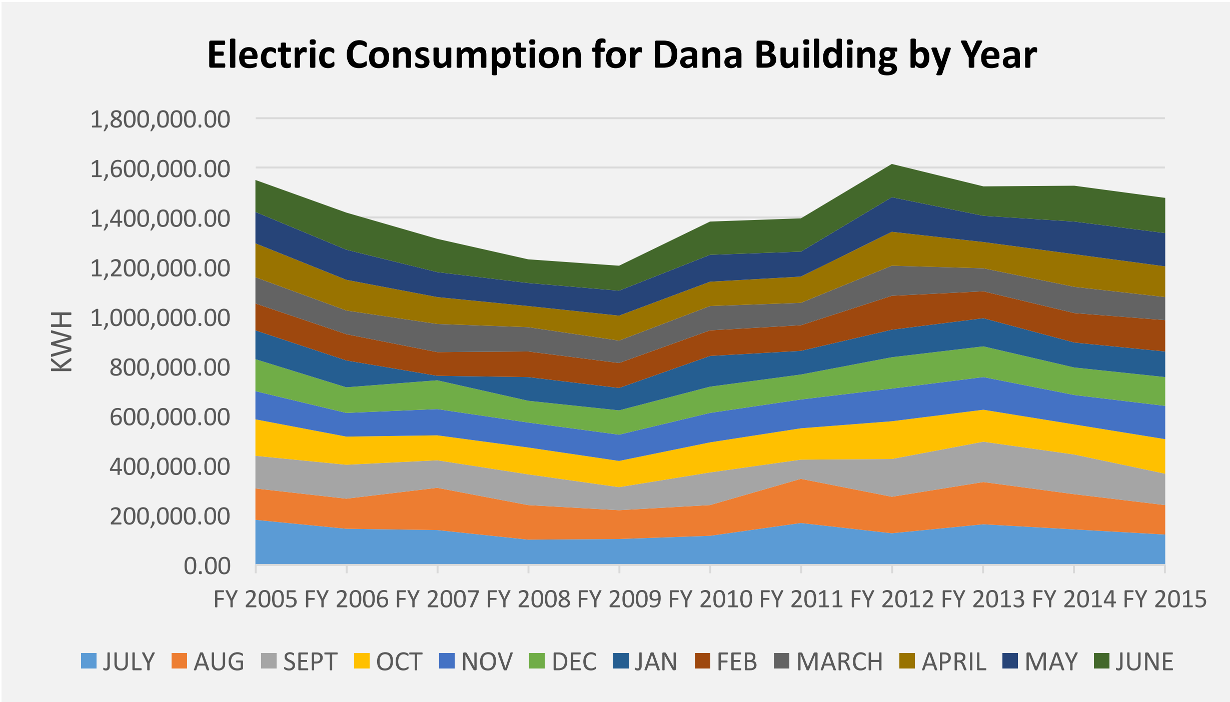


Figure 40: Electric Consumption for Dana Building FY05 to FY15.

JCI Format

With the establishment of the Dana building as the case study for this report, JCI proceeded to conduct an examination of the building as though it were a potential client. The typical process for Johnson Controls as they approach a new client is to first run the LEAN Analysis on the building and proceed with an on-site Level 1 building audit to identify potential ECMs. At this point, if there is a potential for energy savings, JCI will enter into further conversations with the client and both parties will decide whether to proceed with the performance contracting approach discussed in the section titled "JCI in the Campus Energy Industry." This, then, would be followed by a more detailed Level 2 and Level 3 audit. JCI's interactions with the Dana building—and this process—are described in the next few sections.

Dana Building—LEAN Analysis Results

Johnson Controls utilized the Mixed-Use Lab Methodology for the LEAN Analysis of the Dana building, separating the contribution of lab spaces within the building from classroom and office uses. The LEAN Analysis identified a total potential cost savings of $71,000, representing 27% of the total energy budget.[lxxix] The majority of potential savings are attributed to the lab portion of the building ($60,000). Low Cost Measures are reported at $37,000, representing 52% of the total comprehensive savings potential. The results of the energy consumption sensitivity to weather are shown in Figure 41 and Figure 42.

In Figure 41, the electric and fossil fuel consumption is highly temperature dependent for lab spaces in the Dana building, with weather-sensitivity at almost the entire range of ambient temperatures. Breakeven points at which weather sensitivities begin to take effect are relatively extreme, indicating that temperature set-points or building heat loads may need adjustments. In the non-lab portion of the Dana Building (Figure 42), a similar pattern for electricity consumption is observed. For the fossil fuel model, we see sensitivities to both heating and cooling. The presence of a fossil fuel cooling sensitivity may reflect the presence of radiant cooling panels throughout the building driven by absorption chillers, which supplement electric powered cooling systems.

Model parameters from lab and non-lab spaces are then benchmarked against buildings of similar type to show how well the building is operating, and provide potential recommendations based on areas of poor performance. The benchmarking metrics seen in Figure 43 and Figure 44 for the lab and non-lab spaces in the Dana Building are consistent, indicating that the LEAN Analysis may be able to make some inferences about the building as a whole. The benchmark tables illustrate how the Dana building preforms compared with other buildings in JCI's database. The bars have three colors representing poor typical and good performance. The Dana building's results are illustrated through orange and blue lines, representing fossil fuel and electric energy sources. The LEAN Analysis recommendations for the Dana Building were the same for both lab and non-lab spaces: increase cooling set-points; reduce equipment schedules; add fix economizers; decrease heating set-points; and check fossil fuel load a base (full description of recommendations in Appendix G).

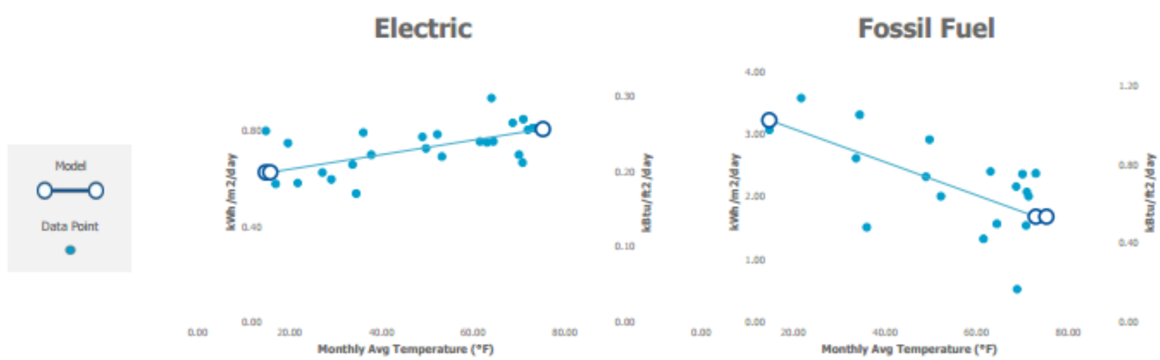


Figure 41: Energy Use Intensity Weather Sensitivity for the Dana Building (lab spaces) (Johnson Controls, 2015).

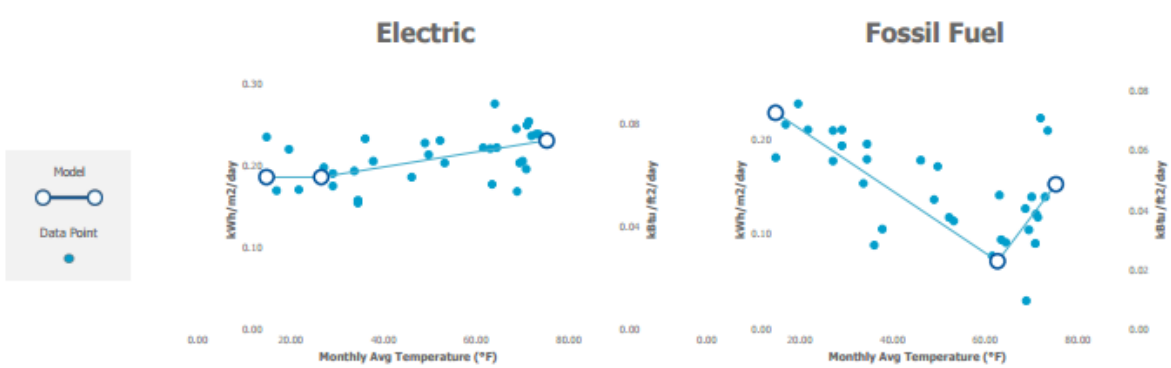


Figure 42: Energy Use Intensity Weather Sensitivity for the Dana Building (non-lab spaces).

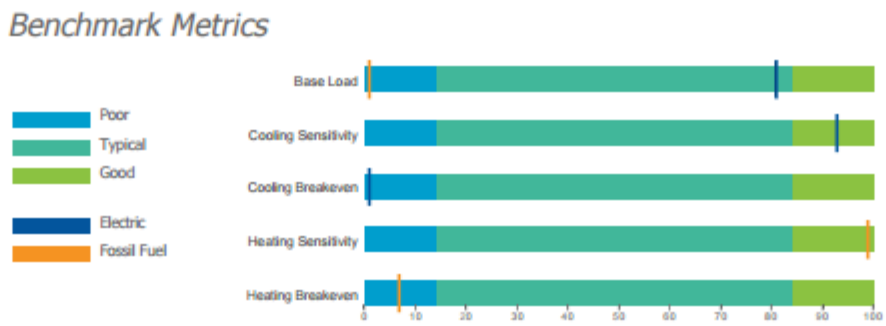


Figure 43: Benchmark Performance of the Dana Building (lab spaces).

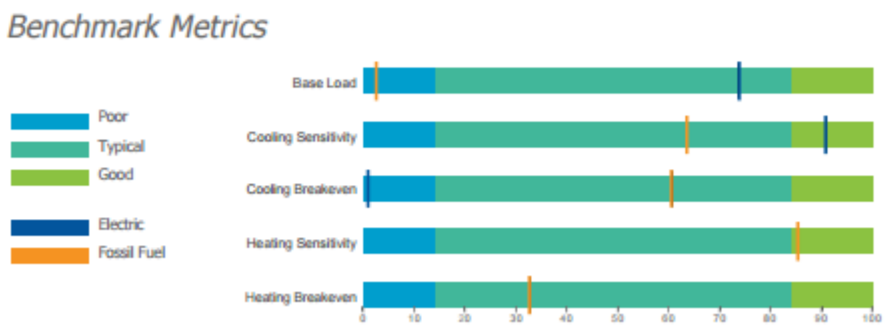


Figure 44: Benchmark Performance of the Dana Building (non-lab spaces).

Dana Building—Level 1 Audit

According to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), a Level 1 Audit is the starting point for building energy optimization.[lxxx] Often called a "walk-through audit" or "simple audit," it typically entails brief on-site interviews with personnel, review of the facility's utility bills or operating data, and an abbreviated walk-through of the building. The goal of an ASHRAE Level 1 Audit is to understand the building energy operations, define the type of systems, and identify preliminary, high-level potential for energy savings. [lxxxi]

As previously mentioned, Johnson Controls typically follows their LEAN Analysis results with a Level 1 building audit. These audits are on-site visits by Johnson Controls personnel to the potential customer, where the LEAN Analysis results are used as a sort of guide for energy auditors to determine capital and/or operational energy efficiency improvements.

Steve Snyder, Energy Services/Smart Building Technology Engineer from Johnson Controls, visited the University of Michigan campus on December 14, 2015, to conduct a typical Level 1 audit for the Dana Building. Prior to conducting his audit, Mr. Snyder requested the following items from the Dana building's regional energy manager, Andrew Cieslinski:

- Architectural Drawings
- MEP Drawings
- Any As-Built Documentation
- Any Previous Studies/Reports

- Equipment Inventory
- Control Diagrams/Sequences of Control
- Balancing Reports
- BAS Screen Shots/Trend Data

Although these were the main items requested, a full list of JCI recommended information is found in Appendix H.

This information, in conjunction with the data provided by the LEAN Analysis, provided Mr. Snyder with a sense of how to approach the building. In the audit, Mr. Snyder did the following: checked for over-lighting using a lighting sensor; checked carbon dioxide levels for air quality and an indication of mechanical ventilation levels; looked at infrared (IR) pictures of the building's envelope for potential leaks; looked at BAS data for the building to check the HVAC schedules and sequences of control; and put up data loggers to be collected during the Level 2 audit conducted a month later.

Some of the more important details from the audit were the data loggers, discussion of air handling units and the BAS data—described in further detail in the following sections.

Data Loggers

The team assisted Mr. Snyder in placing six HOBO data loggers within the Dana Building to measure temperature, relative humidity, and light intensity. The purpose of detecting and documenting temperature is to determine if "too hot or too cold" comfort requests to building management are justified. In addition, temperature readings can show the operating schedules of the heating and cooling systems. The humidity measurement helps to determine if the facility is susceptible to mold growth and is an indicator of occupant comfort levels. Light intensity measurements can be used to elucidate the actual operation of lights, and investigate possible energy savings when areas of the building are unoccupied.

The data loggers were placed in areas to get readings that service each of the three air-handling units (discussed more in the next section), although AHU-G could not be tested due to limited laboratory access. Additionally, the loggers were placed in locations and angles within each room that would provide the most accurate readings of light and humidity.

From the results, as discussed in the following section, the duration and frequency of occupancy for each area based on the lighting levels was estimated. This assumes the automatic lighting controls were functioning properly, i.e., lights off meant unoccupied. Lighting/occupancy would then correspond to temperature requirements. See Table 7 for the locations chosen for the data loggers.

Table 9: Data Loggers in Dana building.

HOBO DATA LOGGERS			
Project:	University of Michigan - Dana Building		
Deploy Date:	12/14/15		
Pick Up Date:	1/12/16		
Data Logger ID	**Location**	**Start Time**	**Stop Time**
JCI-1	3012 (CSS) - Brittany's Desk (served by AHU-1)	3:45 PM	2:45 PM
JCI-2	2315 - 2nd Floor Computer Lab - Windowsill Next to Thermostat (served by FCU-4)	3:55 PM	2:45 PM
JCI-3	Not Used		
JCI-4	1st Floor Common Room - Display Window Sill (served by FCU 5/7)	4:00 PM	2:45 PM
JCI-5	1046 - 1st Floor Classroom - On Wall Next to Thermostat (served by AHU-1)	4:05 PM	2:45 PM
JCI-6	3325 - 3rd Floor Computer Room - On Wall Next to Chalkboard (served by FCU 5/7) <--Deployed 12/15/2015	11:10 AM	2:45 PM
JCI-7	4325 - 4th Floor Conference Room - On Wall Next to Thermostat (served by AHU-2)	3:45 PM	2:30 PM
JCI-8	Not Used		

Air Handling Units (AHU)

The building currently has three air-handling units: AHU-G, AHU-1 and AHU-2. The basement of the Dana building is serviced mainly by AHU-G, which is where the vast majority of the research labs are housed (AHU-G serves all turquoise areas denoted in Appendix E.1). Some of the spaces, though, are serviced by AHU-1 (red color). Due to lack of access to these labs, a data logger was not placed in this area, and readings serviced by AHU-G were therefore not obtained.

AHU-1 services nearly all of the Dana Building: floors 1, 2 and 3 (indicated in red in Appendix E.2, E.3 and E.4). Fan Cooling Units (FCU) services some spaces on these floors (namely the center of the building on the second floor), which are indicated by the purple color. These spaces may rely on FCU for individual temperature control, or for logistical purposes compared to bringing in outside air.

Lastly, AHU-2 services the fourth floor and was added when the fourth floor was constructed during the Greening of Dana in 2005. Similarly, a few spaces, indicated by the color green in Appendix E.5, are serviced by FCUs, with similar reasoning as above.

Mr. Snyder described the importance of these AHU systems and their potential for large energy savings. Most AHU systems circulate a large portion of air from spaces inside the building, a process called recirculation. Although a certain percentage of the air is required to come from outside (20%), circulating existing air has a significant energy-saving benefit because it has already been either cooled or heated. For example, if it were a typical winter day with temperatures of 30 degrees, any air taken from outside would have to be significantly heated up before being distributed throughout the building. However, in taking 80 percent of re-circulated (tempered) air from the building itself and 20% from outside, for example, the energy requirement for heating would be significantly lower when compared to heating 100% of outside air to a comfortable temperature of around 70 degrees. These systems can also utilize airside economizers to introduce 100% outside air when the outside air temperature is cool enough to provide free cooling to the building.

The drawback in recirculating too much air through the AHU, though, is that the carbon dioxide levels may become too high and cause the rooms to be "stuffy," which can make inhabitants feel drowsy and, ultimately, unproductive. This is not a concern for areas that are mostly unoccupied, but for crowded spaces, such as the main lecture hall in the Dana building, it is crucial that the air be circulated with an appropriate amount of outside air.

A typical outside air reading for a CO_2 sensor (i.e. ambient reading) would be approximately 400 ppm, while readings of up to 1100 ppm in buildings indicate adequate ventilations per ASHRAE Standard 62[lxxxii]. Concentrations lower than 1100 ppm could indicate over ventilation and potential energy savings opportunities, while higher concentrations would indicate under-ventilation. Mr. Snyder took several readings with his CO_2 sensor and determined that the occupancy sensors and the AHU most likely are communicating with one another because, in a room that was left vacant for several hours (and on a day that was approximately 60 degrees), and the air inside the classroom gave a reading of around 400 ppm. His assessment was that, since the outside air temperature was favorable enough to be circulated in the building, the AHU was operating in airside economizer mode and introducing 100% outside air. Due to the comfortable outside air temperature, there was very little (if any) energy investment to provide a comfortable temperature to Dana students and staff.

Building Automation System (BAS) data

In addition to checking the physical building for indications of energy savings, Mr. Snyder reviewed all of the BAS data for the Dana building. This data essentially houses all of the automated schedules for the building, including the HVAC systems and AHU systems.

In analyzing this data, the Master's project team and Mr. Snyder discovered that AHU-1 (servicing the majority of the building) is currently scheduled from 6:30 a.m. to 7:00 p.m. AHU-G is running constantly, which is required for the experiments that are being conducted in the research labs in the basement.

The FCUs, however, are not currently on a schedule. Mr. Snyder was also able to confirm that the AHUs have airside economizer control, but that the HVAC systems are not connected to the lighting occupancy sensors. If they were, the HVAC could be turned off when the lights turn off, which would save energy during times when spaces are not being occupied. Additionally, the AHU are not connected to CO_2 sensors, which would better determine exactly how much air should be re-circulated versus outside air.

Dana Building—Level 2 Audit

The ASHRAE Level 2 audit typically builds on the Level 1 audit by going into further detail on the building energy systems to identify a variety of energy improvements. This should include evaluation of "the Building Envelope, Lighting, Heating, Ventilation, and Air Conditioning (HVAC), Domestic Hot Water (DHW), Plug Loads, and Compressed Air and Process Uses." [lxxxiii] The study entails a detailed analysis of energy consumption to quantify base loads, seasonal variation, effective energy costs, lighting, air quality, temperature, ventilation, humidity, and other conditions that may affect energy performance or occupant comfort. [lxxxiv] The resulting report should describe energy efficiency measures including costs and performance metrics.

On January 12, 2016, Victor Ventimiglia, JCI Energy Solutions Development Engineer, came to the University to follow-up on the first building audit. Since the UM energy management team already had adequate energy analyses and the Level 1 audit performed in mid-December was so comprehensive, it was determined that a proper ASHRAE Level 2 audit was not necessary. Instead, Mr. Ventimiglia, the UM energy management staff, and the SNRE team discussed possible building energy improvements for Dana based on the information already accumulated. These results are shown in Tables 8 and 9 in the next section.

In addition to discussing recommendations, the JCI team provided a template of their "detailed audit" (Appendix J) and sample calculations for energy savings due to lighting upgrades, demand control ventilation and HVAC schedule changes.

A level three audit, due to time constraints, was not performed on the Dana building.

Recommendations

The overall purpose of this master's project was to do two things: first, to understand the energy use and energy management structure at the University of Michigan; and second, to apply the LEAN analysis and analysis from subsequent building audits from JCI to identify opportunities for further improvement on campus and, more specifically, at the Dana building. Upon establishing an understanding of the environment for energy consumption and management, the master's project team focused on identifying opportunities in which energy consumption could be reduced or more efficiently consumed. To increase the campus' energy efficiency in order to accomplish a 50% decrease by 2030, is a lofty goal. However, in organizing a cohesive structure and implementing a few operational changes across the University, the team feels that the impressive work already being done by the University in terms of energy efficiency, will be further enhanced.

The following sections outline what the master's project team recommends for campus-wide and Dana building-specific energy efficiency initiatives.

Campus-wide Initiatives:

The University is complex; comprised of several separate—but interconnected—Funds that govern themselves and ensure effective operations across campus. In order to understand how each of these Funds operate, make decisions related to energy management, and work together, the master's project team conducted a series of interviews with each Fund discussed in the Energy

Stakeholder Organization Charts Section. As a result of these interviews, our master's project team crafted organizational charts for each Fund to identify energy stakeholders and personnel responsible for energy management decisions. The intent is for the organization charts to be leveraged by all stakeholders involved in our masters' project, and by leadership at the University, to outline strengths and opportunities in current energy management decision-making and authority. In addition, these organization charts can be used by personnel at Johnson Controls and other third party service providers to constructively approach the University as potential future clients or collaborators, and they can be used as a reference for future students undertaking energy management projects on campus to quickly determine the roles and individuals within each Fund, and approach them for constructive information, input, or access.

Based on the many conversations the master's project team had with energy-stakeholders, the following recommendations were identified.

Energy Conservation Measure (ECM) Structure

Presently, situated within the General Fund, the Energy Management team has established quality procedures for energy management and has a history of implementing energy conservation measures that significantly decrease energy and increase building efficiency. These practices, which mimic the industry standard for identifying and implementing energy conservation measures, should be extended throughout campus. Figure 45 shows how the ECM method currently varies across different funds on campus.

Additionally, we recommend the addition of a Measurement and Verification step to the ECM structure, where possible. This will improve the transparency and accountability of projects, and may elucidate which projects tend to perform close to predicted savings. The University has the opportunity to collaborate with JCI in this process, and utilize building energy models created during the LEAN Analysis process. Building regressions created before retrofits can be extended to predict energy usage that would have occurred without the project. The difference between building energy consumption (post-ECM) and projected usage from the model (without ECM) approximates the actual energy savings provided by the project.

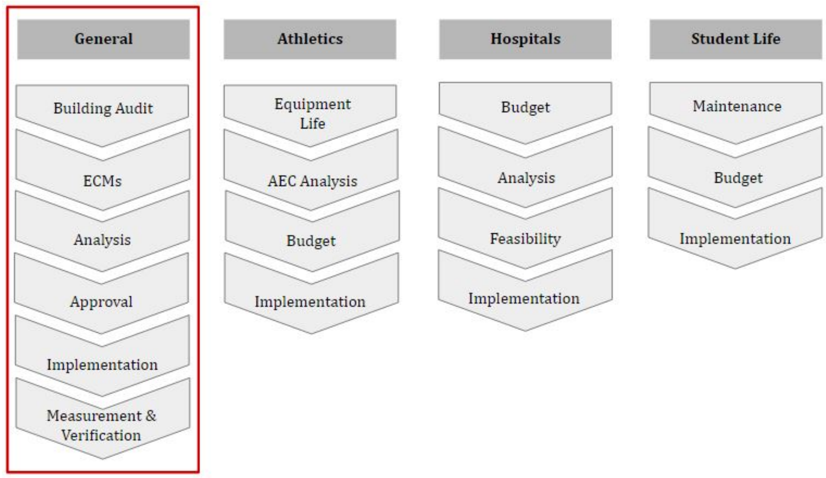


Figure 45: Different ECM methods across four funds are shown above. The General fund ECM process has been implemented by the Energy Management Team. A red box has been around the General fund ECM structure as we believe it is the methodology that should be utilized across all funds.

Energy Stakeholder Organization Chart

To increase the effectiveness of energy management on campus, as well as increase communications between Funds, the master's project team sees a huge opportunity in centralizing Energy Management. This would lead to the sharing of the best energy management practices at buildings and facilities across campus, and provide consistency in how projects and initiatives are implemented. A recommended structure is depicted in Figure 46.

By creating a centralized role for Energy Management that spans across the Funds (depicted by the gray circles in Figure 45), the University can leverage expertise and experience across campus. Each Energy Manager would be responsible for 3-6 buildings (depending on the fund) and work with the building manager at those locations to optimize efficiency in their respective buildings (indicated in blue). The team recommends Energy Managers in the Student Life fund be responsible for 6 buildings. Due to limited access to student dorms and housing, there are not enough opportunities for energy managers to make improvements or suggestions during the academic year, which is why they would be responsible for more buildings when compared to the other funds.

Additionally, the team recommends that each building have a Student Energy Committee (yellow boxes in Figure 45). The Dana building, under the leadership of the building manager, Sucila Fernandes, is currently piloting this type of student group with the "Sustainability Team." This group of students is not only learning about the operations of their building, but they are also active in the operational suggestions and behavior changes that could be implemented. For many buildings—particularly residence halls—students are the drivers of energy consumption. Creating a space for students to become aware of their individual energy footprint will not only decrease the University's energy consumption, but also provide these students (and their friends) with positive sustainability behaviors in the short-term and long-term (after graduation). Although technology can provide extensive advancements in energy efficiency, ultimately, coupling these technologies with behavior changes is necessary in order to maximize overall environmental impact.

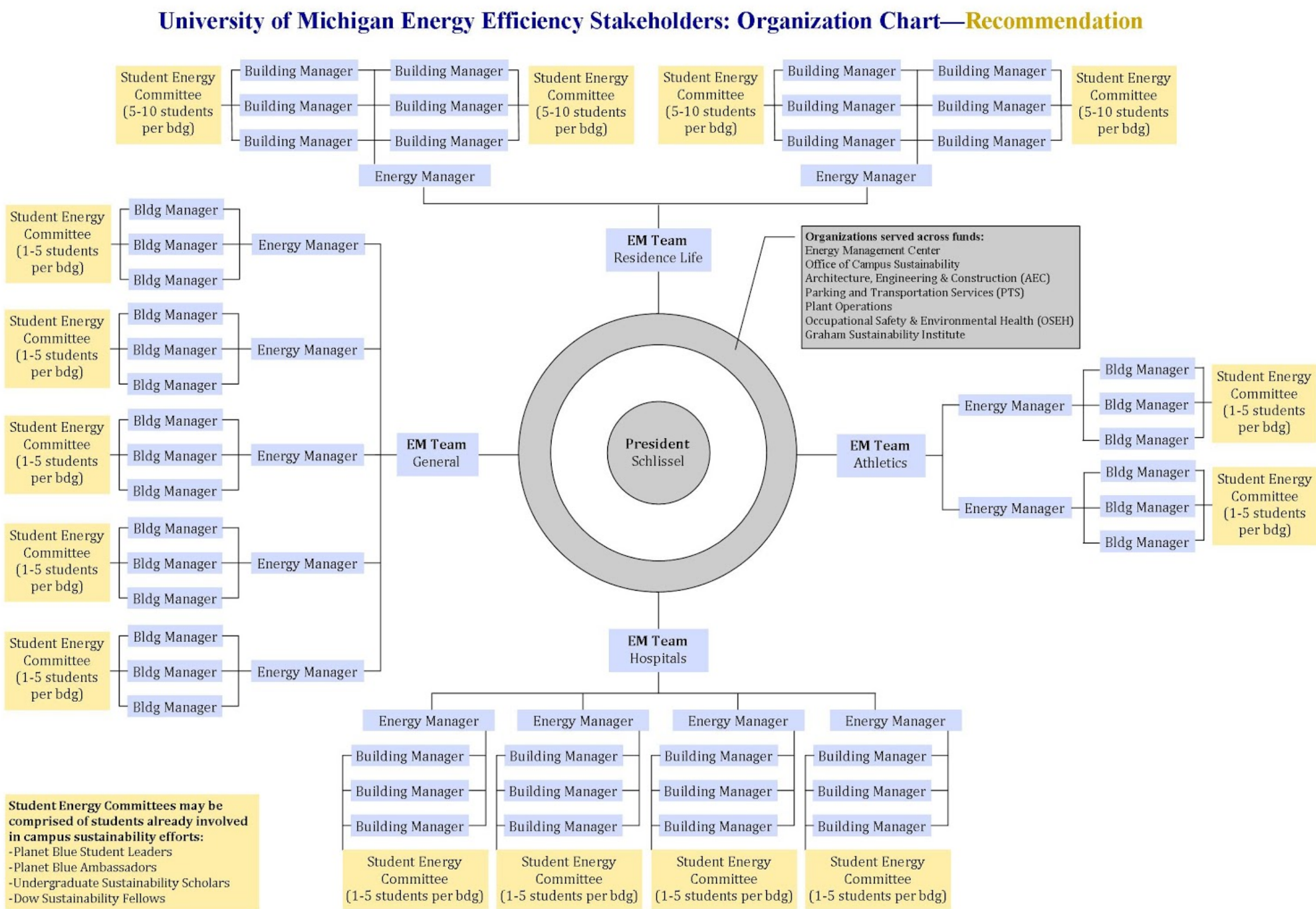


Figure 46: Organization Chart Recommendations. This organization chart is meant to represent ratios of energy managers to building managers to student energy leaders.

Develop and Implement a Campus-Wide Energy Strategy:

The entire campus is currently working to meet the same campus sustainability goals, but there is little coordination across campus on how each fund (and each organization) can help accomplish these goals. For example, each Fund has their own sustainability plan, but the Funds aren't always aware of what each other is doing, how they are doing it, or how they can help each other.

As a consequence, there may be unidentified competing objectives: what serves in the financial best interests of each building may not be in alignment with the best interests of the campus as a whole. For example, the Central Power Plant produces steam as a by-product of producing electricity. If individual buildings are working to decrease their steam consumption in an effort to increase their building efficiency, they will be inadvertently wasting the steam produced by the CPP, which results in an overall increase in carbon emissions and a lowering of CPP efficiency.

These miscommunications would be mitigated if a clear strategy were outlined. Increasing the role of Office of Campus Sustainability (OCS) to not only report on the progress towards the campus sustainability goals (as they do currently), but to also own and report on the strategy to attain those goals, would dramatically increase the momentum of current initiatives on campus and encourage the sharing of best practices. With ownership of the strategy behind campus-wide GHG emissions reduction, OCS could identify and target good and poor-performing campus departments and organizations to enact energy efficiency procedures and practices. As a facilitator across campus and between departments, OCS could highlight best practices of high-performing departments and provide recommendations and support to the poor-performing organizations.

Beyond focusing on specific end-use opportunities like campus-wide lighting or motor retrofits projects, funds dedicated to investigate and create opportunities to implement energy-efficient technologies in existing buildings will develop large-scale energy savings projects on campus.

The master's project team also recommends that OCS own the retrofitting process, as is done at Stanford University. Whole building retrofits achieve "deeper" levels of energy efficiency and represent a "systems thinking" approach that promises bigger efficiency and financial paybacks.

With the University President committed to increased sustainability efforts on campus, the master's project team also recommends an increased role for Planet Blue. With a central role in leading sustainability initiatives on campus, Planet Blue maintains substantial resources that could be focused and deployed to energy efficiency campaigns across the campus Funds and buildings. Leading students and campus personnel, Planet Blue can be an effective collaborator with Energy Management and OCS to recommend practices for increased energy efficiency.

Integrate to Student Orientation:

The largest group of stakeholders on campus are the University's 43,650 students.[lxxxv] Generally, as the primary users of the buildings on campus, students are therefore also a large consumer of energy, either through basic accommodation, or specific operation related to their field of study. As a result, it's imperative to improve student behavior and basic knowledge on responsible energy consumption. In addition to the formation of Student Energy Committees, the master's project team recommends that sustainability be a significant part of all student orientation programs. This will include a consistent and streamlined educational seminar to increase awareness of energy consumption on campus, how to be responsible in their own energy use, and how to get involved in the various campus initiatives associated with sustainability. Designed by Planet Blue, consistent messaging on the importance of responsible energy use, as well as best practices to reduce consumption by students, would be an effective way to increase awareness for energy efficiency that will ultimately contribute to the University's overall goals.

Demand-side Opportunities:

Specialist to audit laboratories:

Based on conversations with UM Energy Management, Stanford Energy Management and results from LEAN analysis, energy conservation initiatives in laboratories are crucial. There are several campus labs that are in extremely controlled environments. Any energy efficiency improvements are, therefore, sensitive in nature, which provides obvious logistical concerns.

Nonetheless, labs are the largest consumers of energy and they, therefore, need to be a priority. As such, the master's project team recommends an energy efficiency specialist being specifically enlisted to audit the labs across campus. This specialist would identify energy efficiency improvements and practices that will complement each lab's operations, but without significantly impacting the research being performed. While we recognize the efforts currently performed by Energy Management and the Office of Campus Sustainability, including the Sustainable Labs and Lab Hibernation programs, we believe a laboratory specialist can enhance and improve focus within this area.

This Laboratory Energy Efficiency Specialist will follow the recommendations outlined by Labs 21 Environmental Performance Criteria.[lxxxvi] Labs 21 is a program sponsored by both the U.S. Department of Energy's Federal Energy Management Program (FEMP) and the U.S. EPA. Their criteria complement the U.S. Green Building Council's LEED for New Construction (LEED-NC) rating system and create an extension for laboratories, knowing the unique challenge labs face in sustainable design and energy efficiency.[lxxxvii] With this set of expertise dedicated to our largest energy consumers, the master's project team feels confident that research labs throughout campus can significantly decrease their energy consumption.

OCS Green Lab Initiative:

To complement energy audits at the campus labs or to work in unison with decreased energy consumption procedures at the labs, the master's project team recommends an initiative to prepare and lead each of the labs towards green certification. Led by OCS, establishing a green certification program would be effective in committing the campus labs to specific engineering, administrative, and behavioral policies and benchmarks for energy efficiency. A standardized approach to sustainability at the labs will achieve best practices at each of the labs while working in concert with specific operations and study at each location. Increasing awareness of energy efficiency goals to the researchers and administrators will be integral to ensuring effective behavior and long-term commitment to energy-saving practices committed through the University.

Real-time Displays:

Real-time information can be informative and can help promote responsible energy consumption. Therefore, the master's project team recommends that the University invest in researching and implementing real-time energy data displays at all campus buildings. Likely a co-led initiative between Energy Management and OCS, the University should contract third parties that can provide reliable software and hardware to assess energy consumption performance.

Real-time displays would be informative for students, building managers, and other energy management administration. The displays would be effective at increasing personal awareness of building energy use, personal impact that each member makes with presence at buildings and use of energy. Additionally, it would further solidify the University's commitment to sustainability by making it an ingrained part of every UM affiliate's culture.

The team also suggests that incentives could be used with these real-time displays. Perhaps buildings could compete with one another for the most reduction based on a Btu/sqft/person basis on a monthly basis. The energy savings realized from that particular building, should they win, could be used to host a celebration. This is one idea on how to further implement sustainable energy into the campus's culture, but there are several other opportunities available through real-time displays.

Dana Building Initiatives:

One of the most effective ways to decrease energy consumption is to identify operational changes to a building that lower energy requirements. These operational items are particularly beneficial because the energy savings can be immediate, and typically no capital costs are involved. The following sections outline some recommendations for the Dana building in terms of building use, operational changes and potential ECM implementation.

Limit room access to consolidate resources:

With the exception of midterms and finals periods, the majority of classrooms and computer labs are unused during late night and early morning hours. Dana building classrooms and computer labs are unlocked 24 hours a day, giving students access to the building's resources at all times. While this may be useful for studying during high-stress periods (i.e. midterms and finals), there are often several empty rooms in the evenings during a typical school day. In these rooms, lights are often left on (if they don't have occupancy sensors) or, if the room is occupied, there may only be one or two students using a large space and utilizing all the lights available. Although a private study area is a sought-out commodity on campus, utilizing large lecture halls for only a few people is wasteful—especially when other spaces are available for studying. Access could be restricted to a percentage of the classrooms and labs, therefore consolidating students and saving energy.

Example—Second floor computer lab:

The Dana building has two main computer labs. After observing lighting data from occupancy sensors, it appears as though there is little or no use in these labs at night. The figure below is a graph of illuminance in the second floor computer lab of the Dana building for a typical two-day period. This graph shows that between the hours of 1 a.m. and 7 a.m. there is little or no lighting during this time, which implies that spaces are not in use (since the lab has an occupancy sensor and would detect if there were activity). As these dates are nearing the final exam period, it can be assumed that there would be even less activity during the rest of the semester.

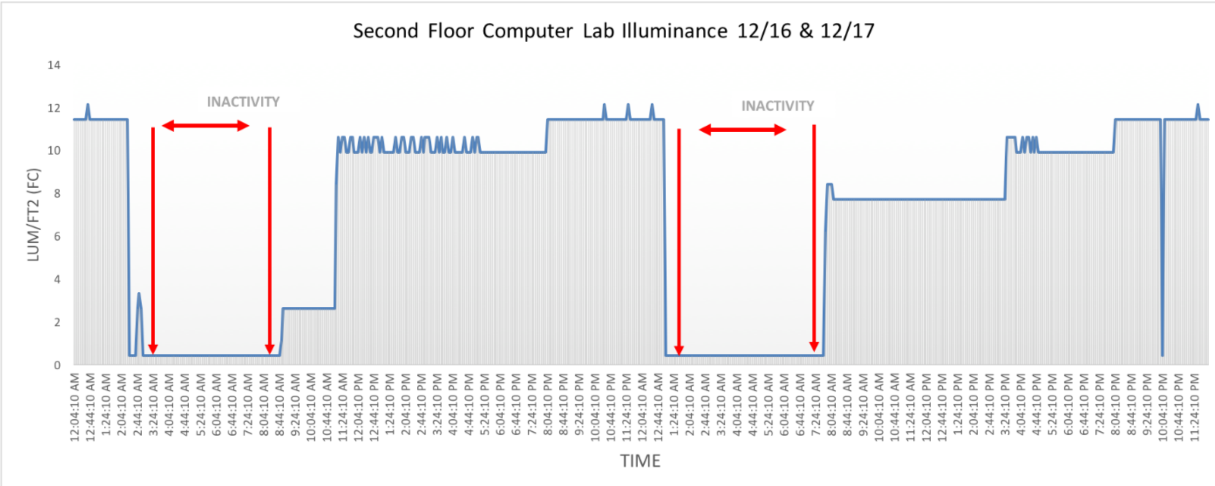


Figure 47: Second Floor Illuminance from HOBO loggers in Dana building.

With proper notification and signage, restricting the use of the second floor computer lab from 12 p.m. to 7 a.m. is feasible. Students would still have access to use the 3rd floor computer lab, which has specialized software required for some of the courses at SNRE, including SimaPro, which is not available in the second floor lab.

Scheduling the closed periods of the second floor lab could save energy on lighting, but also by shutting down the computers. Through coordinating with IT, the computers could be scheduled to shutdown for several hours each night. Scheduling with IT is important because updates are generally pushed through in the evening and would be a consideration when shutting off the computers.

Use timers and remotes on equipment with high standby energy:

The Dana building, along with most buildings on campus, uses equipment that draws energy even when it is not in use. For example, a coffee maker still draws energy when it's plugged in, even if it isn't turned on. The best solution to this is to unplug the devices when they are not in use; however, this often is not possible due to an objects weight or location. Additionally, although unplugging devices is an easy thing to do, behavior change is a difficult thing to accomplish. A relatively easy solution would be to put these devices on a timer.

For example, overhead projectors and photocopiers draw energy in standby mode. By installing timers and/or remotes on these devices, the Dana building could reduce unnecessary energy consumption each year.

Temperature reduction during break times:

After analyzing the data logger information over winter break (Dec. 23-Jan.6), it was observed that the temperature readings were relatively consistent with temperatures observed when school is in session. Two examples are illustrated in Figure 48 and Figure 49.

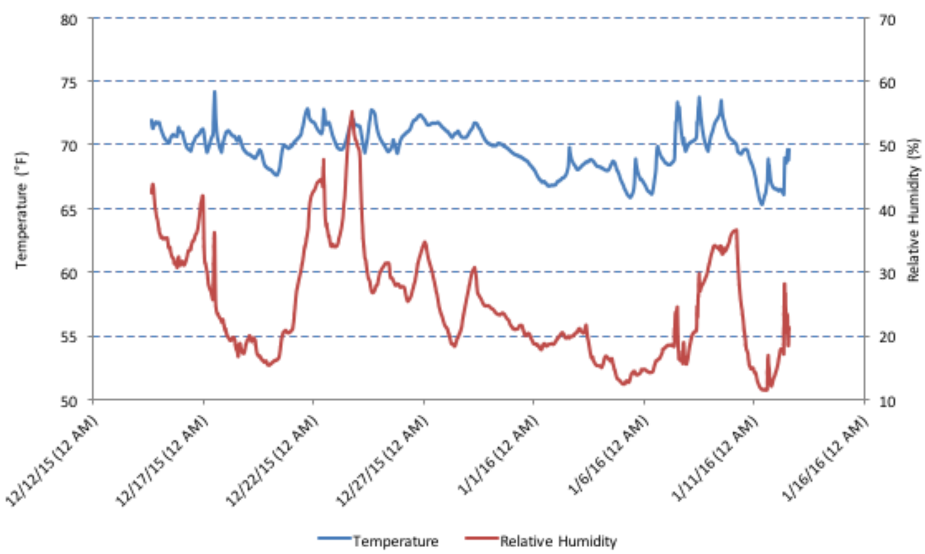


Figure 48: Temperature from first floor classroom in the Dana Building.

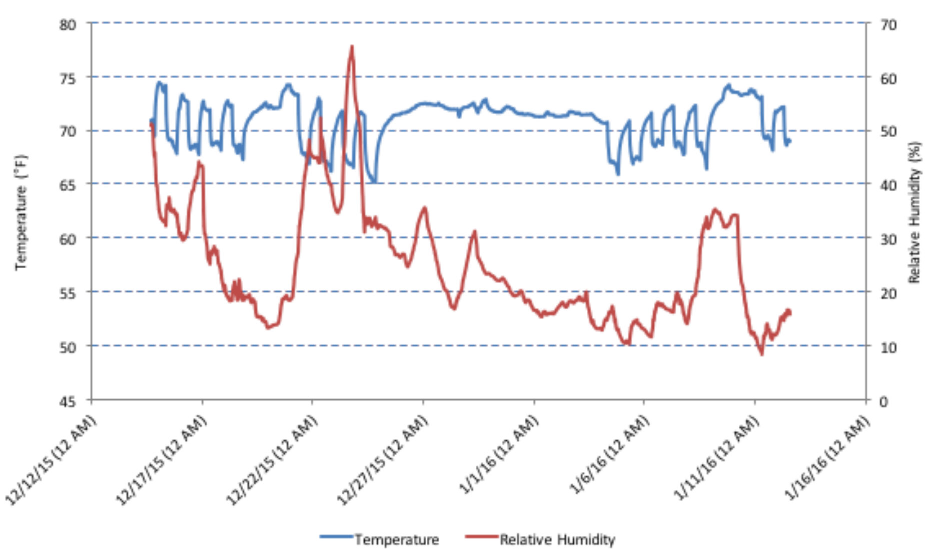


Figure 49: Graph of Temperature and Humidity from Dana building second floor computer lab.

Although faculty and staff still occupy the building on several of these days, there is approximately a week of decreased occupancy. The illuminance graph in Figure 50 shows the decreased occupancy. During these times, temperatures should be reduced from an average of 72 degrees, to an average of 60 degrees. This would significantly save on the building's steam consumption. The base temperature of the room seems to hover at 72 degrees during occupied times as well. This baseline could also be reduced several degrees for further savings.

Figure 50: Illuminance of the second floor computer lab.

Summer heating valve closure:

When looking at the steam consumption data for the Dana building, there is a significant reduction in energy consumption during the summer months from FY 2014 to FY2015, indicated by the red arrow in Figure 50.

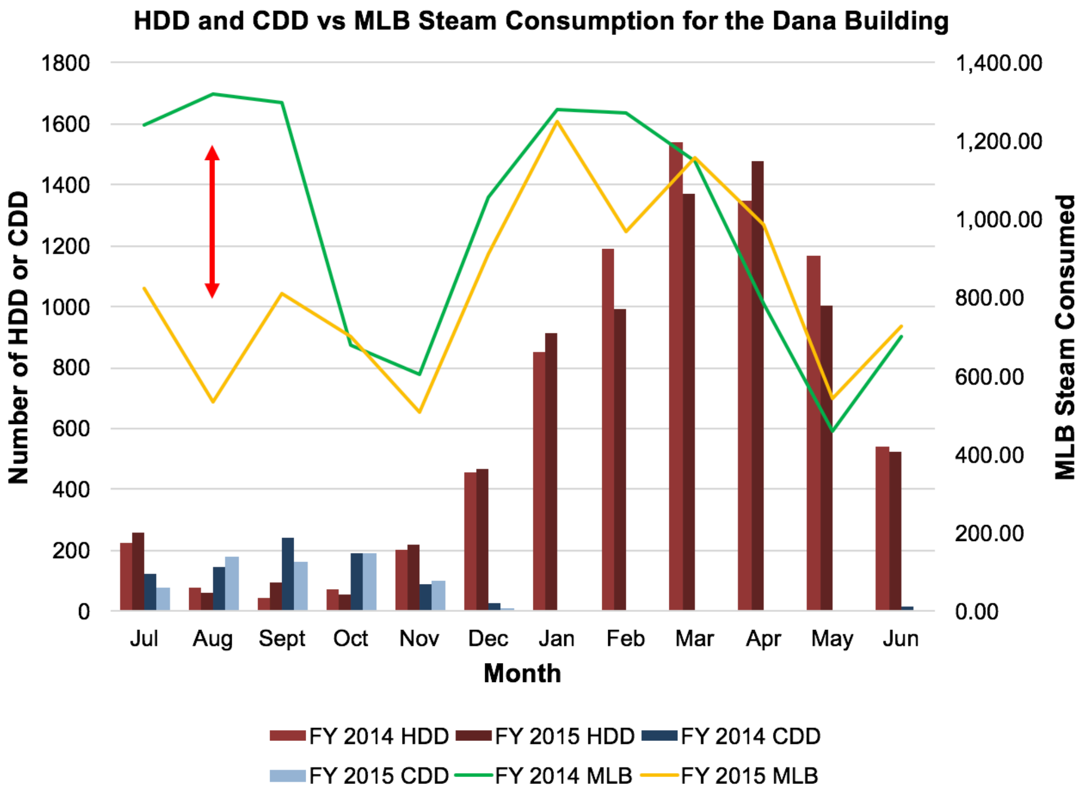


Figure 50: HDD compared with steam consumption by the Dana building. Data from FY2014 and FY2015.

After interviewing the Building Facilities Manager, Sucila Fernandes, and the Regional Energy Manager, Andrew Cieslinski, the master's project team discovered that the steam valve for the perimeter heating was turned off in the summer of 2015. This operation change by Ms. Fernandes and Mr. Cieslinski, is most likely the cause for the drastic drop in steam consumption.

Although little heat is necessary during the summer months, there are times where the heat turns on due to a drop in temperature or due to a control malfunction. By physically turning off the parameter heat valve during the summer months, when heat is needed the least, the reduction in the amount of steam consumed by the Dana building appears to be significant.

To find a dollar value that this energy savings represents, the reported spending on steam was analyzed for both fiscal years. The difference between steam consumption between FY2014 and FY2015 was 1,926 MLB. Since the cost of steam for the Dana building is $14.52/MLB,[7] shutting off perimeter heating saved the Dana building approximately $28,000 in one year.

Closing the valve should be documented, scheduled and formed into a detailed standard operating procedure (SOP). This will allow for two things: the (MLB) steam for heat can be tracked to see if this action is the cause of the decreased steam consumption in Figure 50. If this operational change is in fact the cause of the savings, it will ensure that the Dana building can reduce its energy usage on a yearly basis. If these savings can be realized for the Dana building, this practice should be evaluated for other buildings that rely on steam on campus.

It is important to mention, though, that the Central Power Plant will be generating steam as a byproduct as a result of generating electricity and it will be wasteful if unused. So, although reducing the amount of steam for the Dana building saves in the buildings' utility costs, it does not implicitly reduce the amount of steam being produced. Steam chillers that convert steam energy into cooling are used to cool many of the buildings during the summer. Many of these steam chillers on central campus are being replaced by electric cooling systems. While a financial savings can be accomplished by switching to electric chillers, taking advantage of the steam that the CPP produces would be better for the overall system and GHG reduction. Further inquiry into the financial structure of MLB pricing in the summer should be assessed as to find appropriate price points to incentivize steam over electricity during the summer months.

Suggested Energy Conservation Measures:

After analyzing the LEAN Analysis results and compiling information gathered from the Level 1 and Level 2 audits, the master's project team—with assistance from JCI and University of Michigan stakeholders—identified several ECMs that could significantly impact the energy consumption in the Dana building.

These recommendations were separated into two categories: moderate and aggressive. There are ten moderate ECMs outlined in Table 8 that the team feels may be feasible. The aggressive ECMs are intended to demonstrate what methods could be implemented if costs were not a constraint. There are three ECMs that fall into this category, shown in Table 9, which are to be considered in addition to the ten moderate ECMs in Table 8.

Table 10: Suggested ECMs for a Moderate Approach to Increasing Energy Efficiency in Dana Building.

Category	ECM details
Classroom lighting	Re-lamp w/ LED
	Occupancy Control upgrade to include CO2 sensor
Hallway lighting	Remove every other overhead light
HVAC	Occupied setback
	Steam-automated control of hot water loop
	CO2 sensors
Energy Management	real-time energy data
	building utilization
Building Envelope	window film
Other	De-stratification fans

Table 11: Suggested ECMs for an Aggressive Approach to Increasing Energy Efficiency in Dana Building.

Category	ECM details
Classroom lighting	New LED fixture/re-design
	Daylight sensors
HVAC	energy recover for lab exhaust

In order to determine if these recommendations would be an appropriate choice for implementation, the team recommends that Energy Management review these options for feasibility in terms of cost, efficiency improvement and GHG reduction. Should any of these recommendations prove to provide energy savings within the 8-year payback period outlined by the University, we recommend they be implemented.

Conclusion

The project team has researched and analyzed the history, challenges, and progress of projects dedicated to campus energy consumption and efficiency at the University. The sustainability commitments set by former President Mary Sue Coleman to achieve a 25 percent reduction in GHG's by 2025, compared to a 2006 baseline, set the University on a path towards reducing its carbon footprint and contributing to worldwide efforts to curb global warming.

Under the leadership of UM's current president, Mark Schlissel, the University has committed to further investment in sustainable operations across campus, including an extension of the University's energy conservation programs to include the health system, athletics and student housing facilities,[lxxxviii] as well as accelerating review and performance towards Mary Sue Coleman's original commitments. In line with these increased initiatives, President Schlissel has recognized the need for energy management across the campus,[lxxxix] which likely will lead to an increased role for Energy Management as the master's project team has recommended.

One of the main findings of this project is the lack of a centralized energy management strategy for the entire University of Michigan. While the President is already supporting recommendations for an increased role by Energy Management, the findings outlined in this report support a host of additional initiatives that can both increase energy efficiency and fortify the University's commitment to reduce GHG's by 25 percent by 2025. By centralizing energy management decisions, operations will improve and savings will follow. The University's ability to implement energy conservation programs across funds will increase the likelihood of reaching emissions reductions targets. As part of a centralized campus-wide energy strategy, the Energy Management team will serve all funds and University facilities, and a centralized strategy would enable all sustainable institutions on campus—such as Office of Campus Sustainability and Planet Blue—to increase communication and coordinate effective strategies to reducing the campus GHG footprint.

However, doubling energy efficiency on campus should be considered a "stretch goal" for current energy efficiency efforts. The LEAN Analysis results suggest that the campus may have a 15-20% demand-side energy savings potential (based on the 20 buildings analyzed) and, as indicated in this study, the campus-wide median for energy use intensity is only slightly higher than the national college median, which similarly suggests an opportunity for improvement, but doubling efficiency would be very difficult to achieve.

Attempting to achieve a 50% increase in efficiency will require a significant investment into Energy Management personnel, and a restructuring of the energy stakeholders to offer both energy efficiency best practices and a streamlined ECM process for all campus buildings. Achieving this goal will also require vast improvements in commercial energy efficiency technologies and their affordability in order to meet the 8-year payback period outlined by the University, and it will require that building managers make operational changes and that all persons on campus make positive behavioral changes.

Although the findings outlined in this study have substantial implications for energy efficiency on campus, the project scope was limited to focusing on demand-side building energy efficiency. Building energy efficiency only represents one area the University can pursue to meet its goals. Additional evaluation should be conducted on remaining sectors, including but not limited to: transportation systems, education and outreach, energy supply and electricity generation.

The University should investigate further opportunities to engage, utilize and expand upon the relationship with Johnson Controls and all potential stakeholders to generate an effective energy management strategy. To ensure campus sustainability goals are met, and are truly impactful, campus wide goals should include more program evaluations, performance assessments, and benchmarking internally and externally on a regular basis. Through addressing these three findings—the development of a campus-wide management strategy, expansion of the Energy Management team and increasing coordination and communication between existing sustainable organizations on campus—we look forward to watching the University of Michigan continue to advance its energy planning and conservation efforts.

Appendix

Appendix A

Master's Project Team

The graduate students comprising the master's project team include six students from SNRE at the University of Michigan. Each of the graduate students possess a diversity of background education, professional work experience, and focus for their graduate studies. Working together for a majority of their graduate school experience at the University, the team was enthusiastic to work with Johnson Controls, a leading institution in energy management and building technology and services, to develop sound technical solutions for the University's building energy consumption. By leveraging their interdisciplinary studies and interest in energy efficiency, the graduate students have a great opportunity to leverage Johnson Control's industry experience and leadership to create positive impact at the University of Michigan and lead the school's path towards increased sustainability.

Brittany Szczepanik comes from a 5-year career in education, where she taught high school English in Southern Louisiana through Teach For America, and was the science coordinator for grades pK-12 at a private school in Baton Rouge. In this latter position, Ms. Szczepanik was responsible for initiating and/or creating 18 different STEM programs and writing/receiving over $35,000 in grant money from organizations such as NASA and Toshiba America Foundation. She was also selected to serve as summer principal, and was responsible for managing 21 different summer camps. Since that time, Ms. Szczepanik has moved back to Michigan (her home state) and has worked in development at Teach For America-Detroit while also tutoring locally. She began graduate school at SNRE in the fall of 2014 in the Sustainable Systems track, and will join the Energy Systems Engineering program in the fall of 2015. Ms. Szczepanik received a BA in English from Cornell College and plans to receive a BA in Chemistry from Wayne State University this spring.

Kristin Steiner, a San Diego native, has survived her first winter in Ann Arbor where she is pursuing a dual MBA/MS degree from the Ross School of Business and the School of Natural Resources and Environment at the University of Michigan. After receiving her BS in Civil Engineering at San Diego State University, she made her way to San Francisco to design and manage road, utility, and grading construction projects, such as the 49ers Stadium. After several years, the draw of big apple was too great to ignore and she moved to New York City for the excitement and to work on storm water management projects - creating solutions to flooding and water shortage issues by capturing, storing, and reusing storm water.

John Dooley, after six-plus years as a certified public accountant (CPA) working in San Francisco, ventured to the Midwest to pursue a dual MBA/MS degree from the Ross School of Business and the School of Natural Resources and Environment at the University of Michigan. Prior to school, John's professional experience included several years in client service via the Big 4 accounting industry and subsequently focused on financial reporting related to power generation and environmental remediation at a public utility. While inspired from his experience working on the regulation and transparency of corporate reporting practices, John has since transitioned to a more fulfilling career focused on sustainable business practices and technology that positively impact stakeholders beyond the bottom line. John spent his first summer in the dual MBA/MS program interning with the Environmental Defense Fund in Bentonville, Arkansas developing recommendations for Wal-Mart to reduce greenhouse gas emissions from its corporate value chain.

Whitney Johnson, a Vermont native, has joined the School of Natural Resources and Environment at the University of Michigan to pursue a MS degree. After completing a BA degree in Anthropology from Wheaton College in Massachusetts, Whitney worked for several years in the food industry ranging from specialized farms that directly supplied restaurants to serving as a Garmache chef in Boston, MA. She left the food industry to work for Boston's bike share as their Operations Supervisor where she developed solutions to mitigate station outages and improved service metrics. Whitney spent her past summer interning with Pentair Valves and Controls in Harlingen, TX leading cross functional teams towards achieving Pentair's corporate sustainability goals.

Divyesh Kumar, an international student coming from New Delhi, India, is doing his masters in Sustainable Systems track from the School of Natural Resources and Environment at the University of Michigan, Ann Arbor. After his graduation with Bachelor of Architecture at the Indian Institute of Technology, Roorkee, India, he worked as a Project Architect for a leading building design and consultancy firm on LEED rated commercial projects in the Middle East. He is quite inclined towards the Zero Energy Buildings (ZEBs) and integration of renewable sources of energy into the buildings. During his under-graduation, Divyesh has utilized all of his summer break to work as an intern-architect in Bangalore (India), Torino (Italy) and Shanghai (China).

Benjamin Kunstman, is a Master's candidate at the University of Michigan Ann Arbor, pursuing a dual-degree in Engineering Sustainable Systems, including a M.S. from the School of Natural Resources and Environment and a M.S.E. from Environmental Engineering. Benjamin graduated with a BS in Environmental Engineering, cum laude, from the University of Colorado Boulder, with a focus in renewable energy. He has spent several summers working on energy systems modeling projects at the National Renewable Energy Laboratories in Golden, Colorado, and is interested in doing similar projects in the workforce.

Appendix B:
Tour at Stanford University's New Separate Heat Recovery Power Plant

Appendix C:
Michigan Athletics Sustainability Game Plan

Michigan Athletics Sustainability Game Plan

Embracing environmental stewardship, promoting sustainability and living Planet Blue

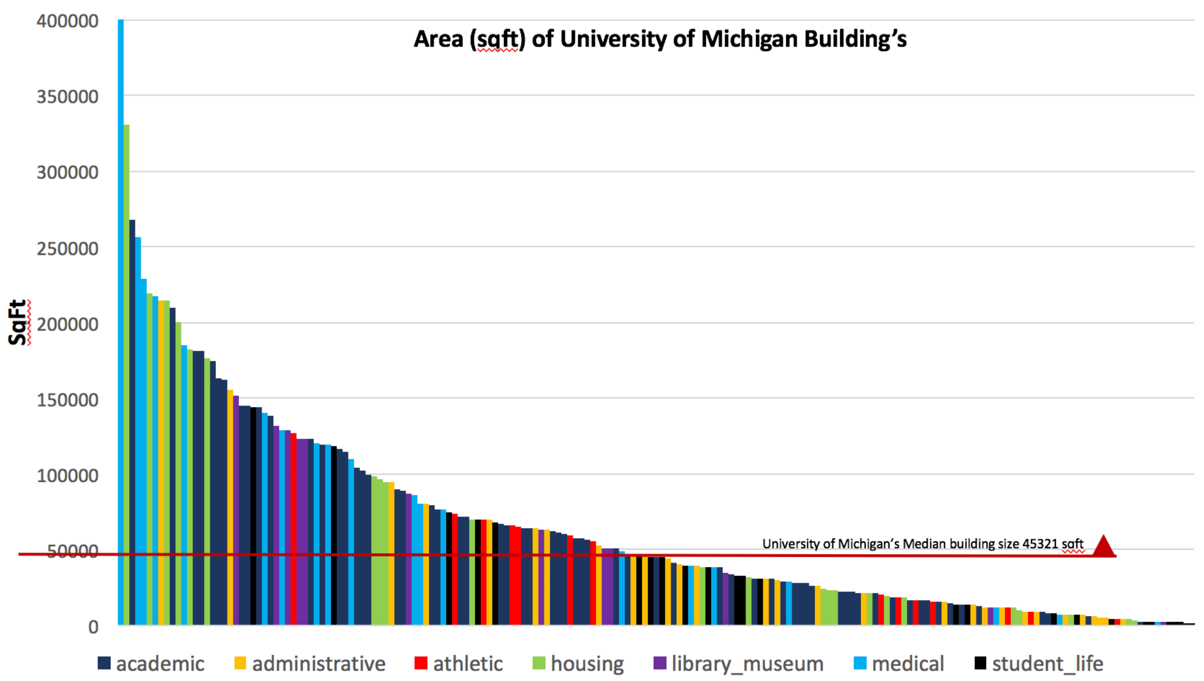
M	Waste Reduction and Recycling, Both Game Day and Everyday	Energy Efficiency and Sustainable Building Infrastructure	Water Conservation, Chemical Usage and Sustainable Cleaning	Education and Awareness
Long-Range Goals	• Limit solid waste production to necessary waste only • Achieve an average annual waste diversion rate that exceeds the campus average • Develop game day specific waste diversion programs, including large scale zero-waste events	• Operate all facilities at maximum levels of energy efficiency • Incorporate sustainability in design and construction of all major facility projects • Reduce internal gasoline consumption and promote alternative transportation	• Protect streams and rivers by controlling use of synthetic land management chemicals • Monitor water consumption and promote conservation • Clean facilities using sustainable products and methodology while maintaining high cleanliness standards	• Engage our student athletes, coaches, team members and fans as active participants in sustainability and living planet blue • Outwardly demonstrate our commitment to sustainability • Prioritize sustainability in decision-making processes
Strategic Initiatives	• Implement a compostable waste diversion program • Conduct annual audits of day-to-day recycling operations at all facilities • Conduct annual audits of game day recycling at all sports • Create a messaging campaign, including customized recycling signage • Procure standardized dual stream waste containers	• Utilize building automation software to control HVAC and lighting systems • Install occupancy sensors in all applicable settings • Conduct annual energy consumption audits for each facility and identify outliers • Produce an alternative transportation map • Emphasize sustainability in design of all construction projects	• Investigate and utilize sustainable landscape management practices • Ensure all irrigation systems are monitored and set at appropriate levels • Utilize low flow toilets and fixtures where possible • Review cleaning products and methods and identify opportunities to incorporate sustainable practices	• Provide sustainability training and education, customized to specific job roles • Solicit sponsorship funding for sustainable initiatives • Host zero-waste meetings • Achieve multiple 'sustainable workplace' certifications • Embrace MSAS and leverage their enthusiasm • Highlight sustainability efforts at events & video boards
SMAC Objectives	• Achieve overall annual waste diversion rate of at least 45% for FY 2013; 50% for FY 2014 • Achieve annual average recycling rate of at least 35% at each facility/collection point for FY 2013 • Develop operational recycling guidelines for facility managers by Jan 1, 2013	• Reduce energy consumption by 5% from FY12 to FY14, measured by BTU's/sq ft • Develop a central database to track and measure sustainability initiatives at each facility by May 1, 2013 • Reduce gasoline usage by 10% in FY 2014 compared to FY 2013	• Install at least three bottle refill stations by June 30, 2013 • Specify standardized cleaning products and practices by September 1, 2013 • Ensure pesticide and fertilizer usage is within the office of campus sustainability's standards for 2013	• Create content and launch MGoblue.com/sustainability by June 1, 2013 • Create a 'submit your idea' form and add a 'sustainability resources section' to intranet site by May 1, 2013 • Develop a sustainability presentation for 2014 incoming freshman student athletes

Appendix D:
University of Michigan personnel interviewed for Organization Charts

Person	Title
Terry Alexander	Executive Director of Occupational Safety and Environmental Health and Office of Campus Sustainability
Rich Robben	Executive Director of Plant Operations
Kevin Morgan	Regional Energy Manager at Planet Blue
Andrew Berki	Manager of Office of Campus Sustainability
Steve Kunselman	Energy Management Liaison
Scott Wells	Lead Electrical Energy Engineer
Kenneth Keeler	Senior Sustainability Representative
Andrew Cieslinski	Regional Energy Manager
Corbin Todd	Director of University of Michigan Golf Courses
Paul Dunlop	Senior Facility Manager for Michigan Stadium-Crisler Center
Keith Soster	Director of Student Engagement
Colin Murphy	Building Systems & Energy Manager, UMHHC Facilities
Joe Hepler	Athletics Maintenance Manager

Appendix E:
University of Michigan Building Size

The University of Michigan buildings organized by size.



Appendix F (on following pages):
Example of ECM Project proposed and implement by Energy Management

Pages 101-118 have ben removed for proprietary data protection.

Appendix F:

Example of ECM Projects Proposed and Implemented by Energy Management

Pages 101-118 have been removed for proprietary data protection.

Appendix G (on following pages):

Lean Analysis Results

Appendix G-1: Lean Analysis Results from Single-Use Buildings at University

University of Michigan, Ann Arbor

LEAN Energy Analysis

This report is provided to be a directional guide and indication of what you could reasonably expect from an energy efficiency retrofit of the identified buildings. This analysis does not replace a professional engineering audit. Johnson Controls has the engineering expertise and operational excellence to retrofit your buildings with the right approach for you and your stakeholders. We should not be held liable for the results outlined by this report.

Johnson Controls

Sunday, November 29, 2015

Overview

Individual Facilities

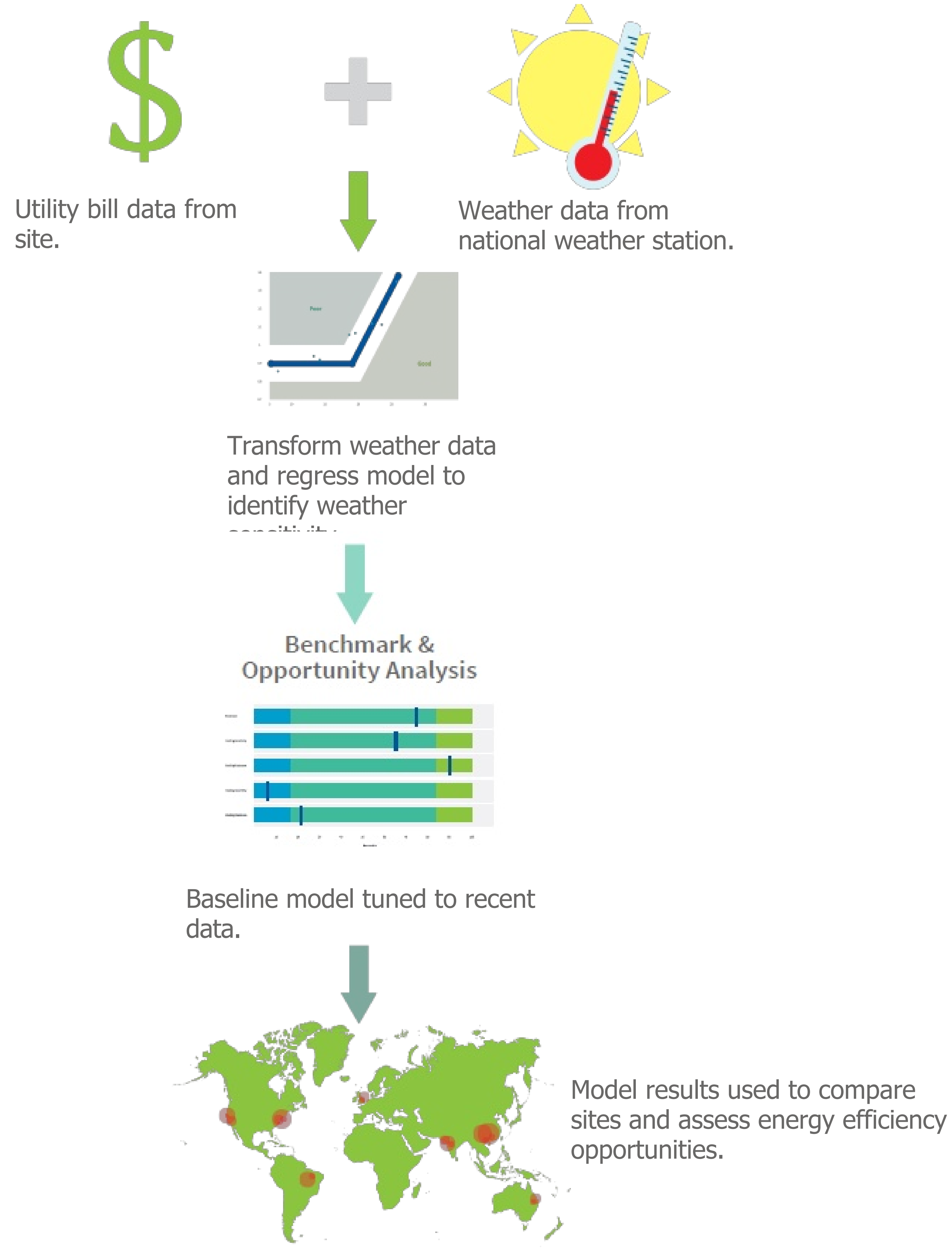
I. Introduction

What is LEAN Energy Analysis?

LEAN Energy Analysis provides building owners and managers visibility into the performance of their buildings and information to make informed decisions on where to target energy efficiency efforts. The performance of each building is benchmarked against similar buildings to identify energy efficiency opportunities. Results from a LEAN Energy Analysis help to target and focus further energy audits and studies.

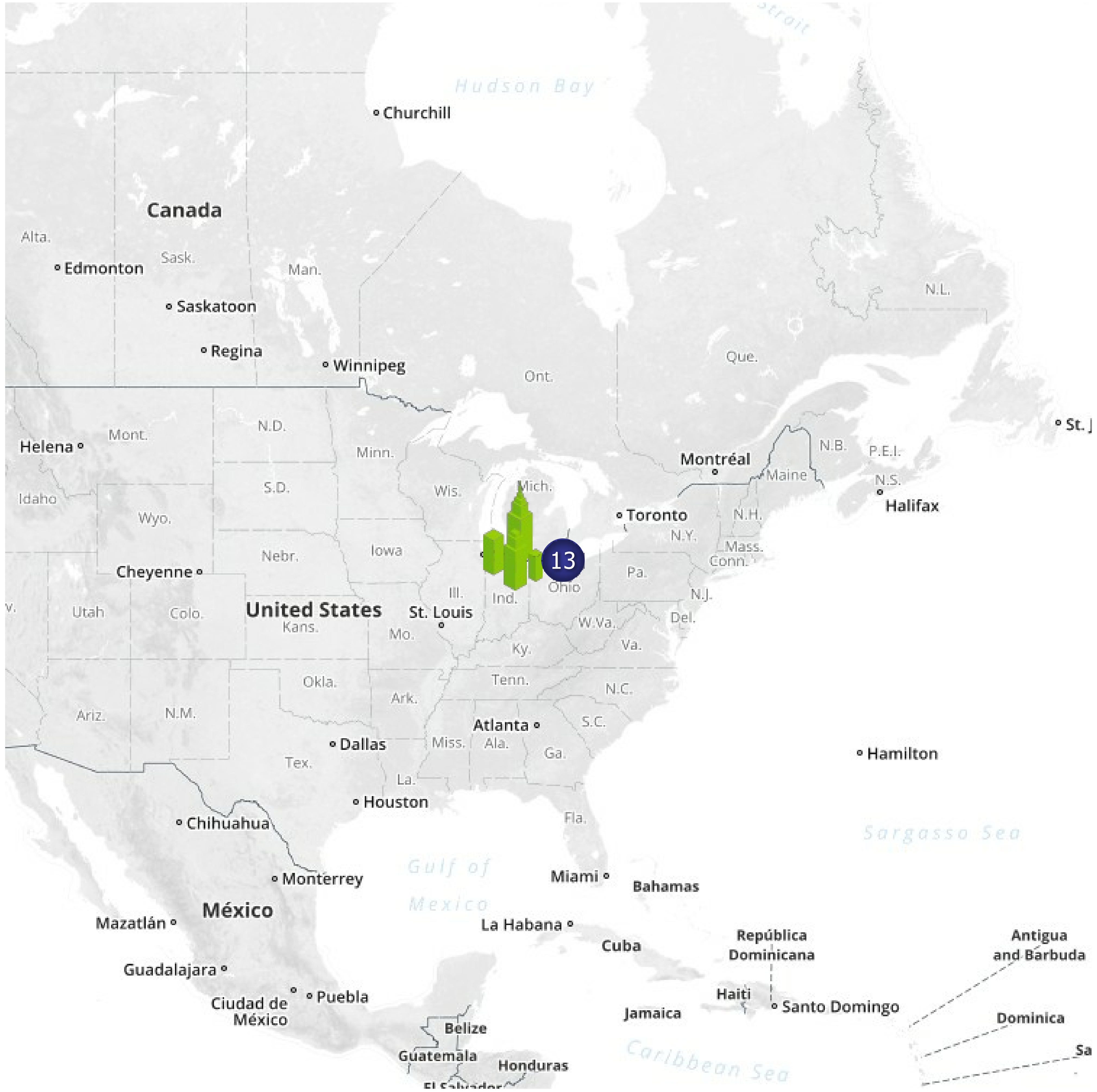
How does it work?

LEAN creates models of building energy usage from utility data and utilizes them to identify trends and benchmark performance. The models are built using sophisticated regression techniques that correlate energy usage to weather and other factors that influence energy usage. The models provide detailed insight into the physical and operational characteristics of each building and allow the performance and operating characteristics to be benchmarked and compared to populations of similar buildings.



II. Summary

Executive Summary of Opportunity



Highest Savings

University Hospital

Michigan Stadium

3 facilities at this savings level

8 facilities at this savings level

Lowest Savings

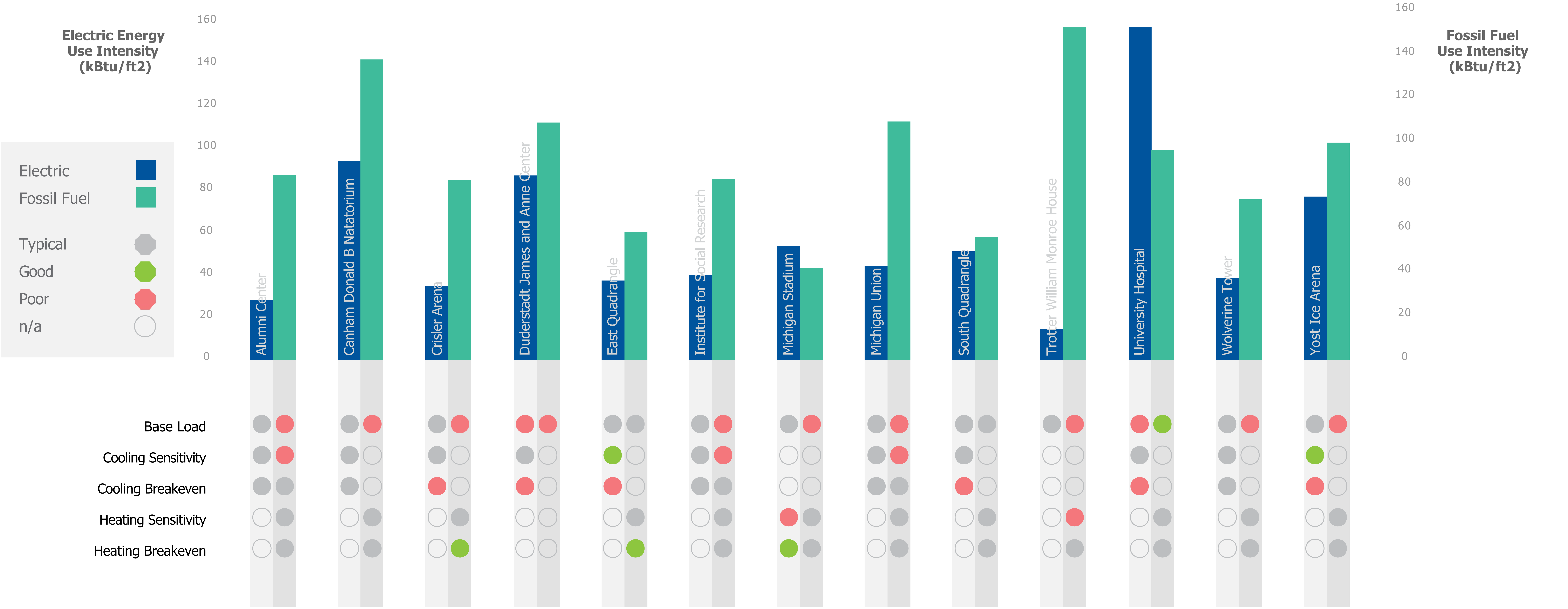
Total Potential Savings

$1,630,300

Top Individual Potential Savings

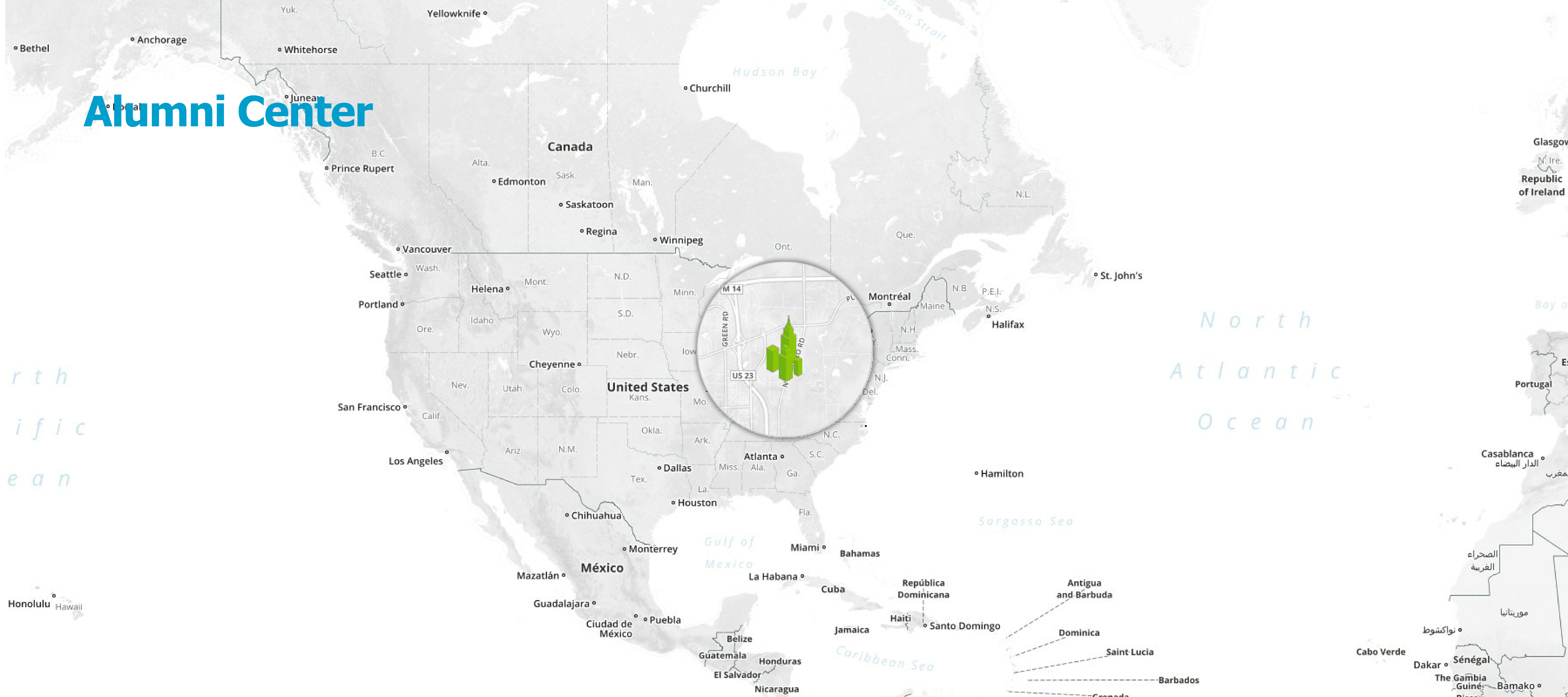
University Hospital	
Savings	700,000
Michigan Stadium	
Savings	260,000
Duderstadt James and Anne Center	
Savings	130,000
South Quadrangle	
Savings	130,000
Michigan Union	
Savings	120,000

Summary of Performance Benchmarks for Electricity and Fossil Fuels



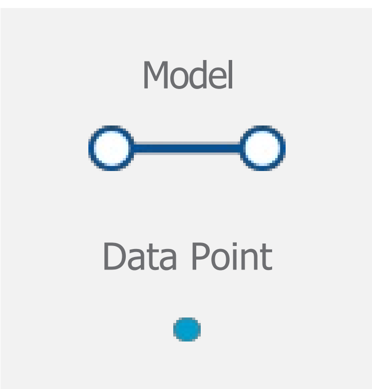
III. Individual Sites

Alumni Center

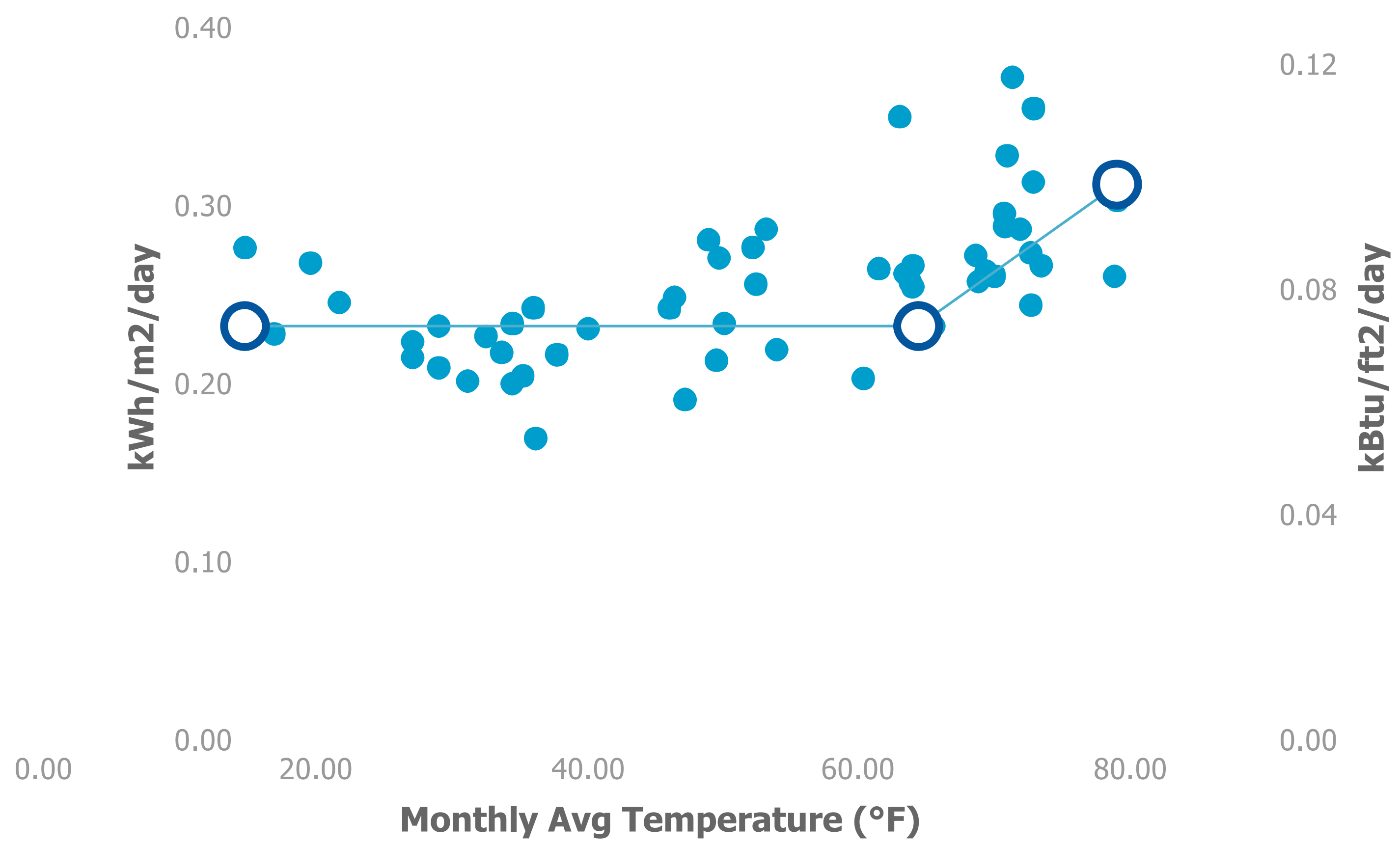


Alumni Center

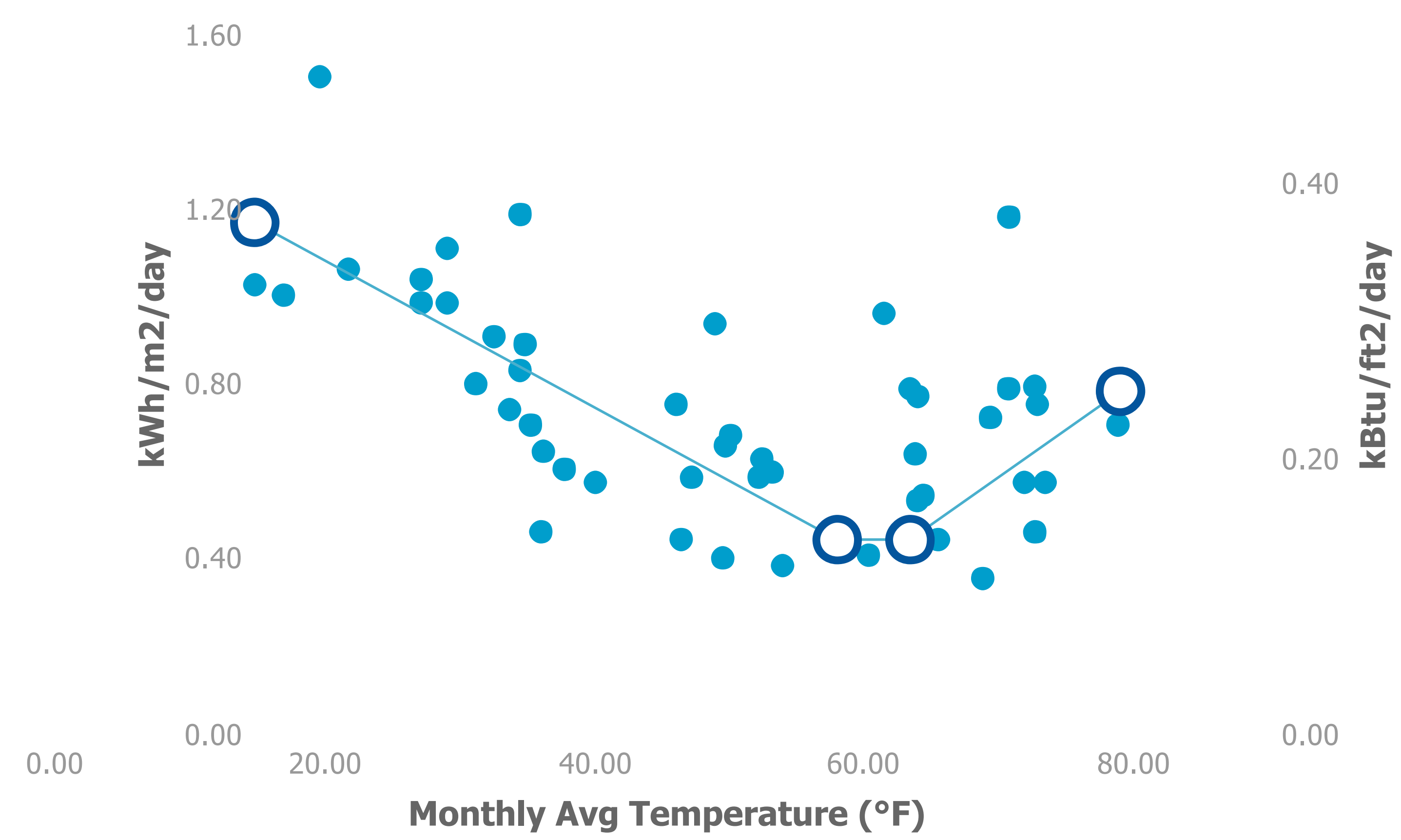
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$17,000

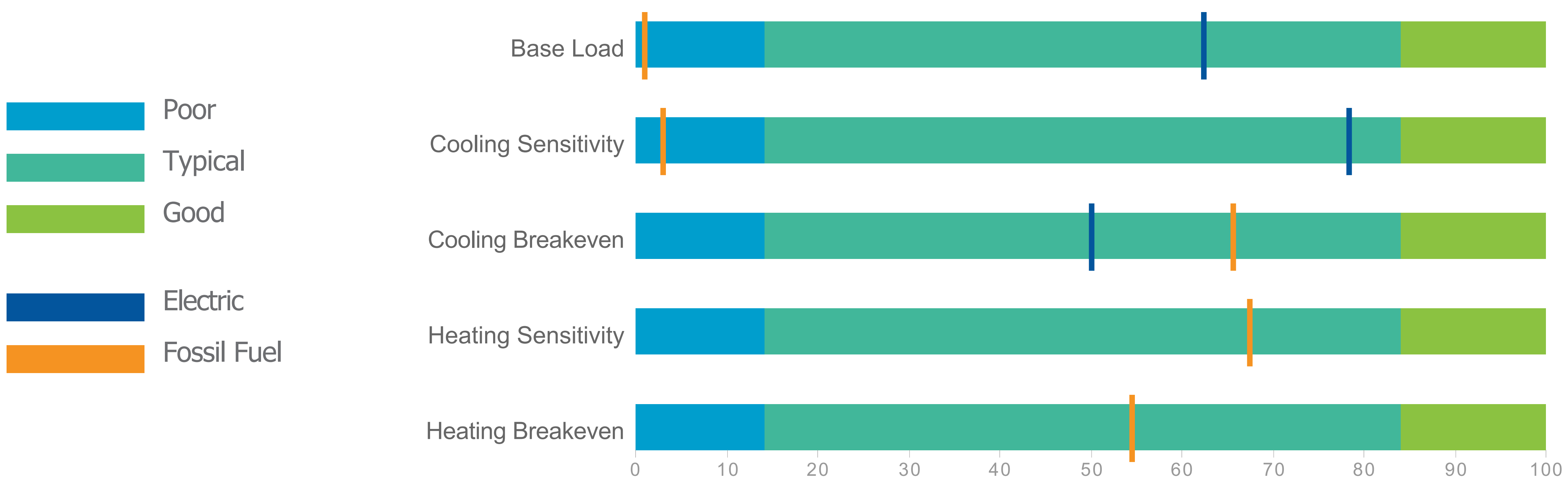
Total Potential Percentage Savings

29%

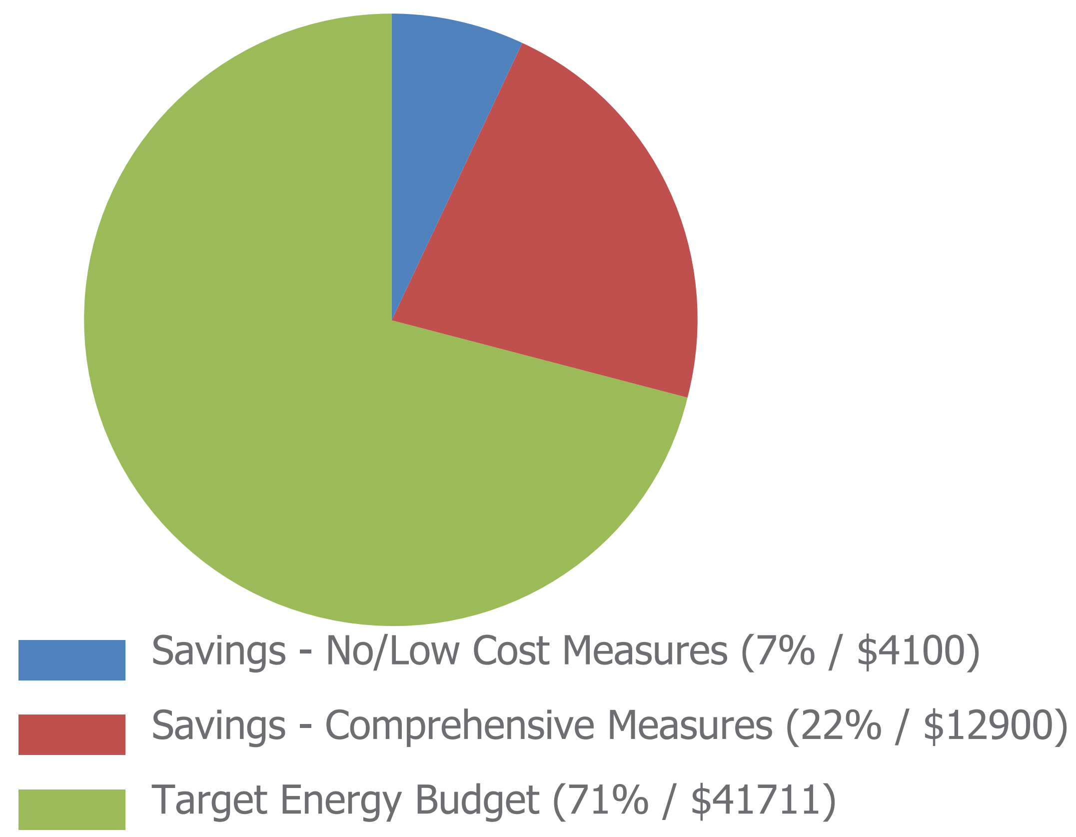
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Increase cooling system efficiency
- Check fossil fuel base load

Benchmark Metrics

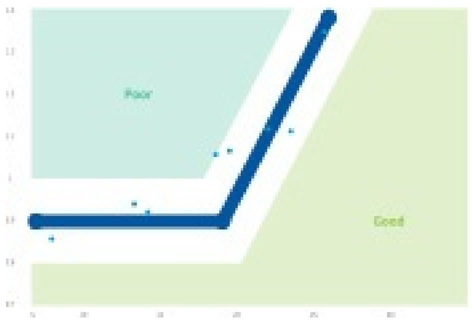


Savings Breakdown



Alumni Center

Recommendations



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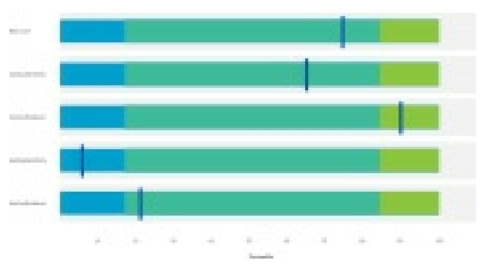

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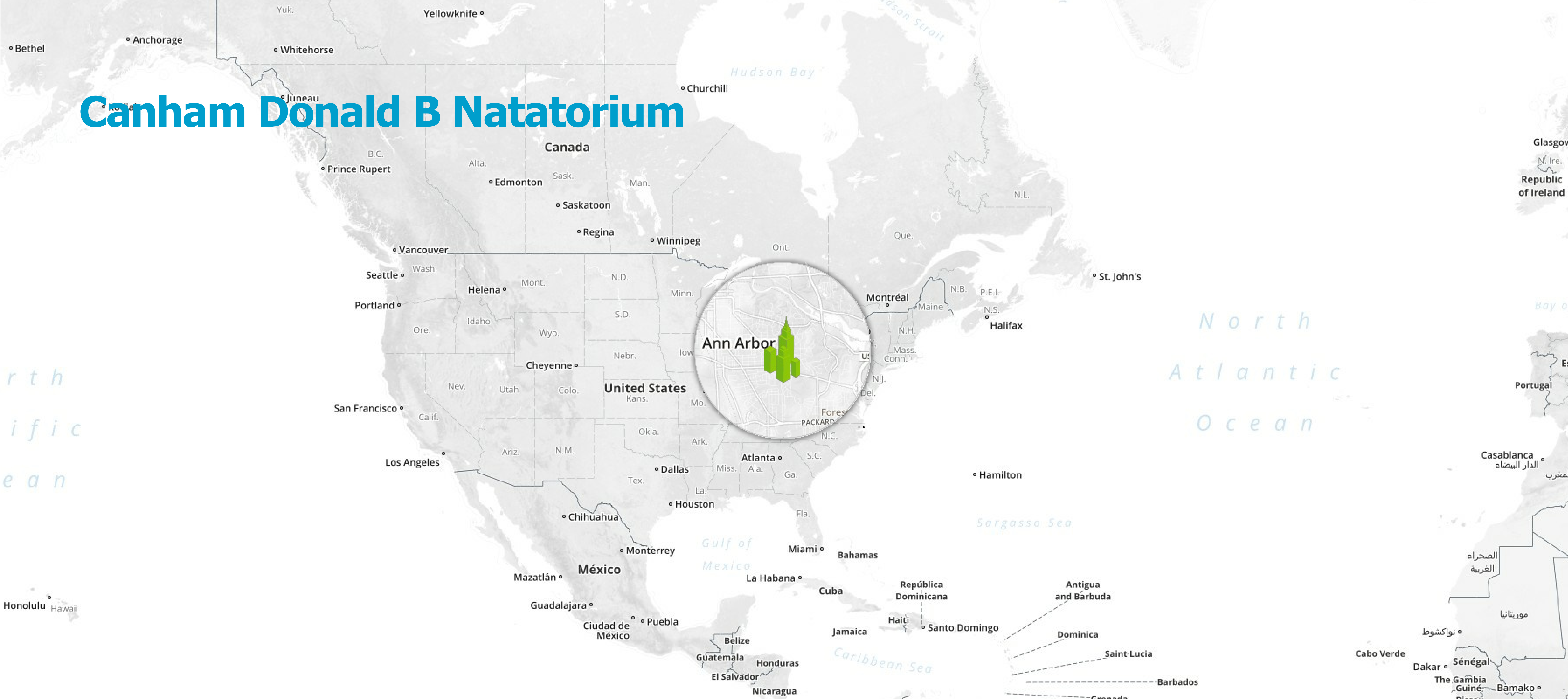
Canham Donald B Natatorium



Canham Donald B Natatorium

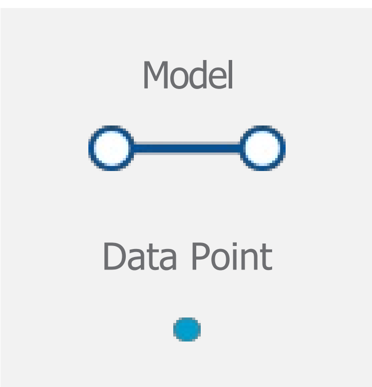
Weather Sensitivity

Total Potential Location Savings

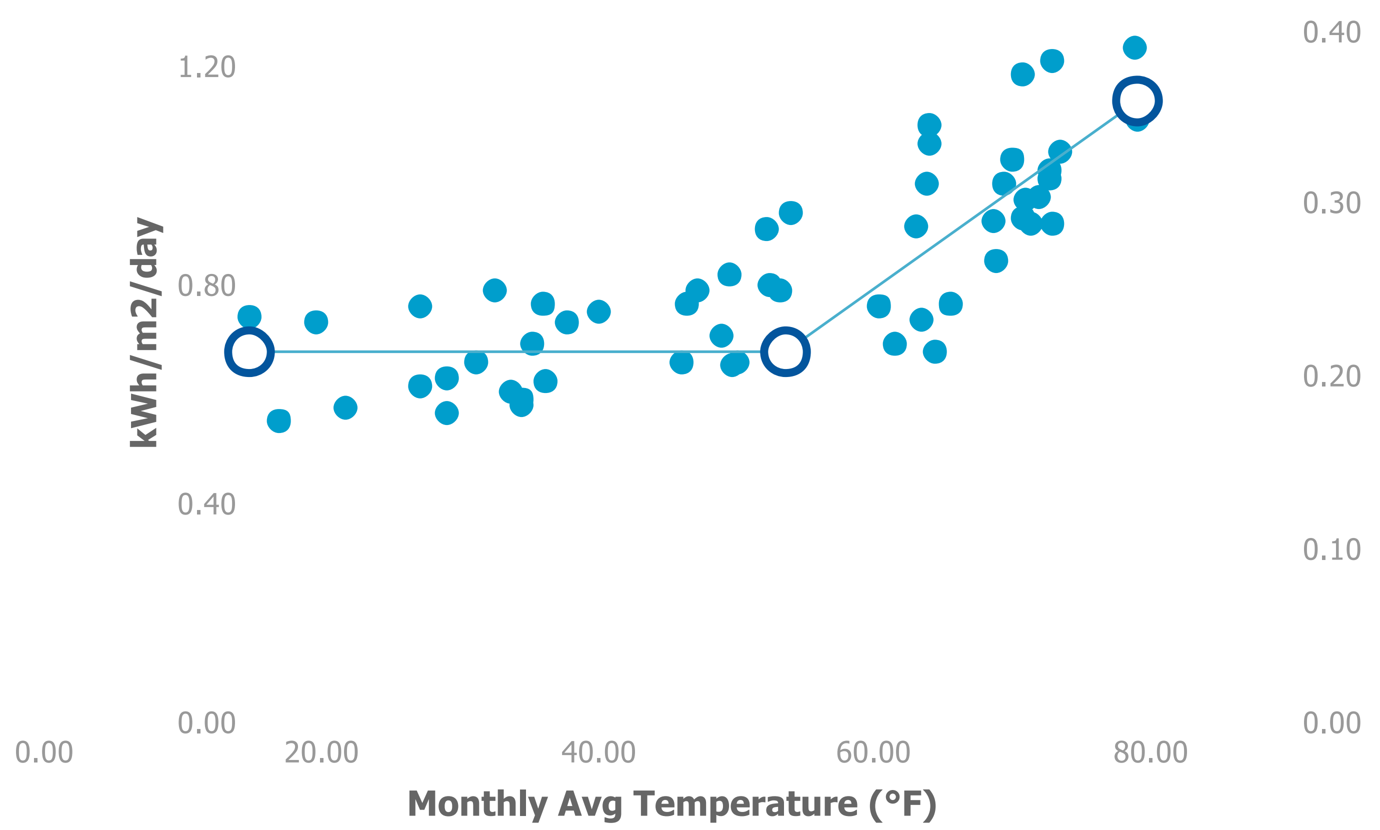
$48,000

Total Potential Percentage Savings

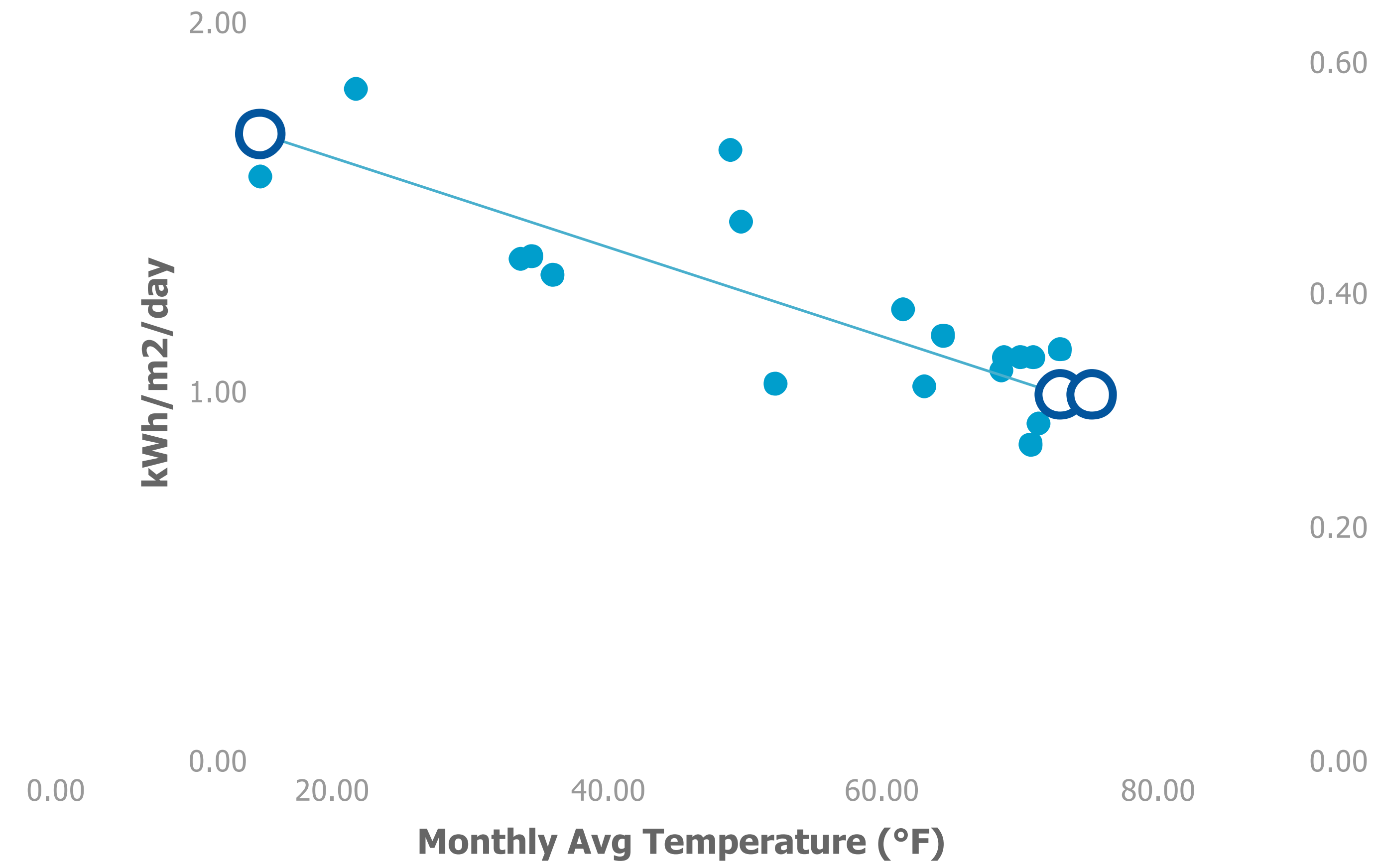
16%



Electric



Fossil Fuel



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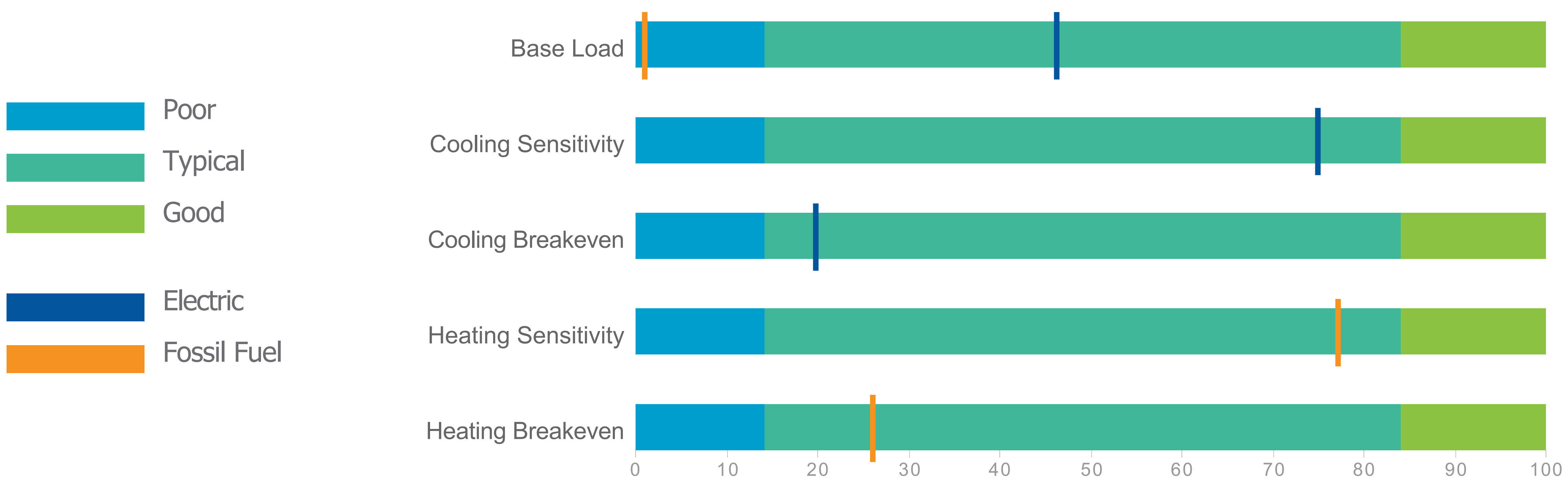
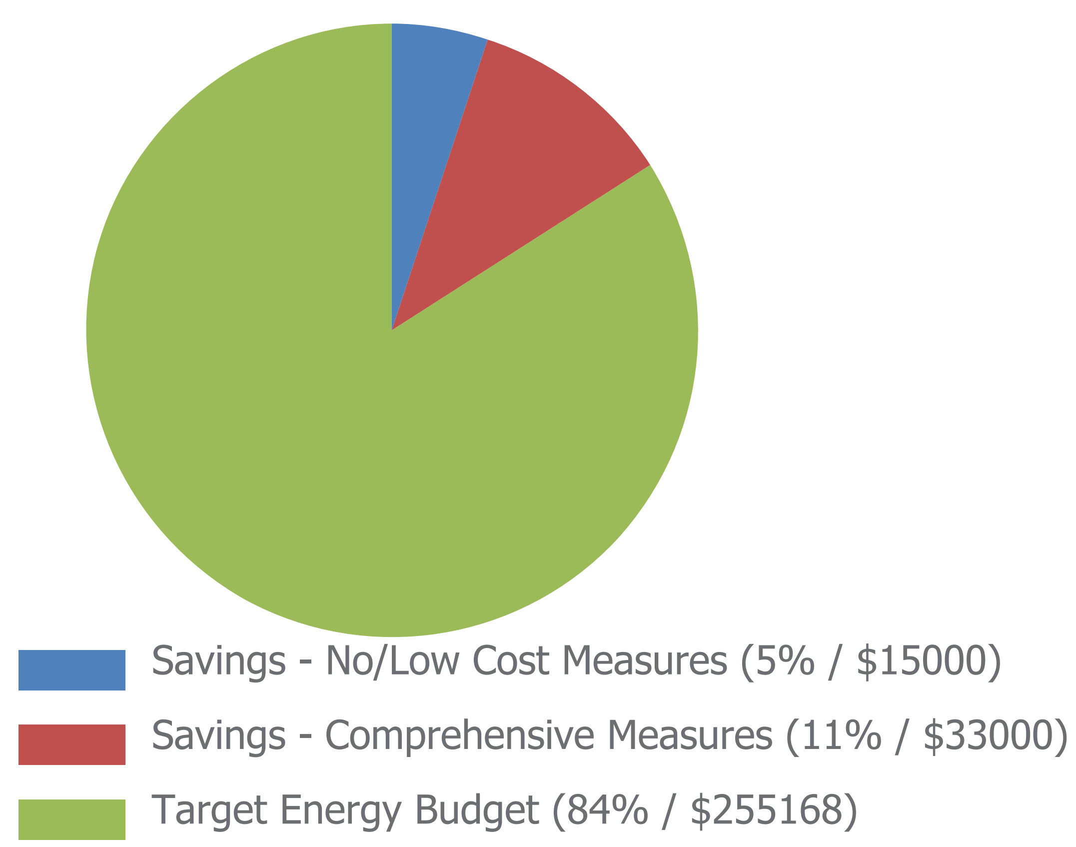
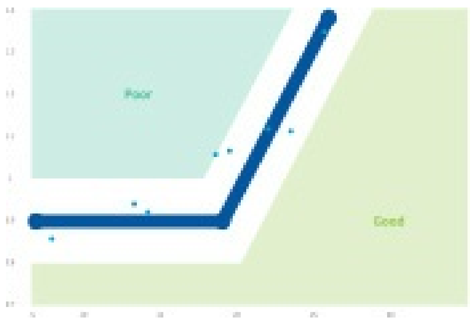


Savings Breakdown



Canham Donald B Natatorium

Recommendations



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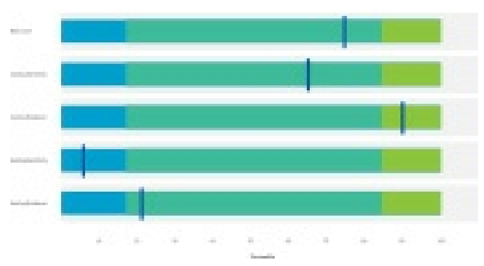

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Check Fossil Fuel Base Load

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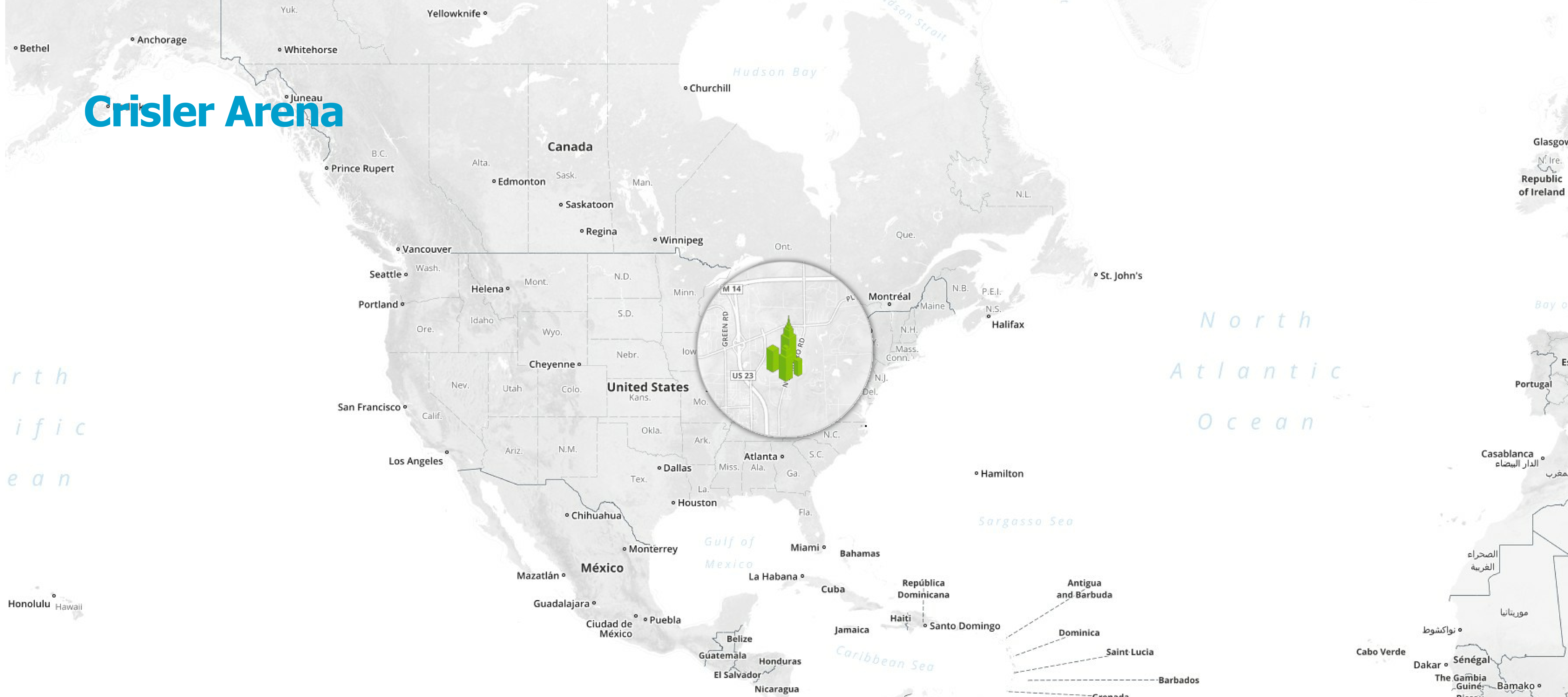
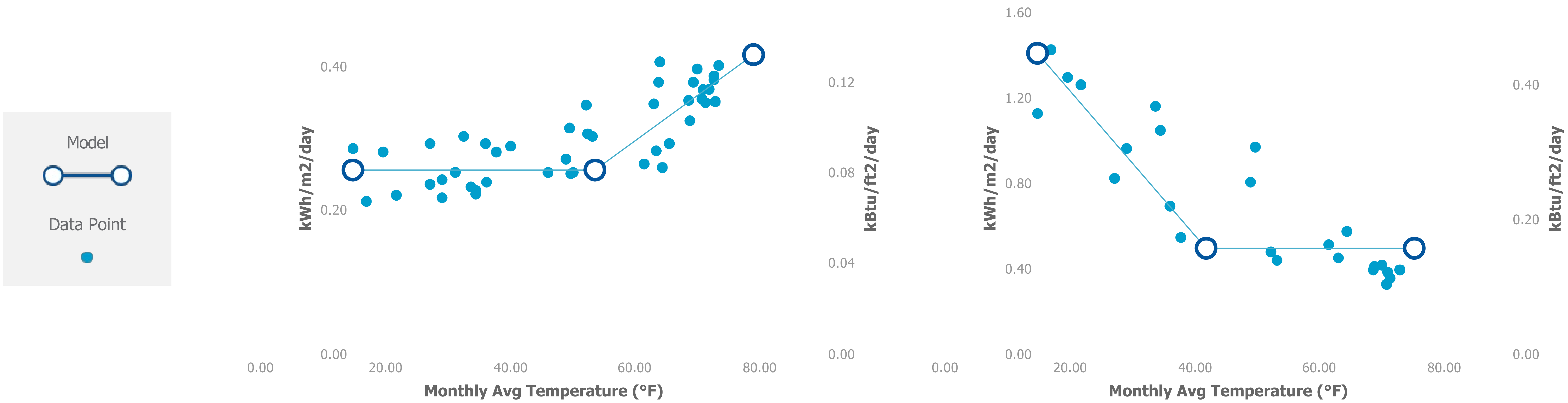
Crisler Arena



Crisler Arena

Weather Sensitivity



Total Potential Location Savings

$60,000

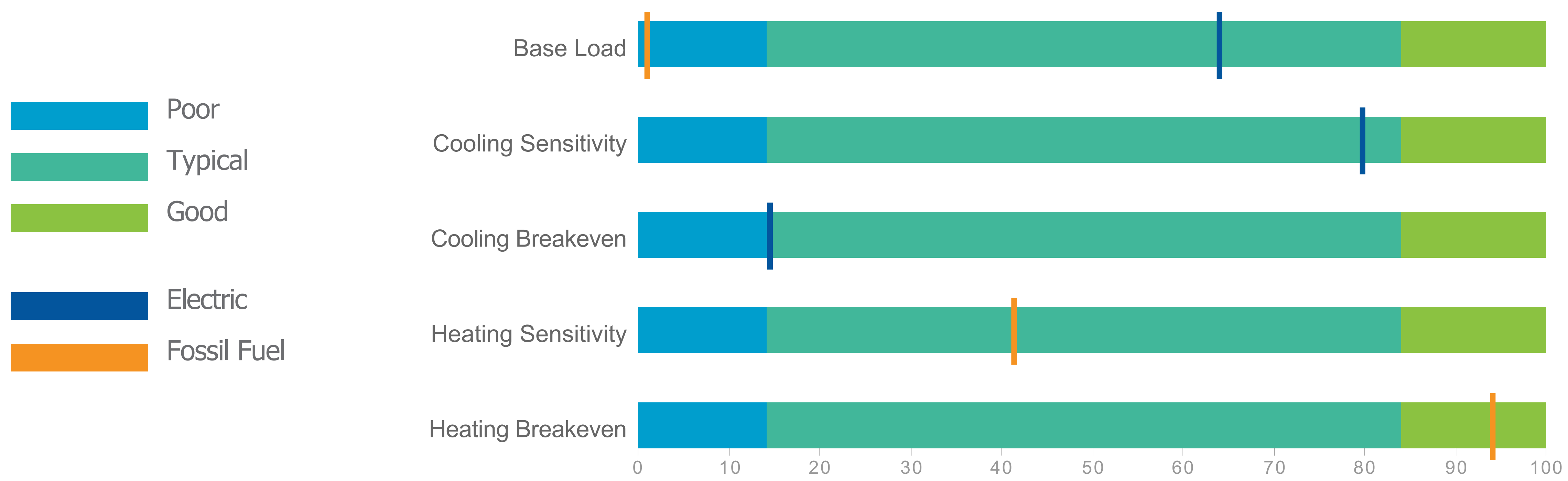
Total Potential Percentage Savings

17%

Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics



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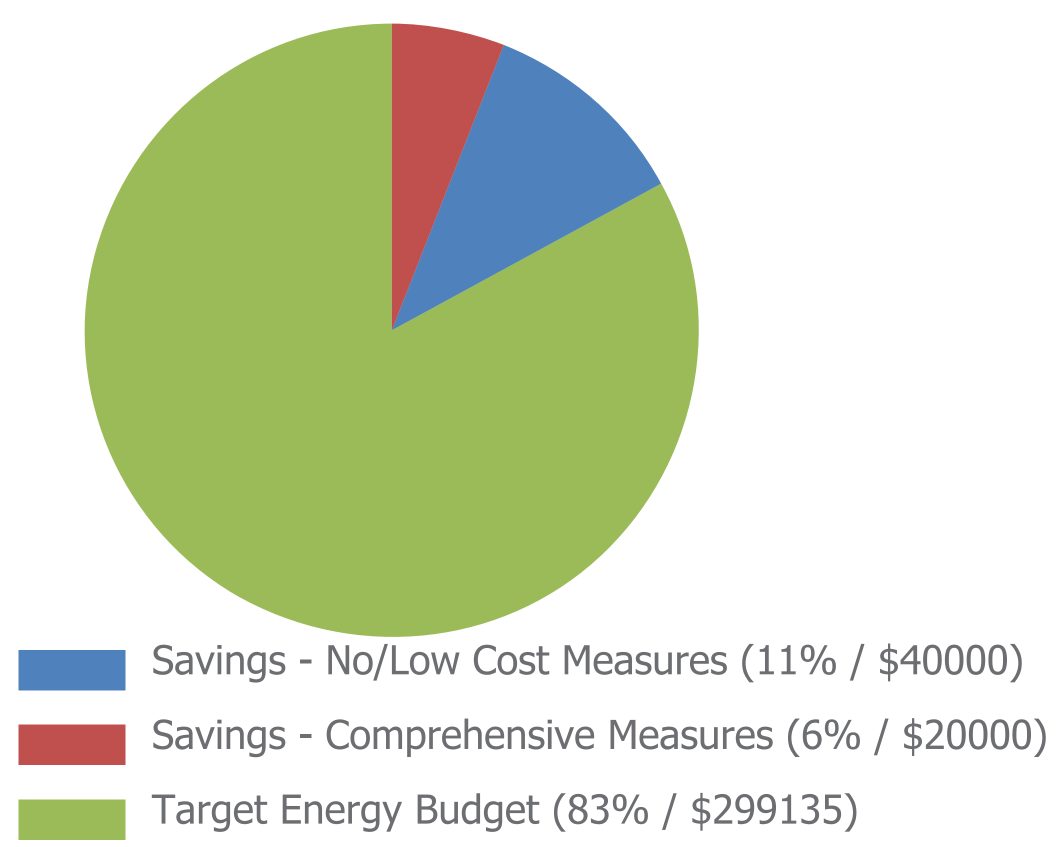
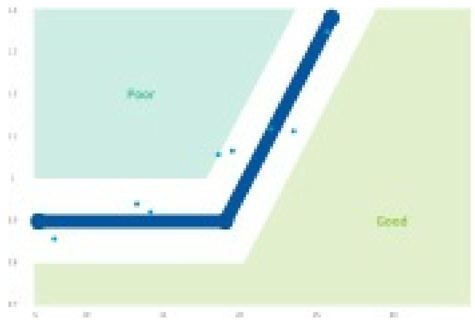


Crisler Arena

Recommendations



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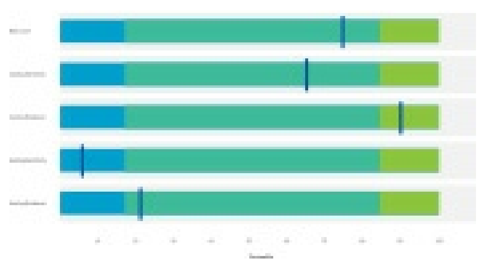

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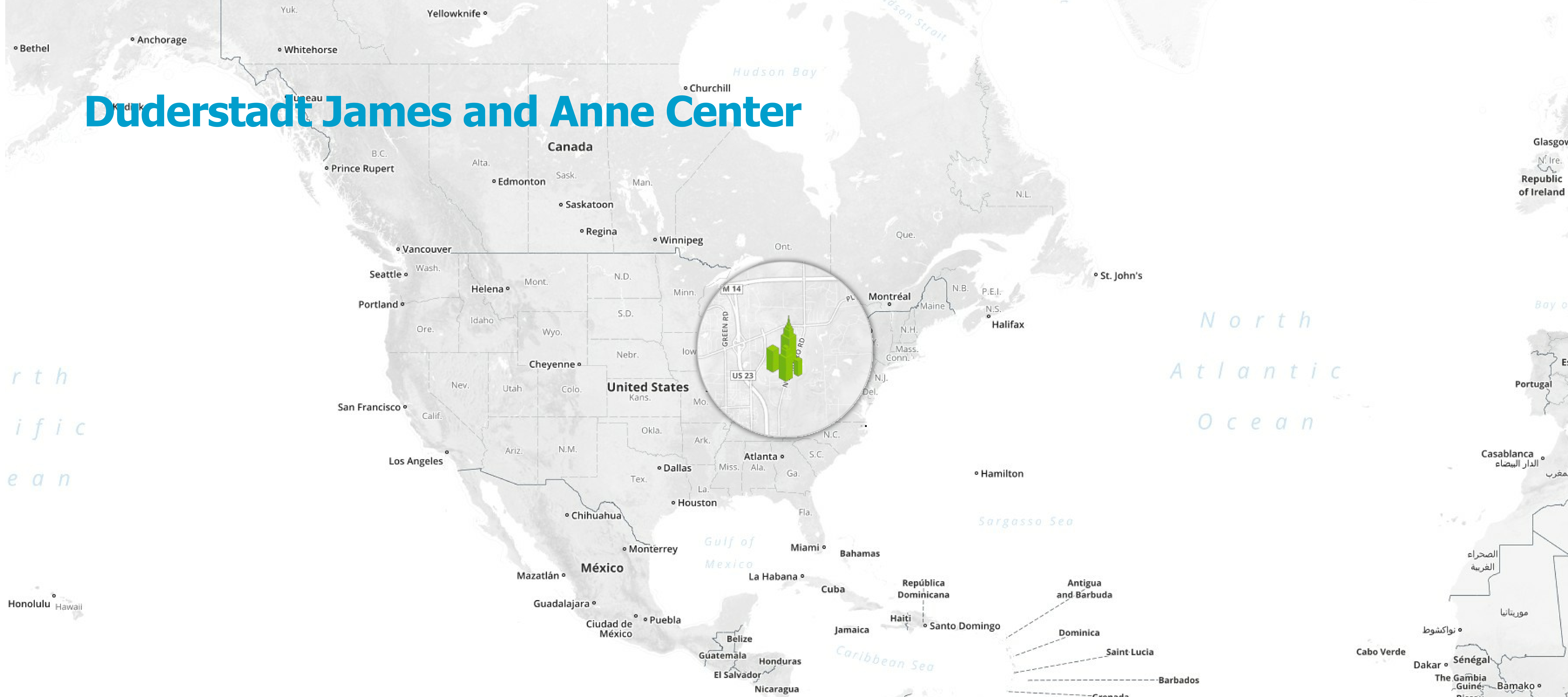
Duderstadt James and Anne Center



Duderstadt James and Anne Center

Weather Sensitivity

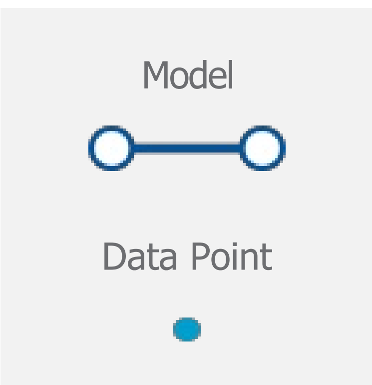
Total Potential Location Savings

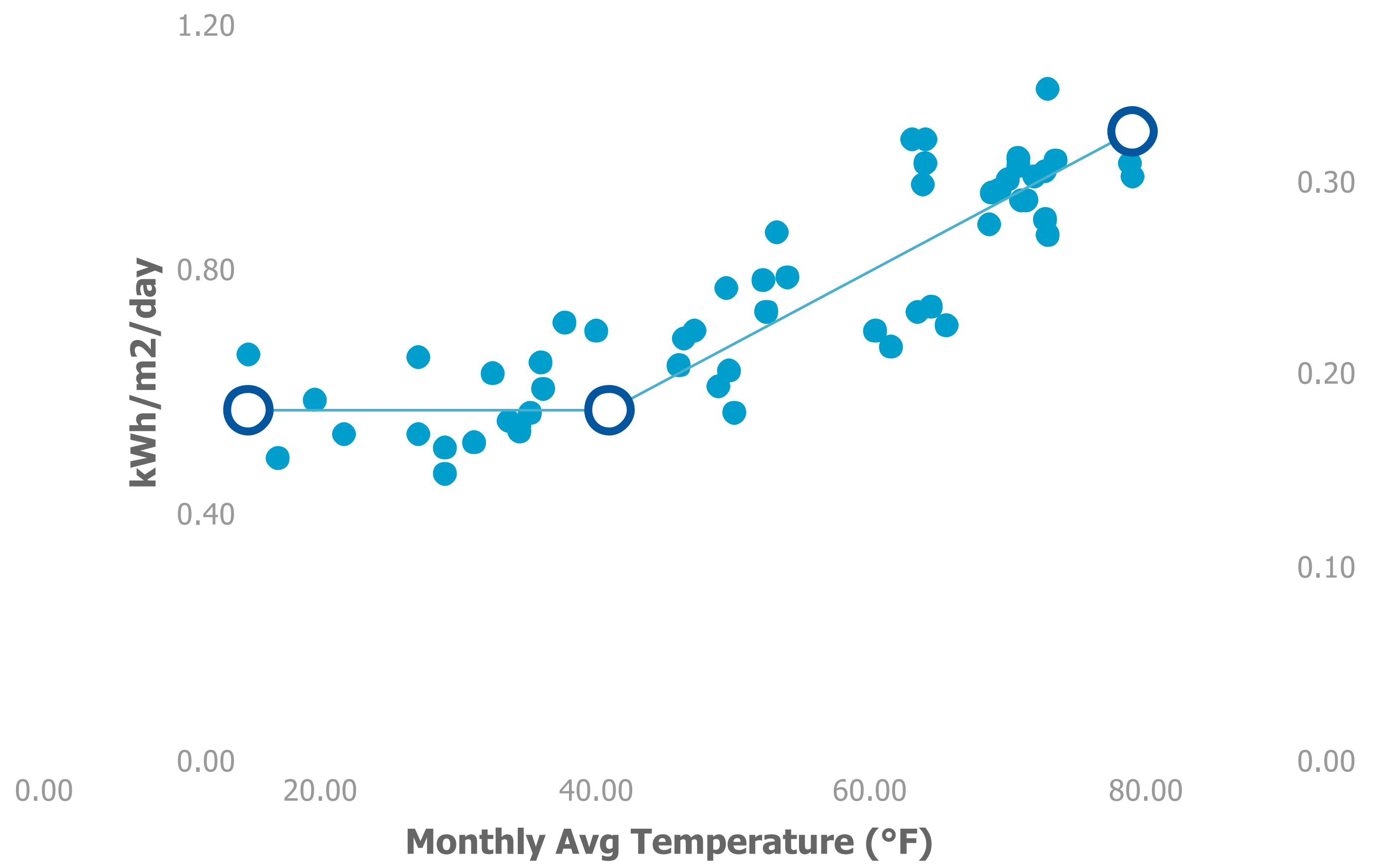
$130,000

Total Potential Percentage Savings

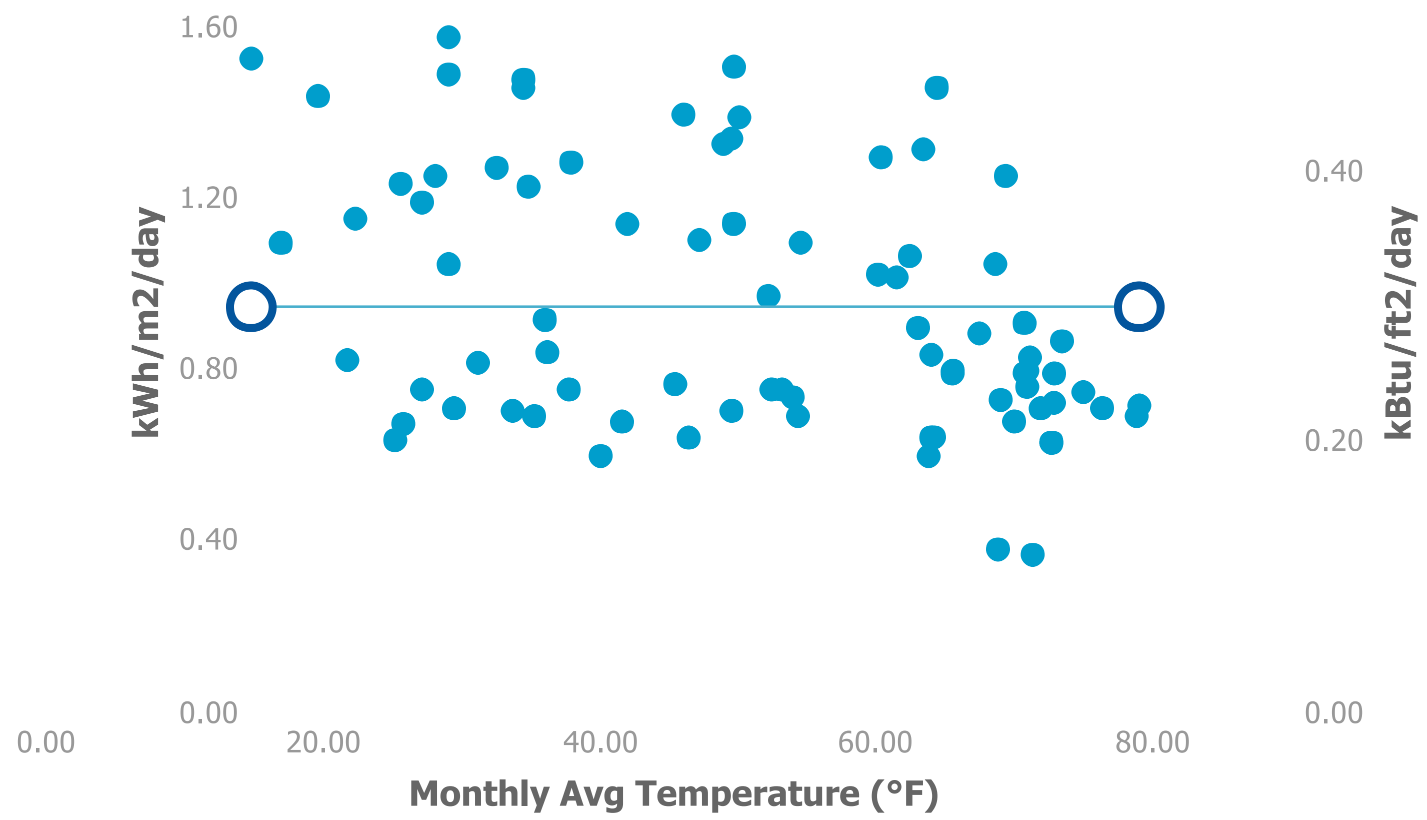
21%

Electric





Fossil Fuel



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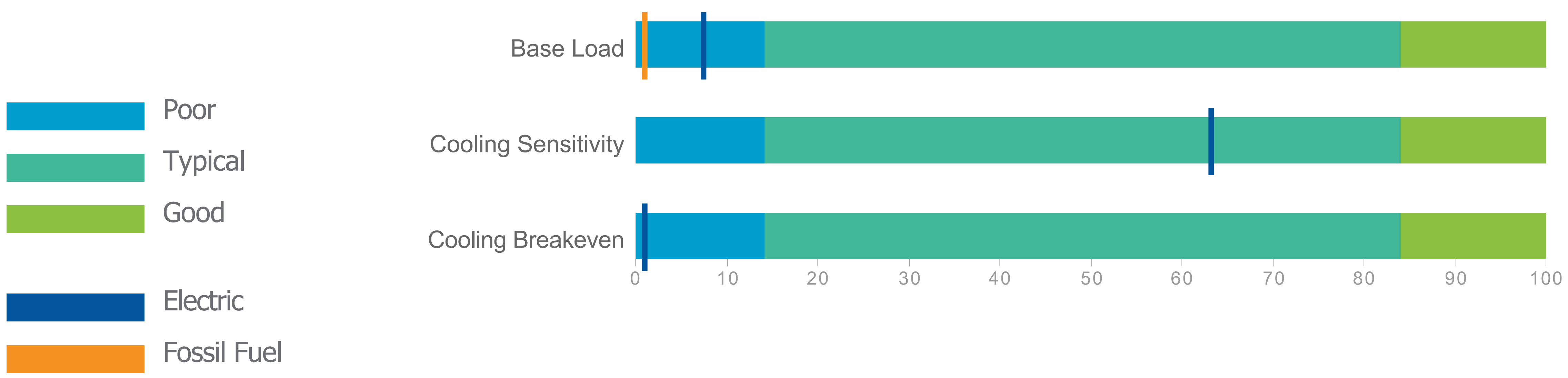
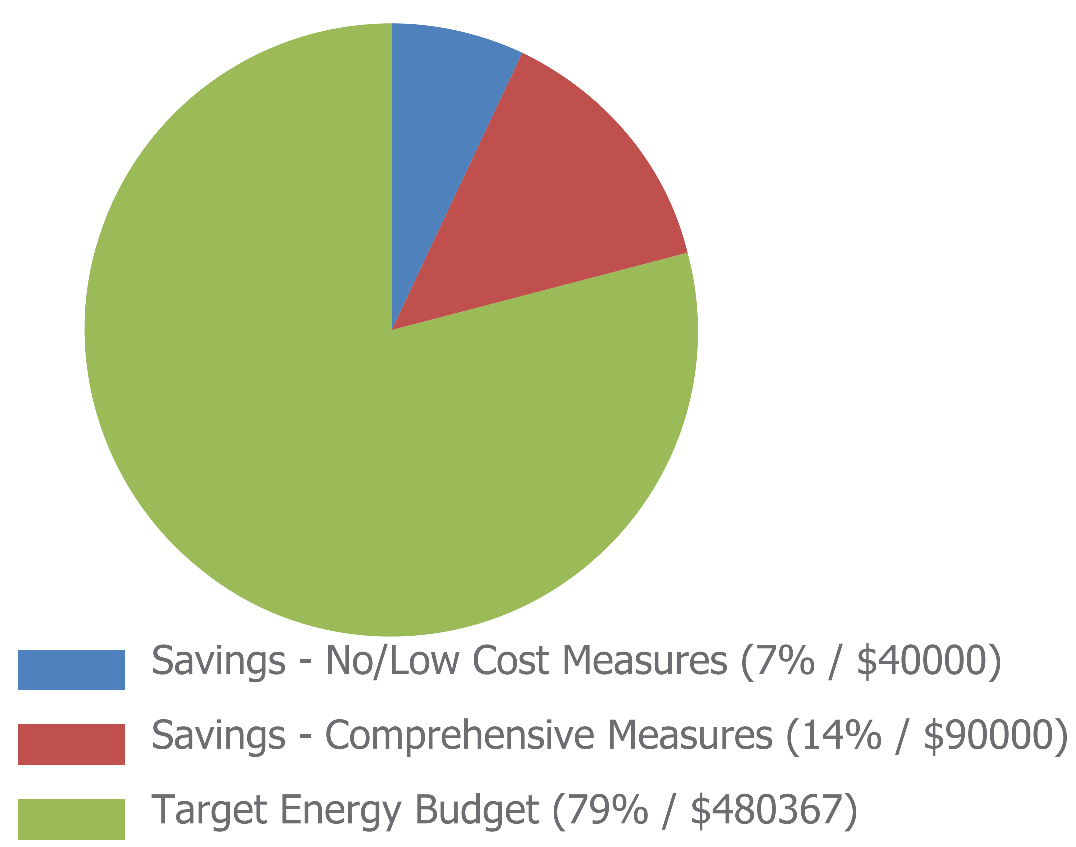
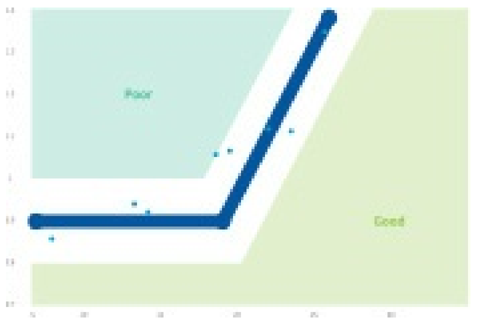


Savings Breakdown



Duderstadt James and Anne Center

Recommendations



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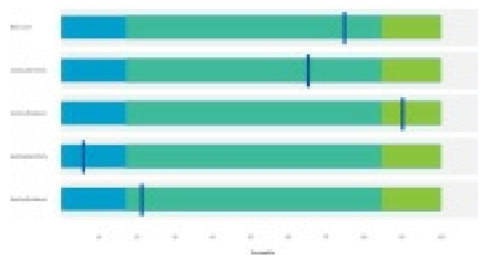

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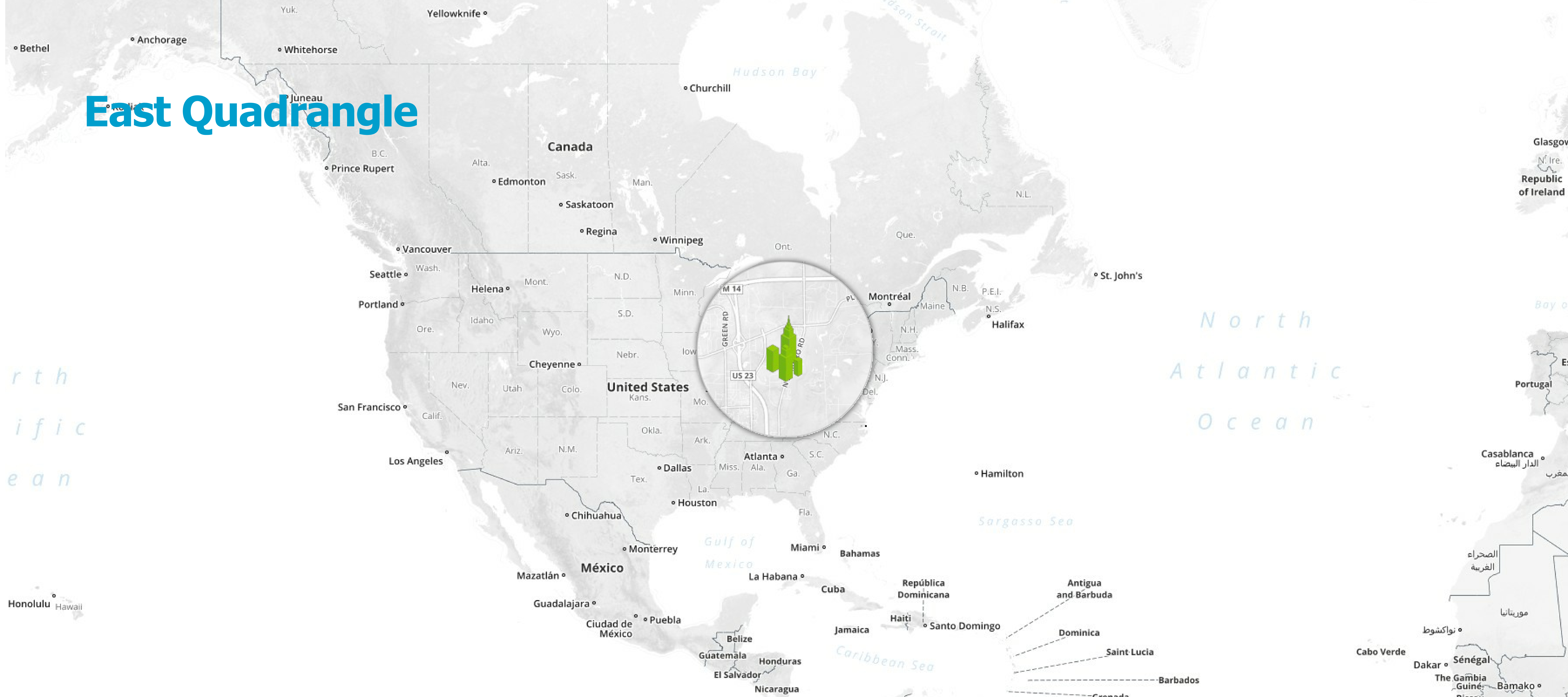
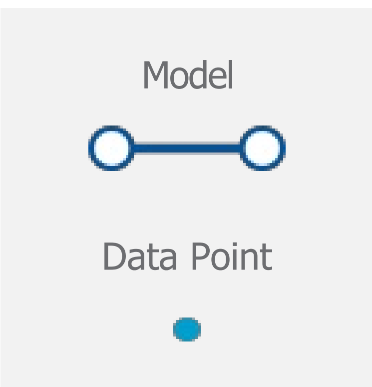
East Quadrangle

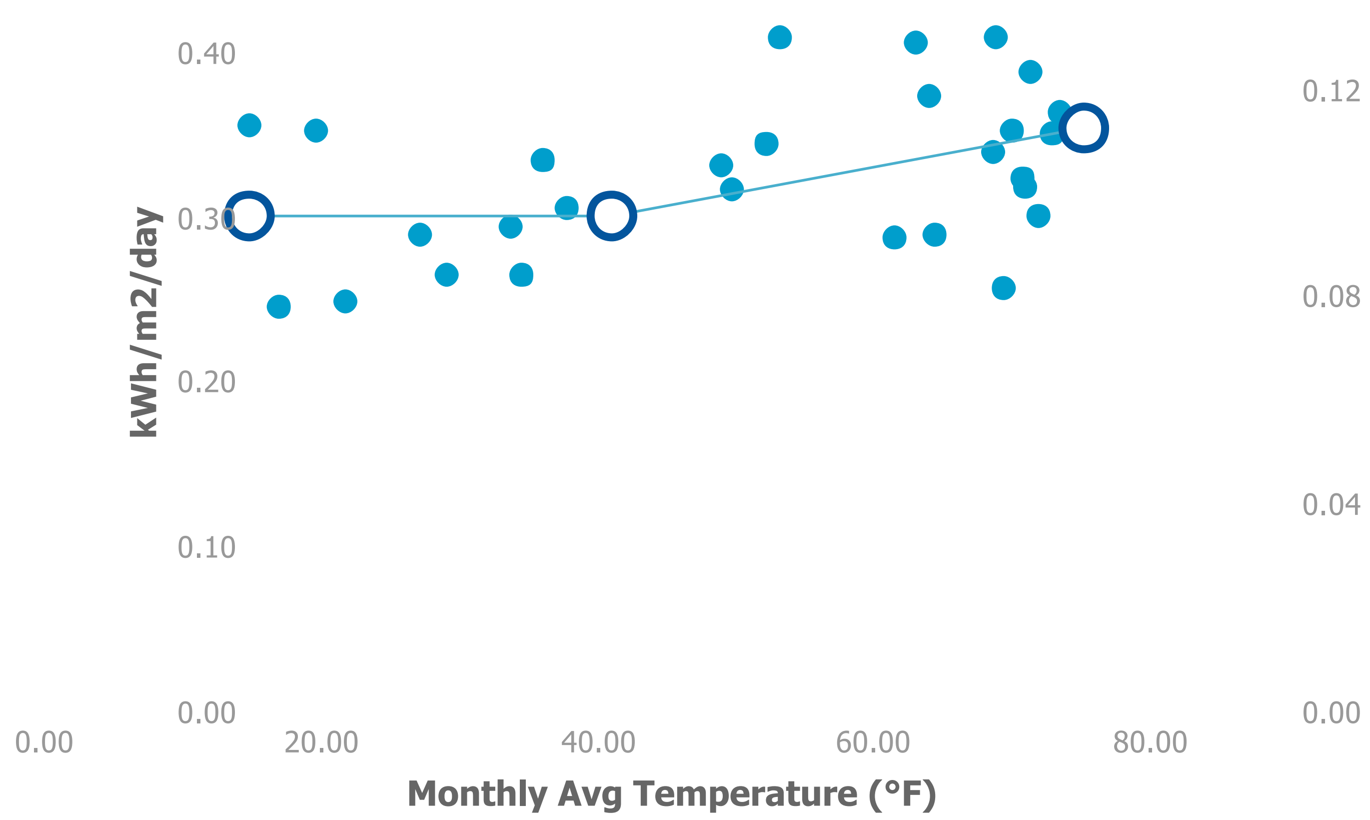


East Quadrangle

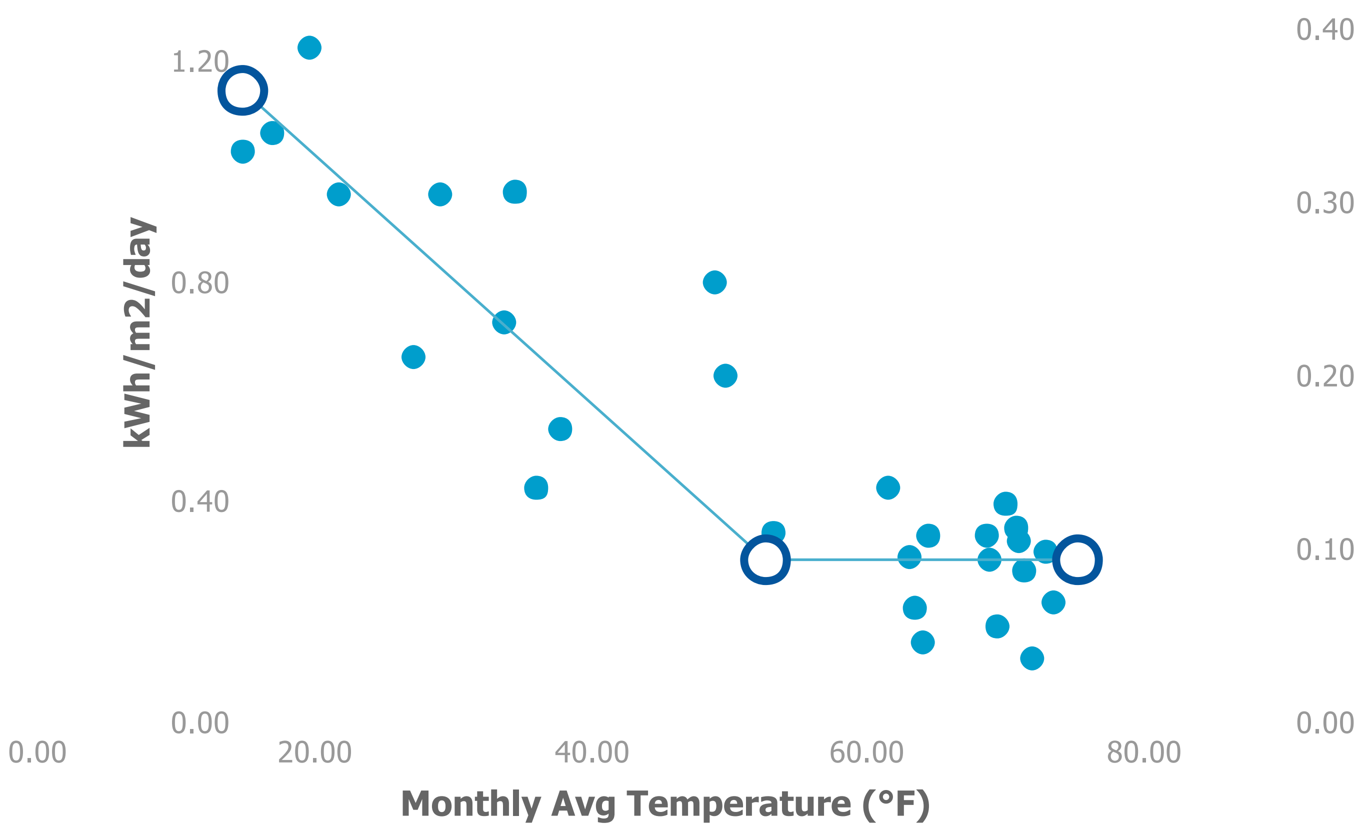
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$80,000

Total Potential Percentage Savings

15%

Recommendations

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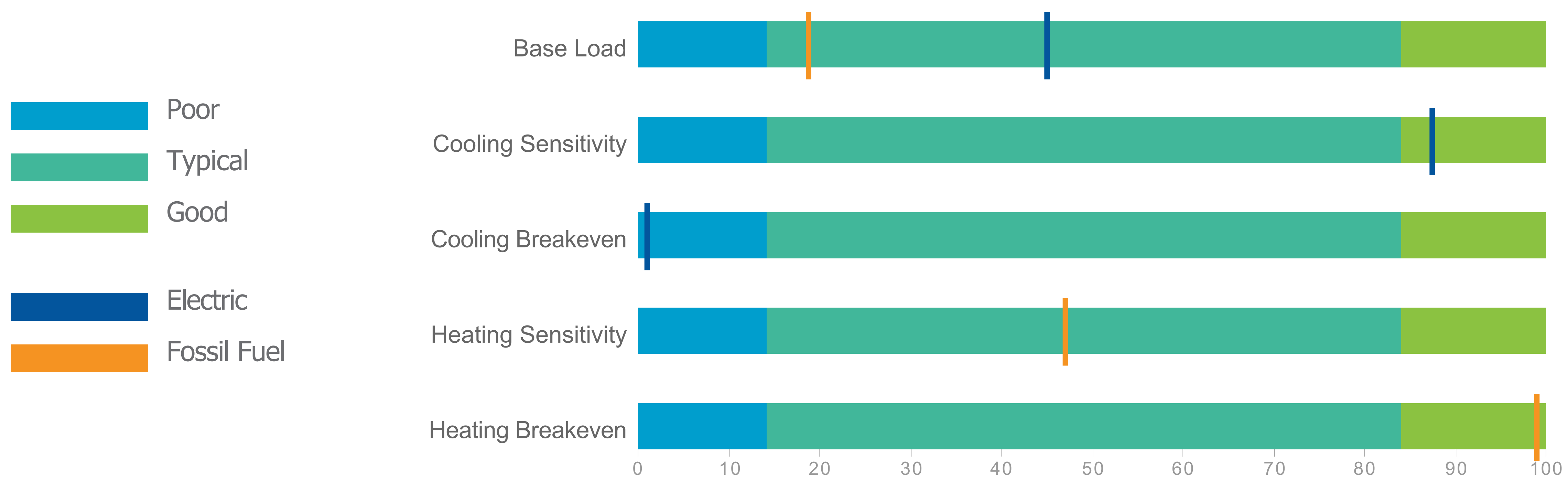
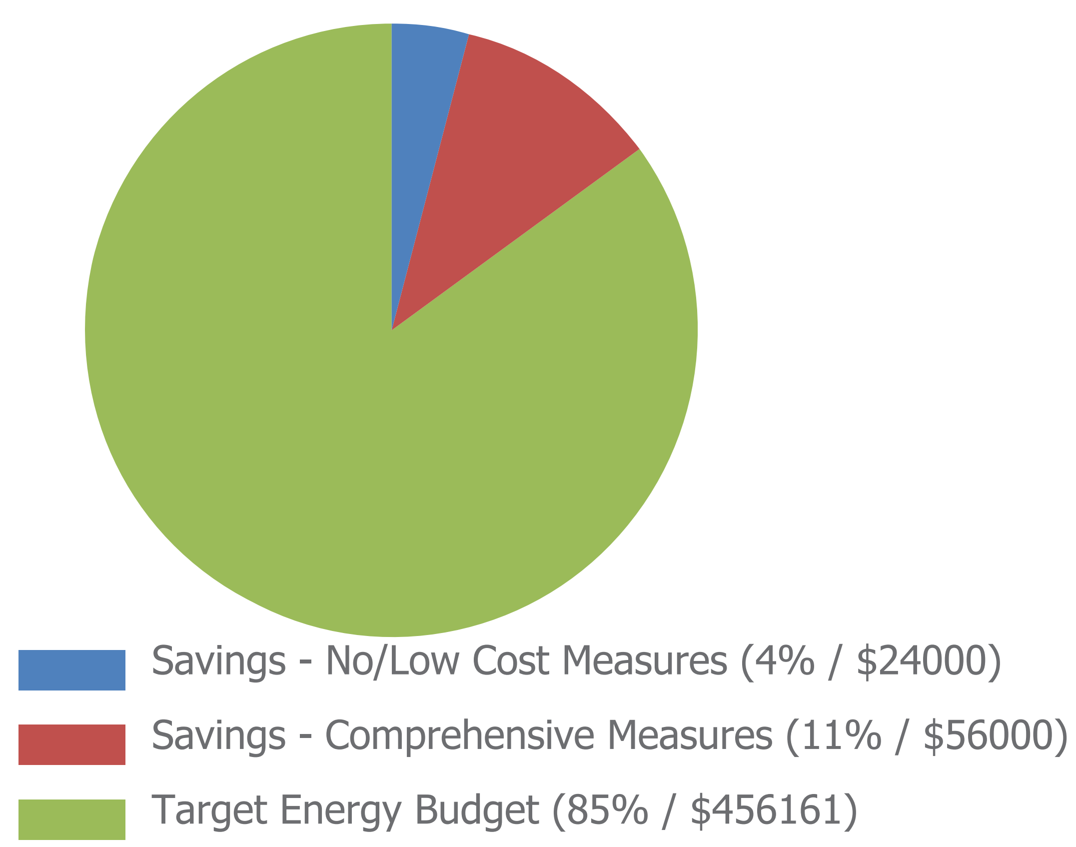
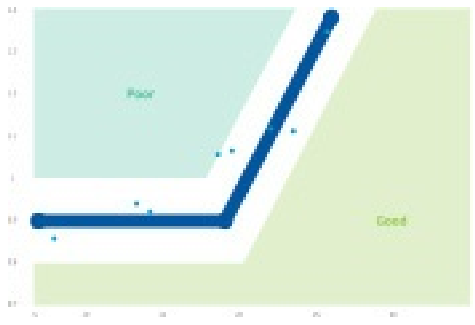


Savings Breakdown



East Quadrangle

Recommendations



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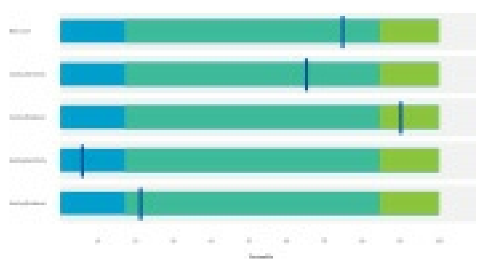

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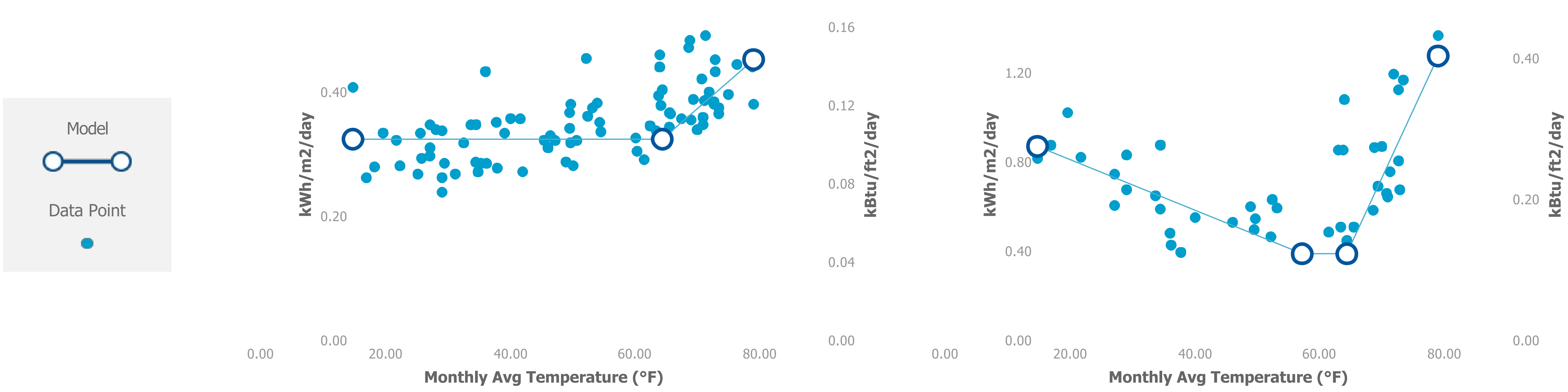
Check Fossil Fuel Base Load

The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Institute for Social Research

Institute for Social Research

Weather Sensitivity



Total Potential Location Savings

$47,000

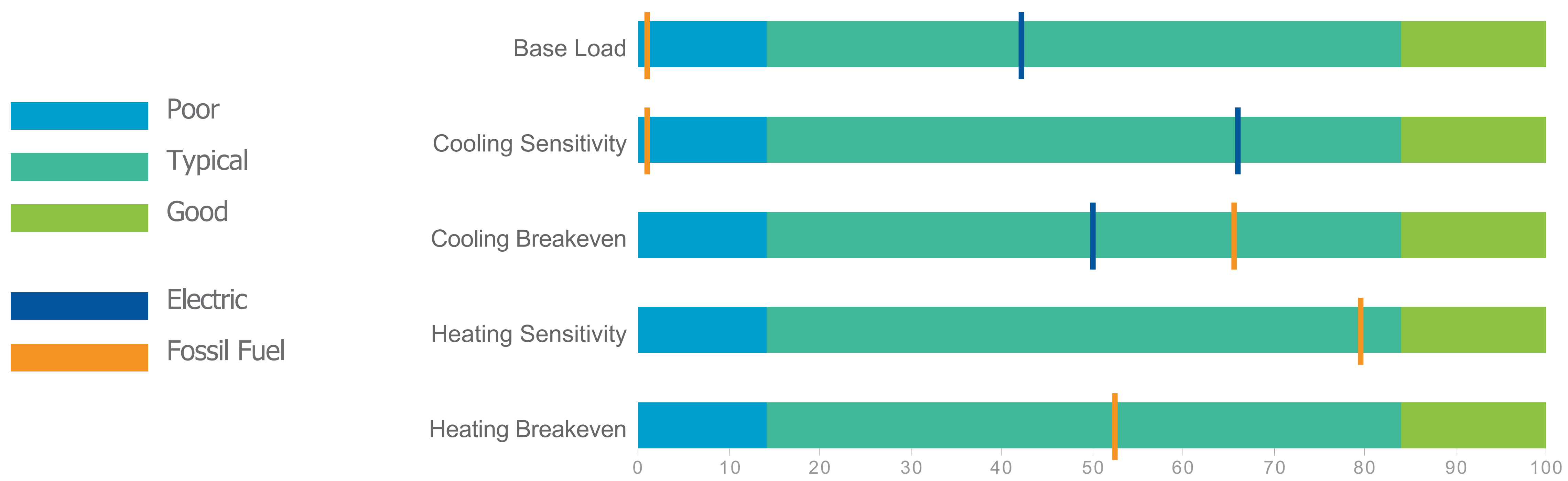
Total Potential Percentage Savings

11%

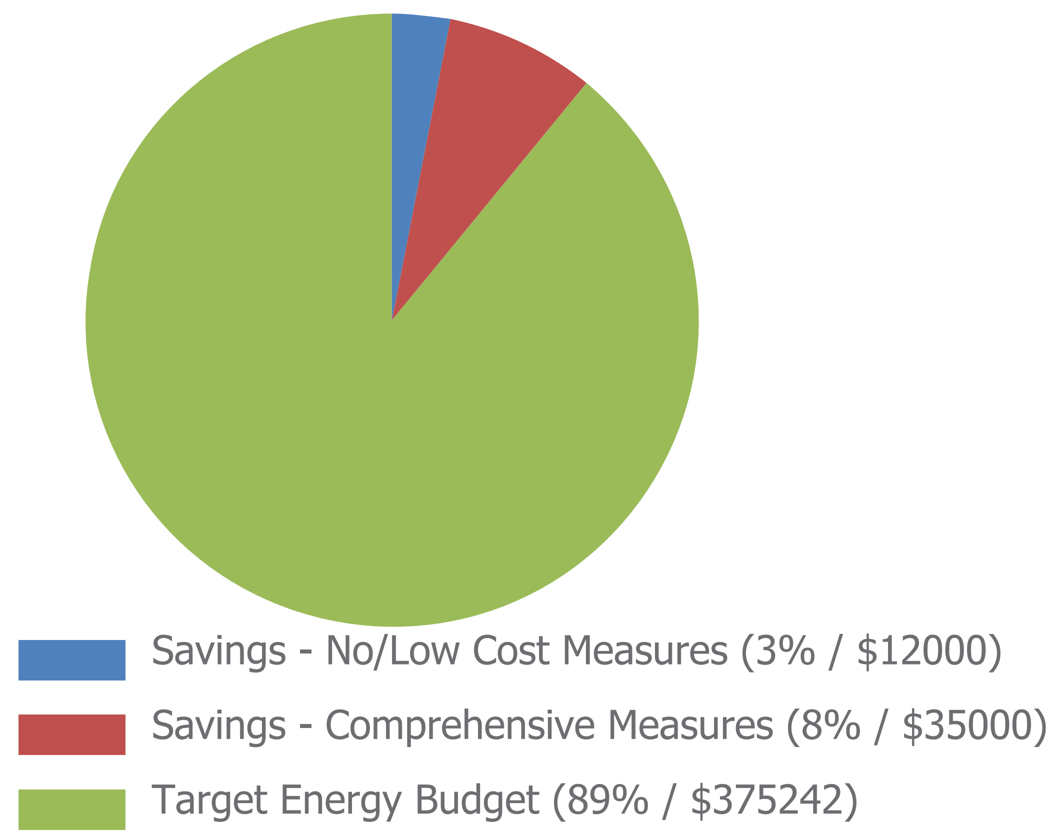
Recommendations

- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Increase cooling system efficiency
- Check fossil fuel base load

Benchmark Metrics

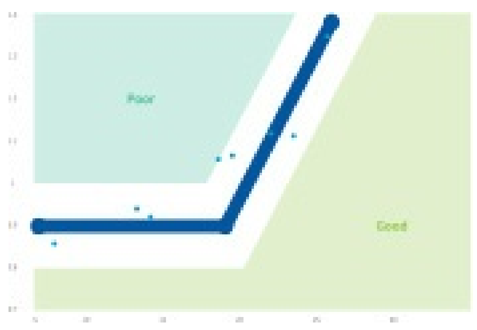


Savings Breakdown



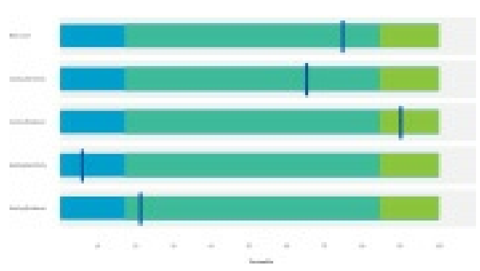
Institute for Social Research

Recommendations



Weather Sensitivity

LEAN models are used to determine a building's sensitivity to weather. The regressed model parameters represent the weather independent energy use (or baseload), weather dependent energy use (or heating/cooling sensitivity), and the building balance-point temperatures (or temperatures where the building starts to use additional energy for cooling or heating).



Benchmark Metrics

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Reduce Equipment Schedules

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Reduce Lighting Load

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Reduce Plug Loads

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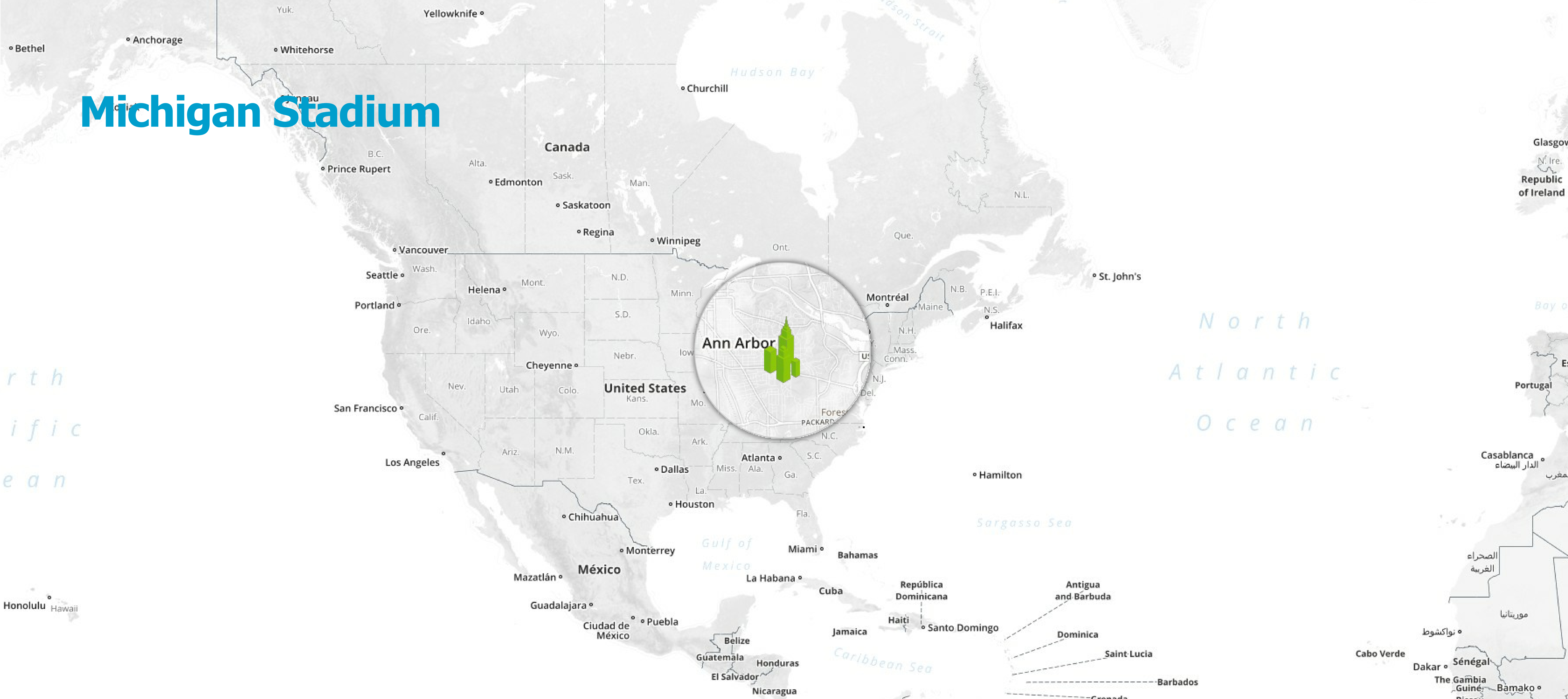
Increase Cooling System Efficiency

The overall performance of the cooling equipment and systems in this building is below the typical performance found in similar buildings. Check all cooling related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Check Fossil Fuel Base Load

The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Michigan Stadium



Michigan Stadium

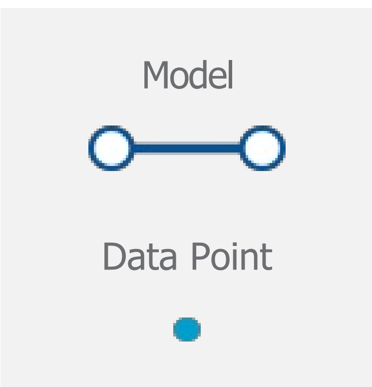
Weather Sensitivity

Total Potential Location Savings

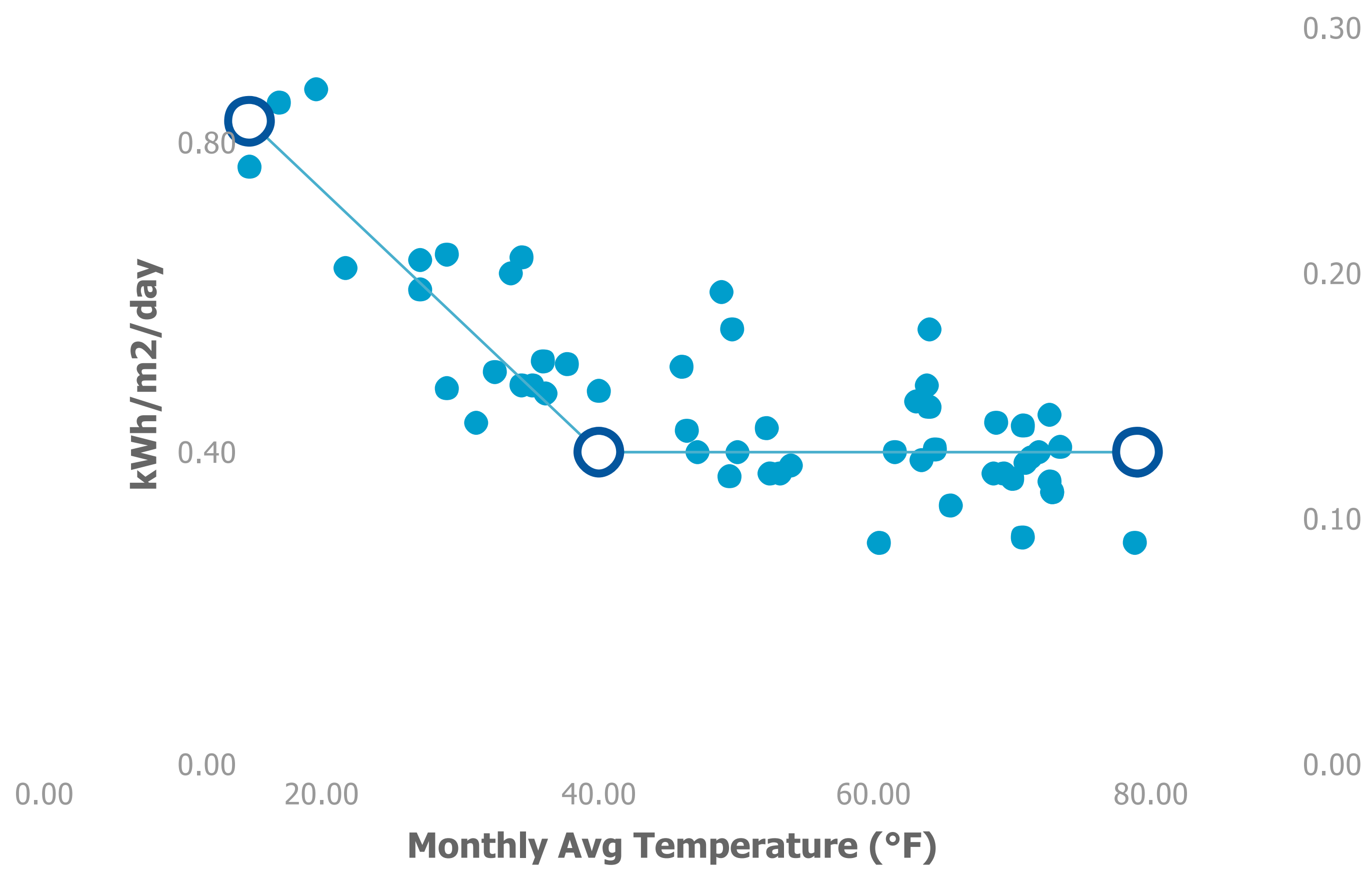
$260,000

Total Potential Percentage Savings

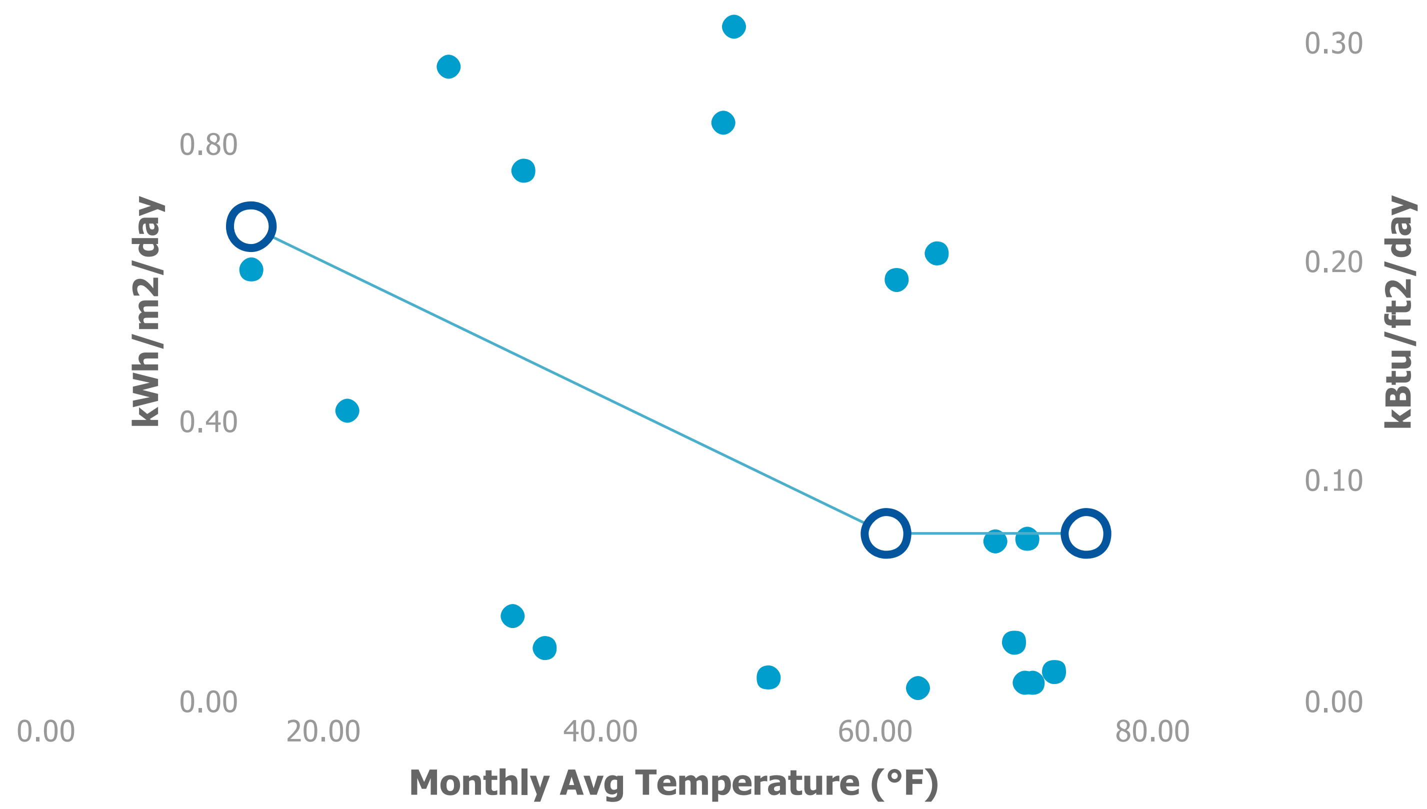
30%



Electric



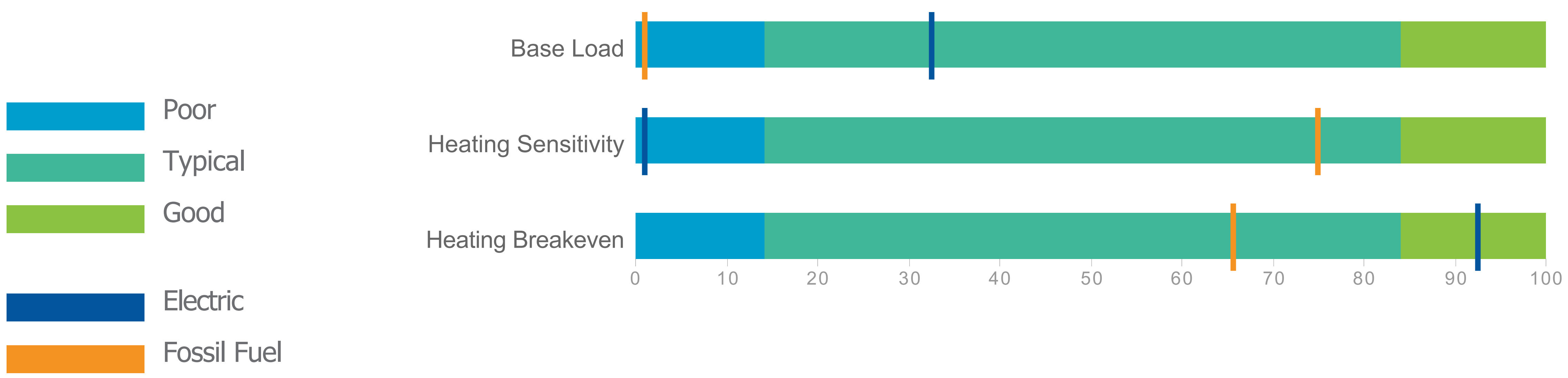
Fossil Fuel



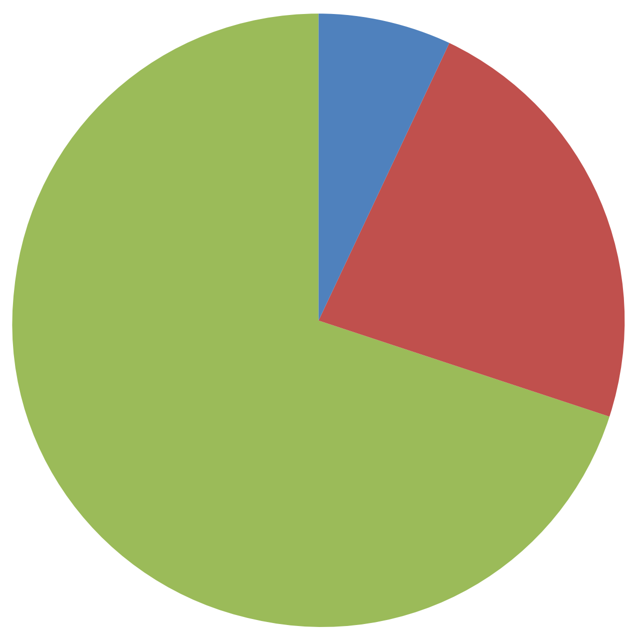
Recommendations

- Reduce equipment schedules
- Eliminate electric heating
- Reduce lighting load
- Reduce plug loads
- Increase heating system efficiency
- Check fossil fuel base load

Benchmark Metrics



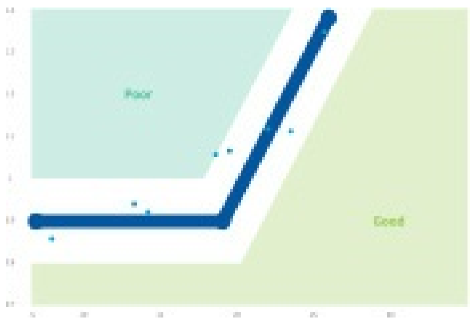
Savings Breakdown



Savings - No/Low Cost Measures (7% / $60000)
Savings - Comprehensive Measures (23% / $200000)
Target Energy Budget (70% / $604214)

Michigan Stadium

Recommendations



Weather Sensitivity

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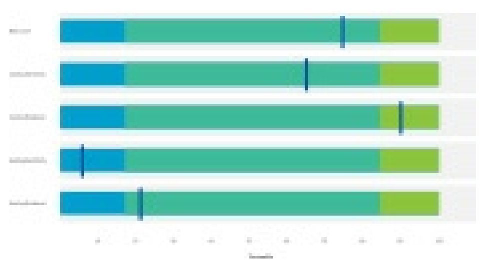

Benchmark Metrics

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Reduce Equipment Schedules

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Eliminate Electric Heating

Check for any electric heating and re-heating of air delivered by air-handling and terminal units and for direct heating of building spaces. Where possible, eliminate or reduce these forms of heating and evaluate the economics of replacing them with fossil fuel based or other non-electric forms of heating.

Reduce Lighting Load

Lighting loads are reduced by improving both the control and efficiency of the lighting and by taking advantagve of natural daylighting whenever possilble. Existing or upgraded controls are used to dim and turn-off the lights appropriately; and lighting efficiency is improved by upgrading the bulbs and fixtures. Daylight utilitzation can be improved with better control of lights that are near existing windows and skylights, and with renovations to the building envelope and internal space configurations.

Reduce Plug Loads

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Increase Heating System Efficiency

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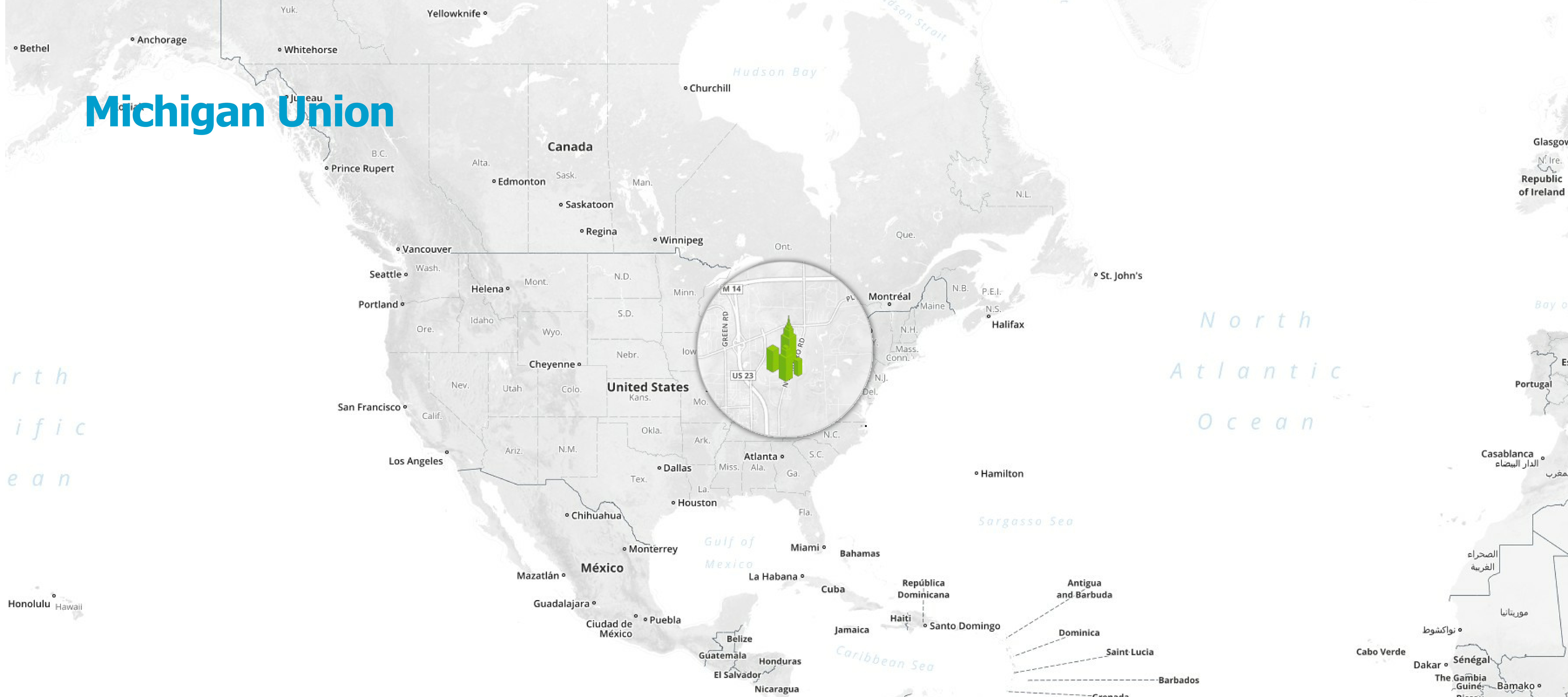
Check Fossil Fuel Base Load

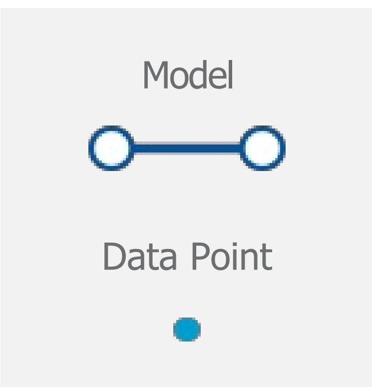
The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Michigan Union

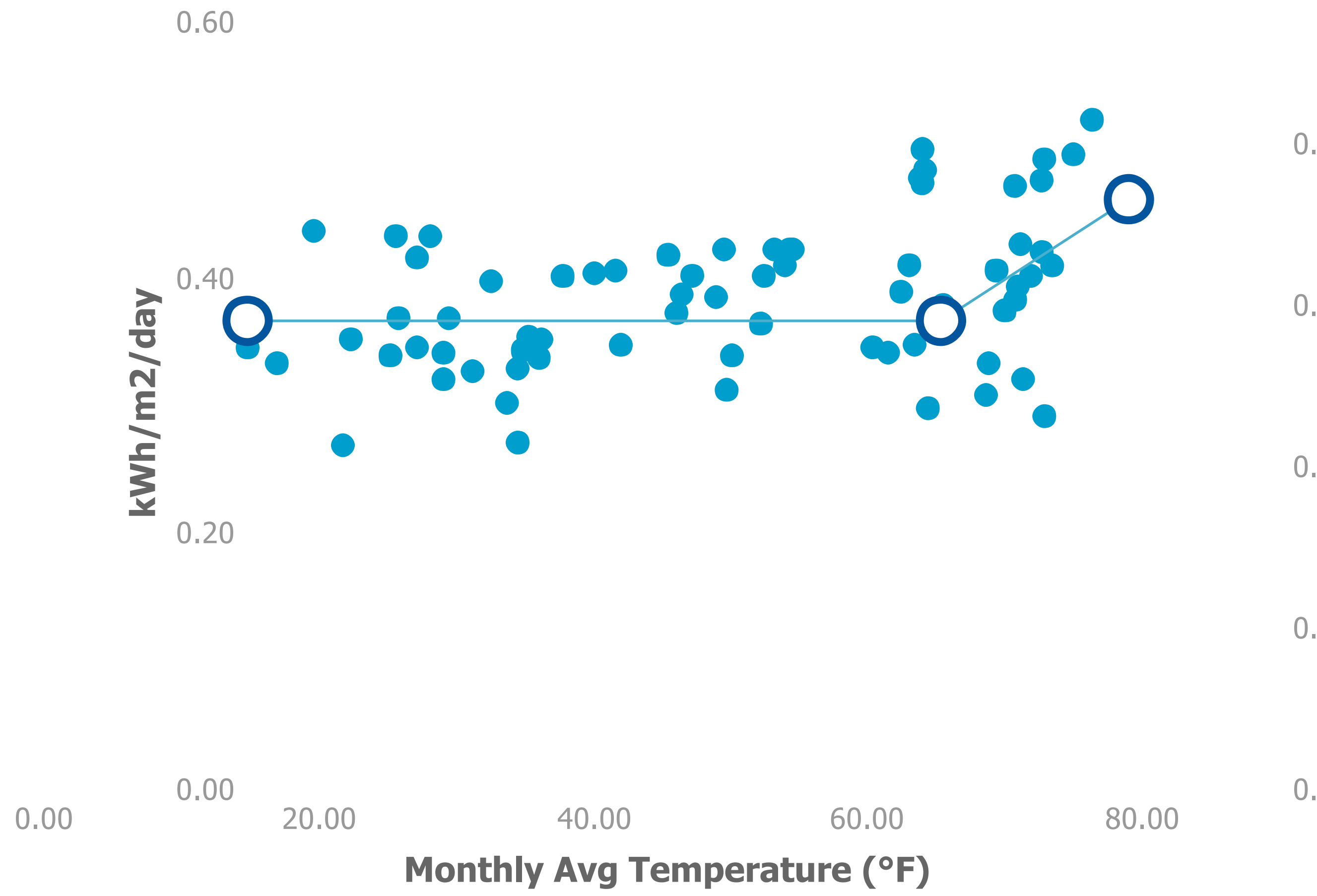


Michigan Union

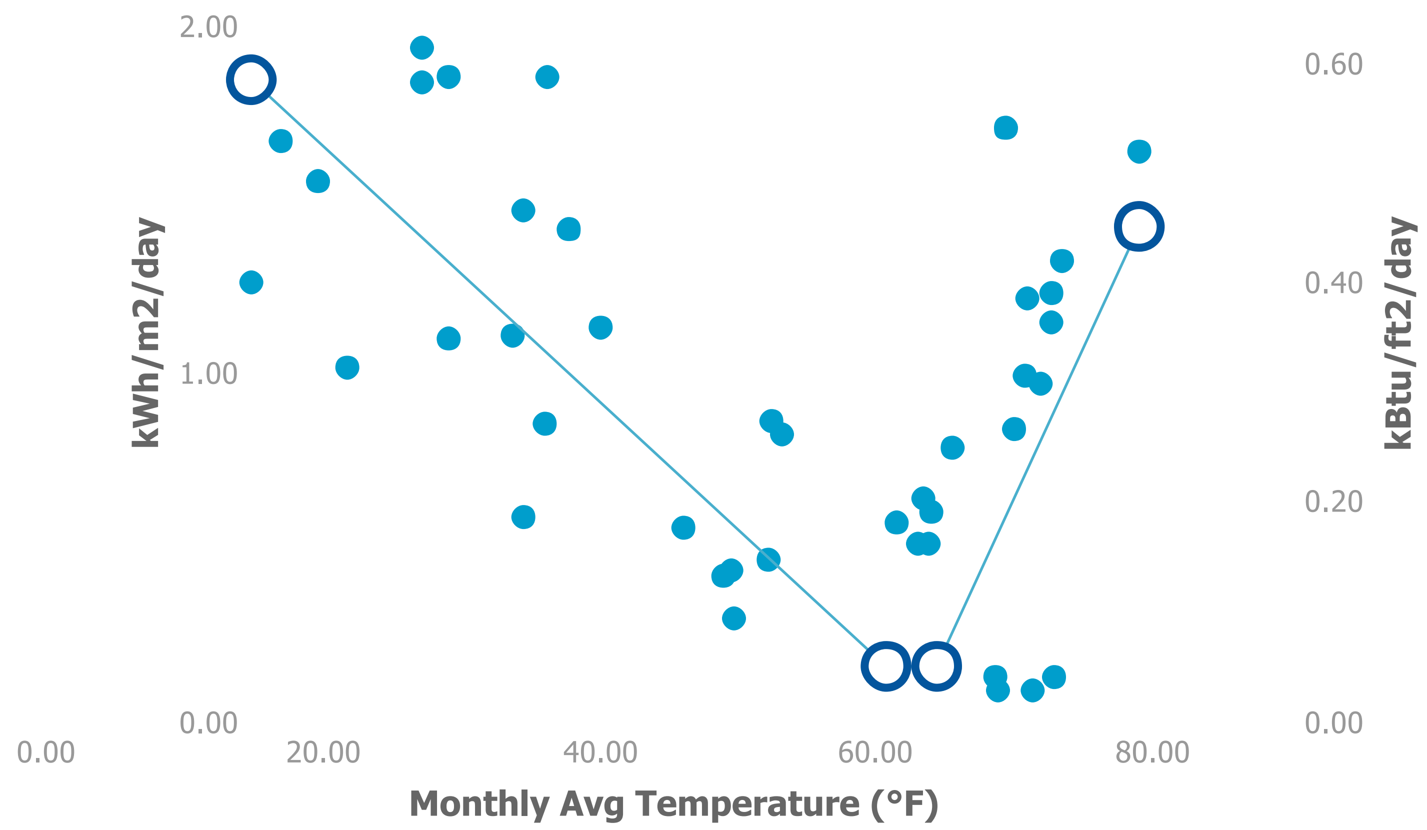
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$120,000

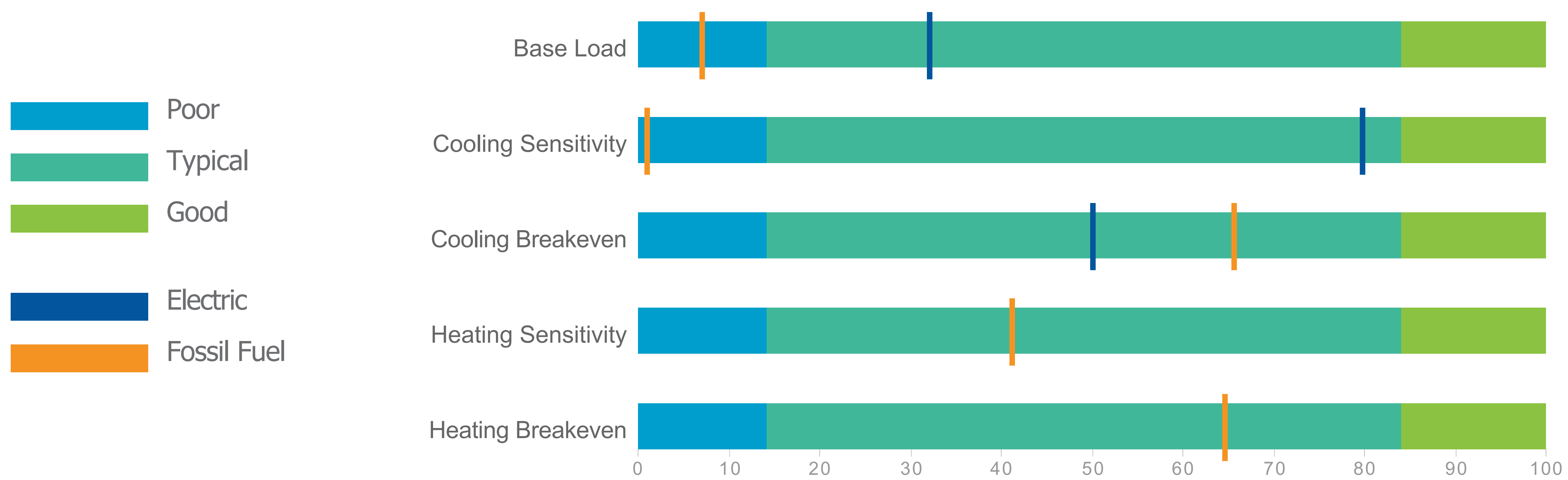
Total Potential Percentage Savings

16%

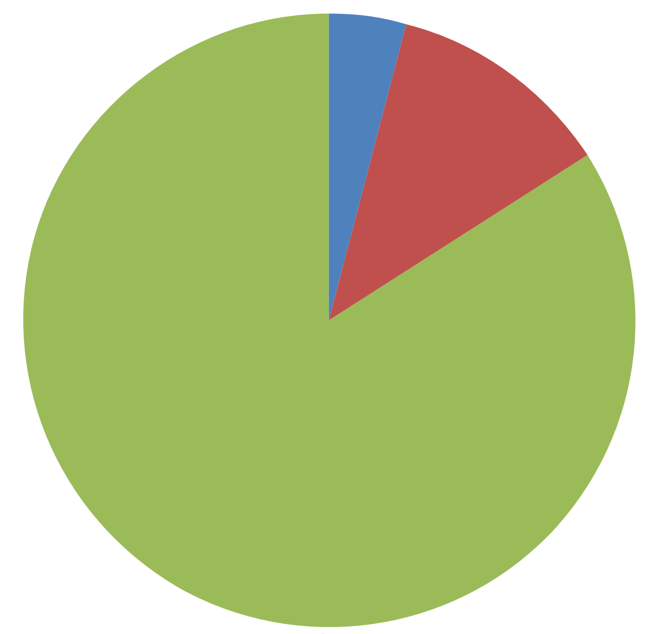
Recommendations

- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Increase cooling system efficiency
- Check fossil fuel base load

Benchmark Metrics



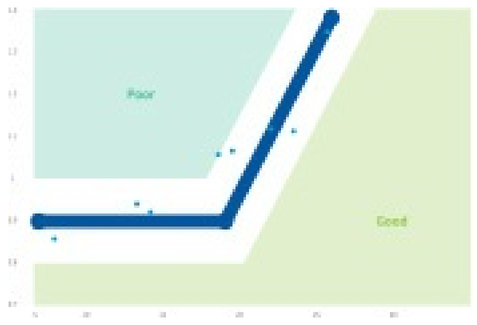
Savings Breakdown



Savings - No/Low Cost Measures (4% / $31000)
Savings - Comprehensive Measures (12% / $89000)
Target Energy Budget (84% / $618267)

Michigan Union

Recommendations



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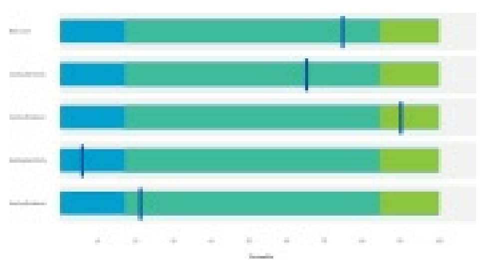

Benchmark Metrics

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Reduce Lighting Load

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Reduce Plug Loads

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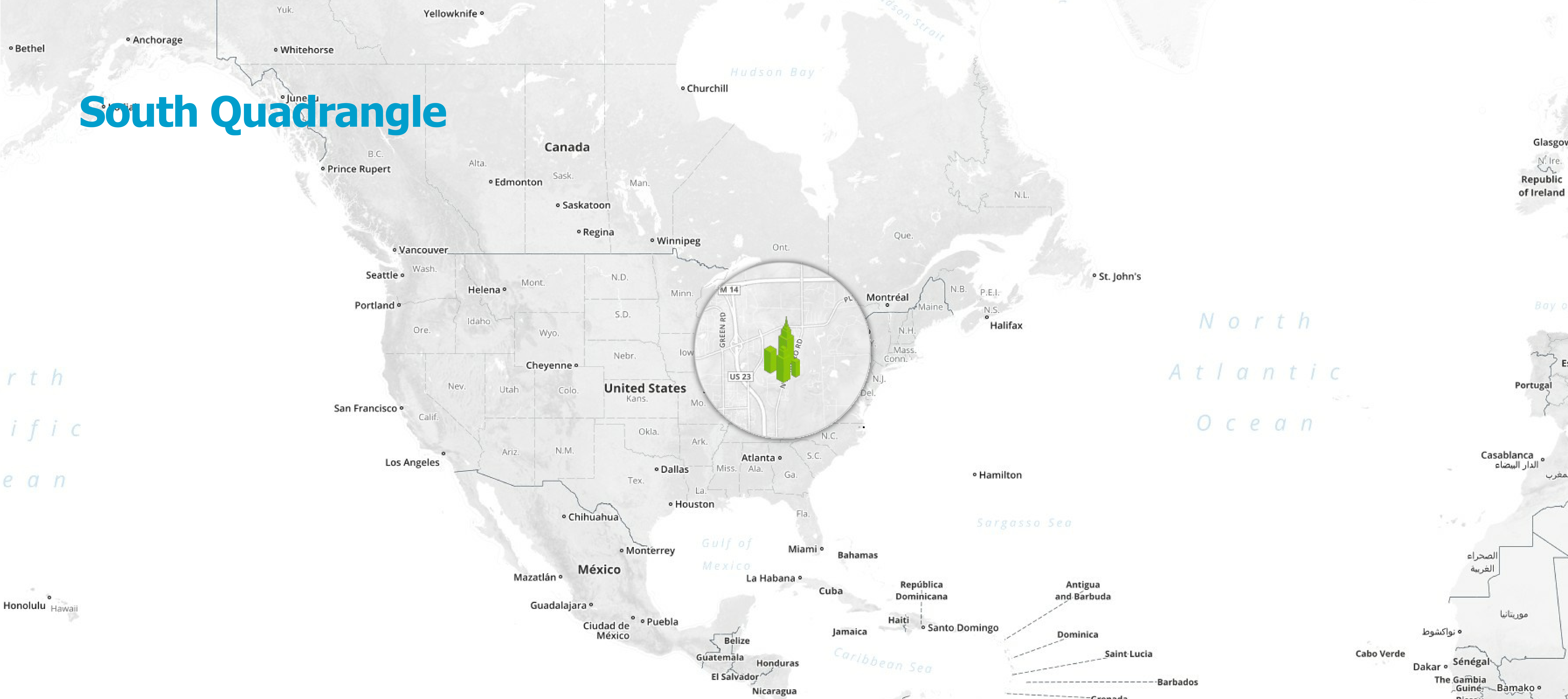
Increase Cooling System Efficiency

The overall performance of the cooling equipment and systems in this building is below the typical performance found in similar buildings. Check all cooling related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Check Fossil Fuel Base Load

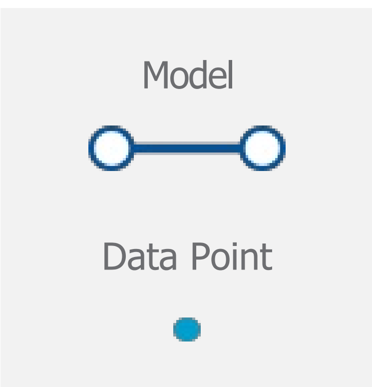
The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

South Quadrangle

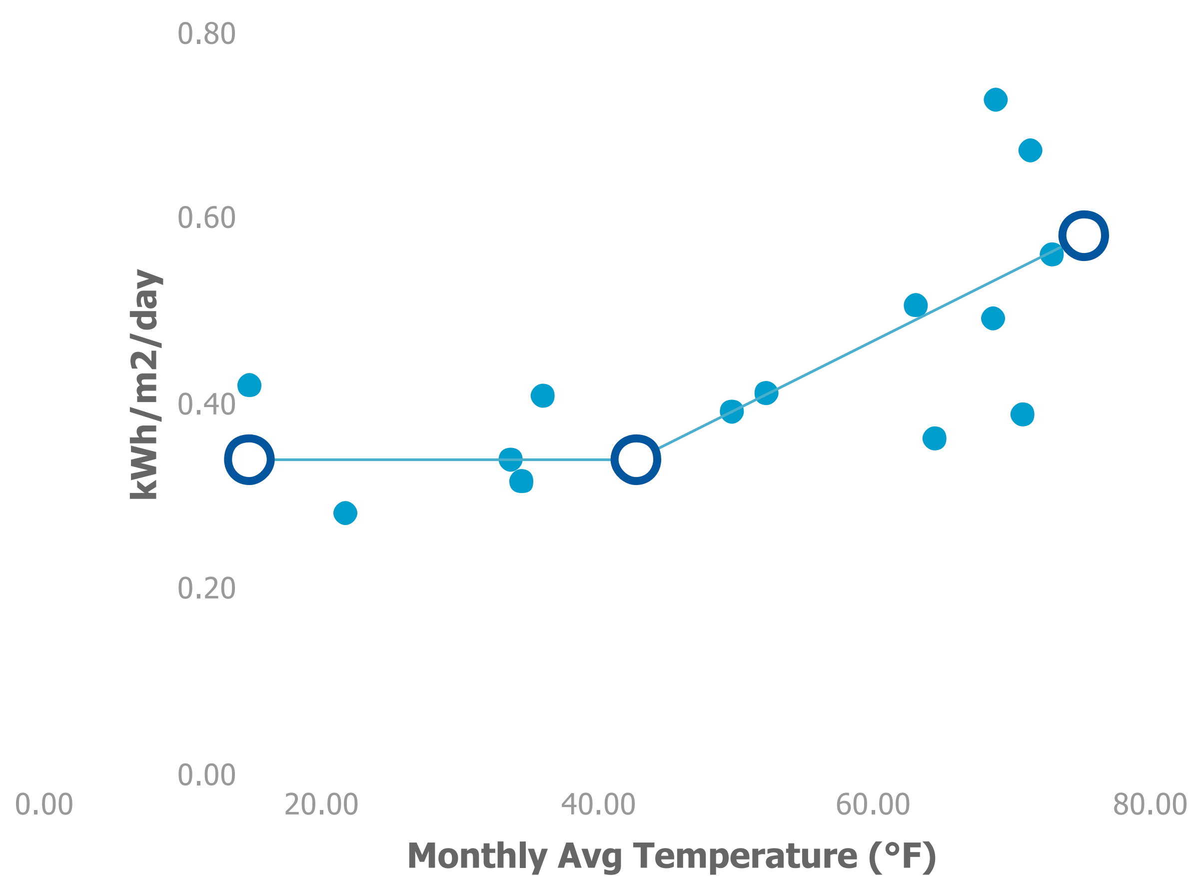


South Quadrangle

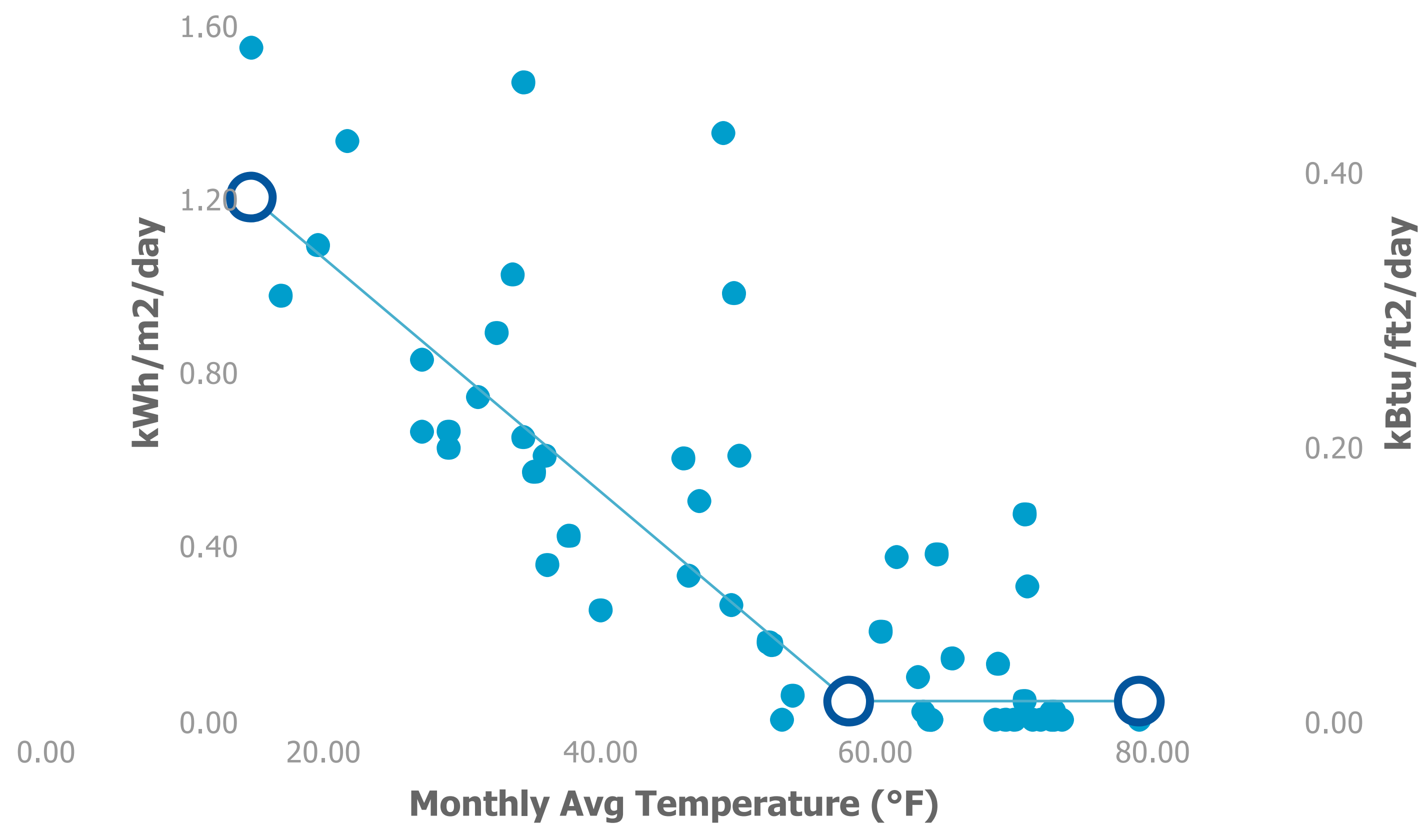
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$130,000

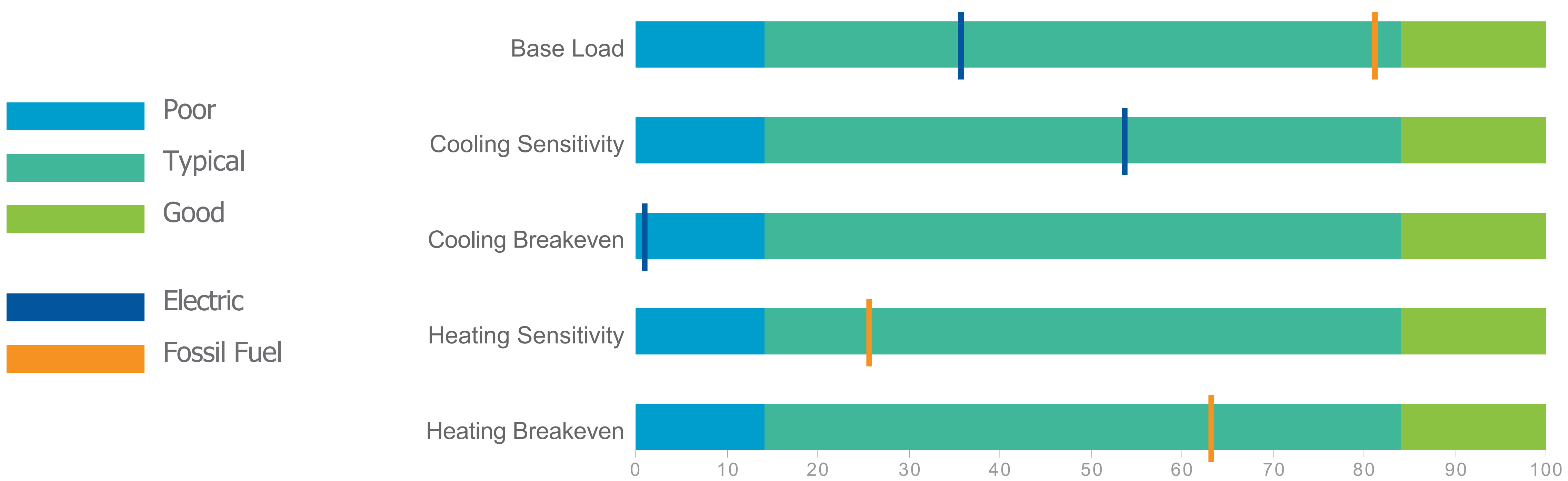
Total Potential Percentage Savings

19%

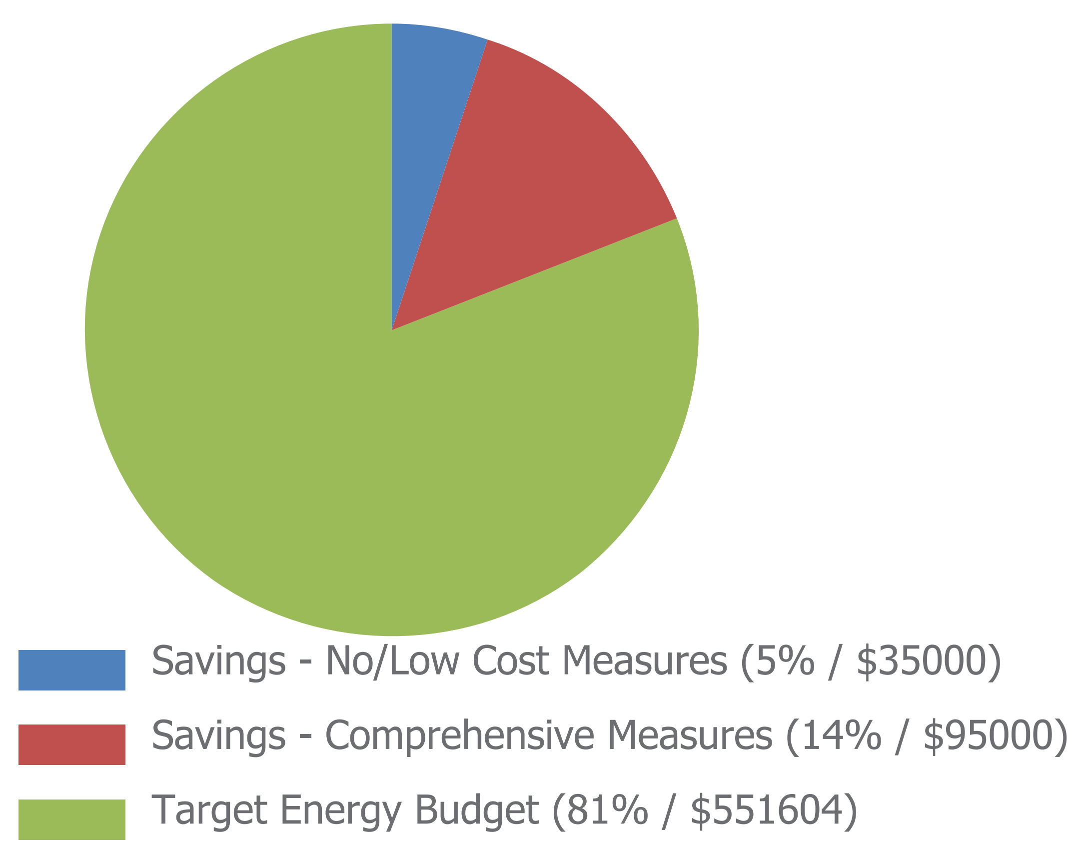
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Increase heating system efficiency

Benchmark Metrics

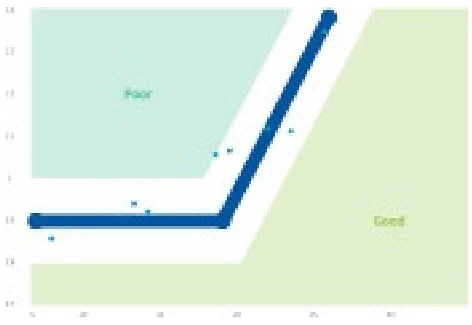


Savings Breakdown



South Quadrangle

Recommendations



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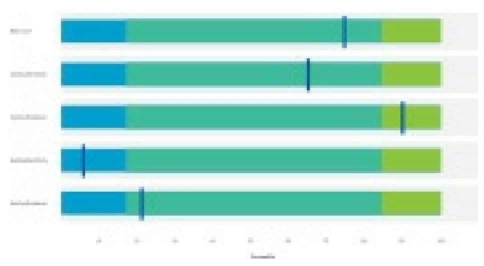

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Increase Cooling Setpoints

Both the occupied and unoccupied setpoints used during the cooling season or on zones that require cooling year round should be checked for opportunities to increase them. Increasing cooling setpoints will reduce the cooling loads of the building and the energy usage of cooling equipment and systems serving them.

Reduce Equipment Schedules

A building automation system should be used to schedule the equipment and systems that operate within a building. Look for opportunities to turn-off equipment during unoccupied times or during times of reduced occupancy and building use. Alarms should be setup and monitored to identify when over-ridden schedules are not returned to normal.

Reduce Lighting Load

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Reduce Plug Loads

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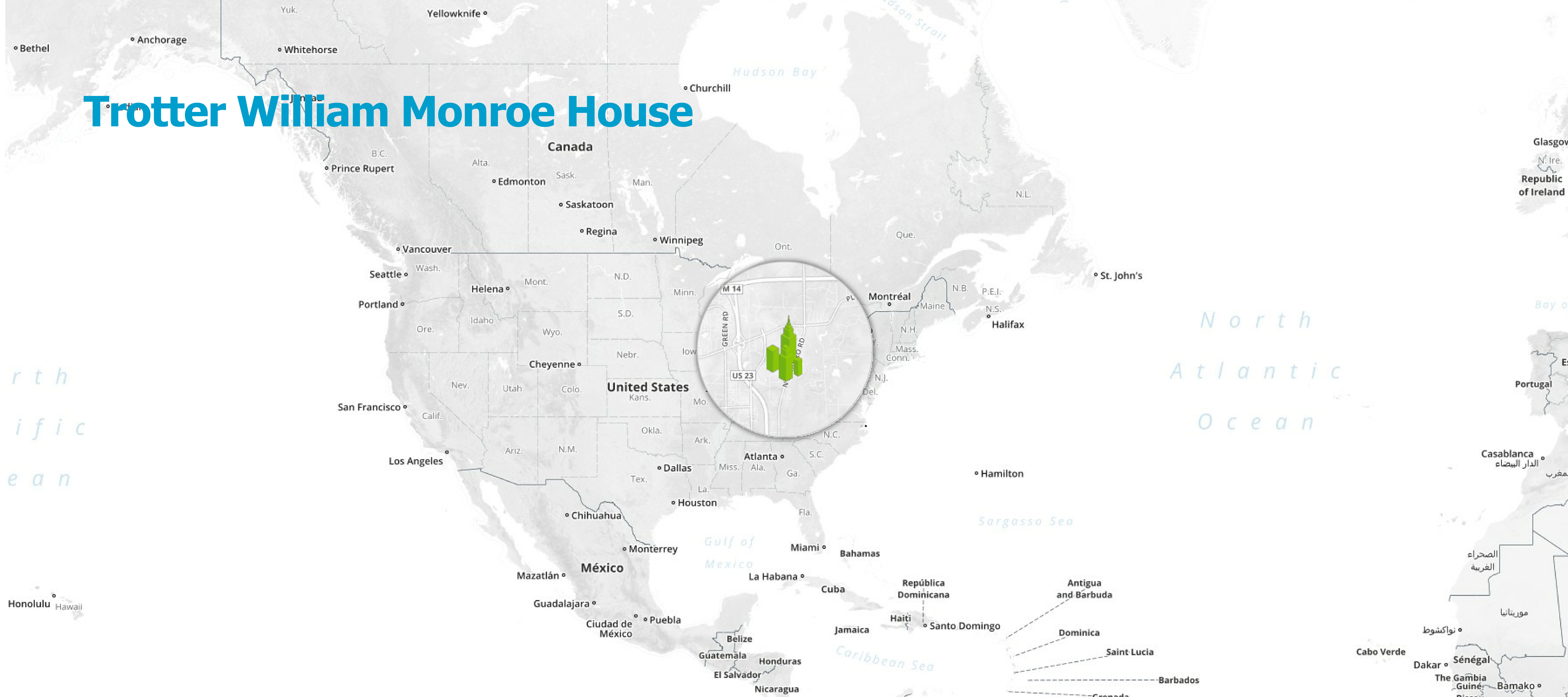
Add Fix Economizers

Fixing or installing air-side conomizers can significantly reduce the energy used to cool a building by bringing in outside air that is cooler and/or dryer than the inside air. This is often referred to as free cooling because there is little to no additional energy needed to use outside air to condition a building. Existing economizers should be checked for proper and efficient operations.

Increase Heating System Efficiency

The overall performance of the heating equipment and systems in this building is below the typical performance found in similar buildings. Check all heating related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Trotter William Monroe House



Trotter William Monroe House

Weather Sensitivity

Total Potential Location Savings

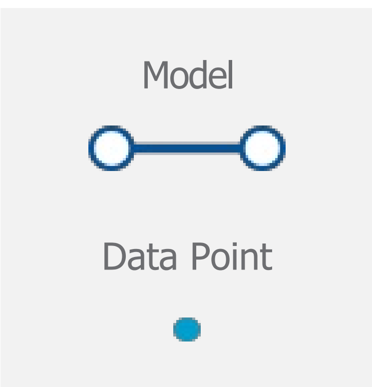
$3,300

Total Potential Percentage Savings

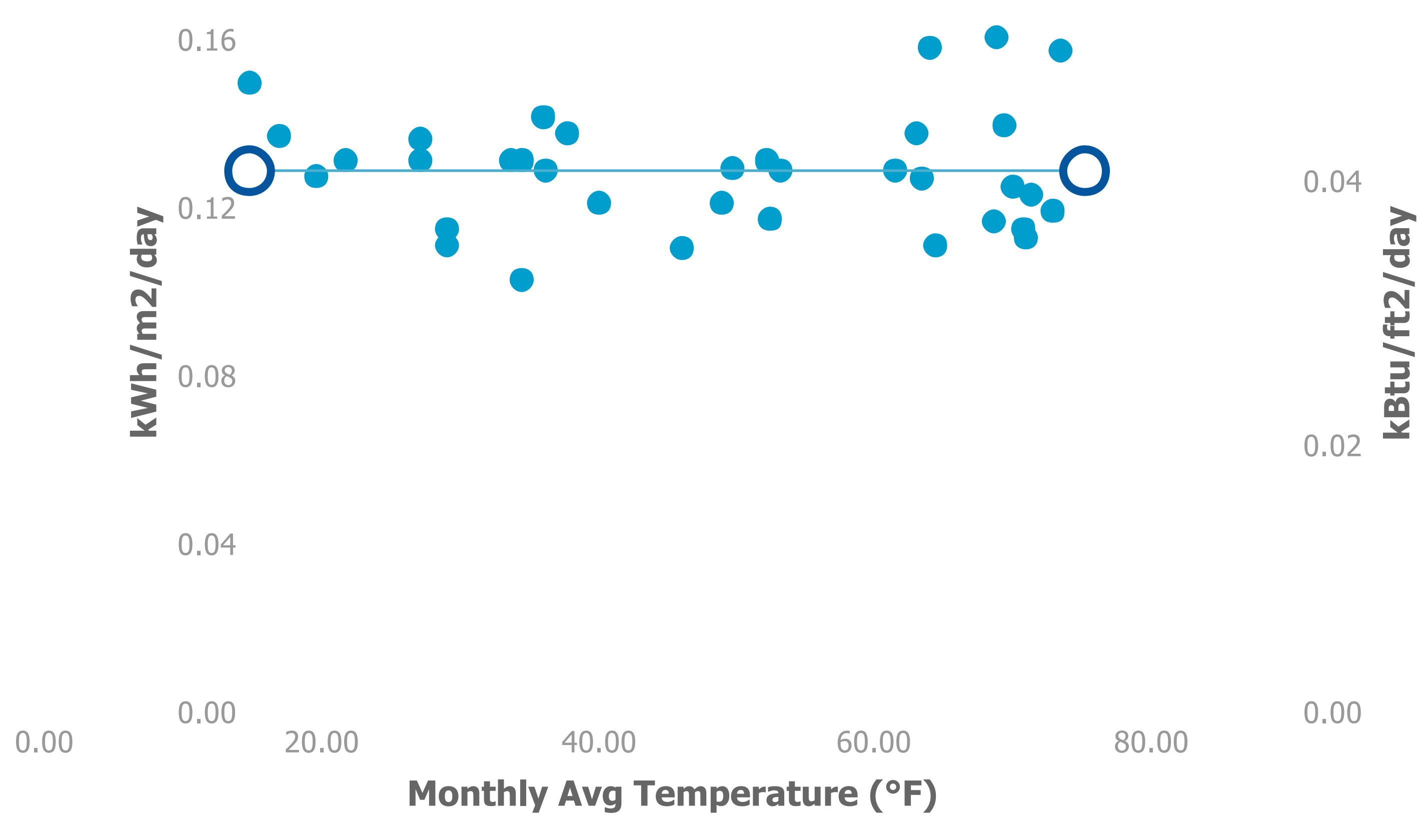
13%

Recommendations

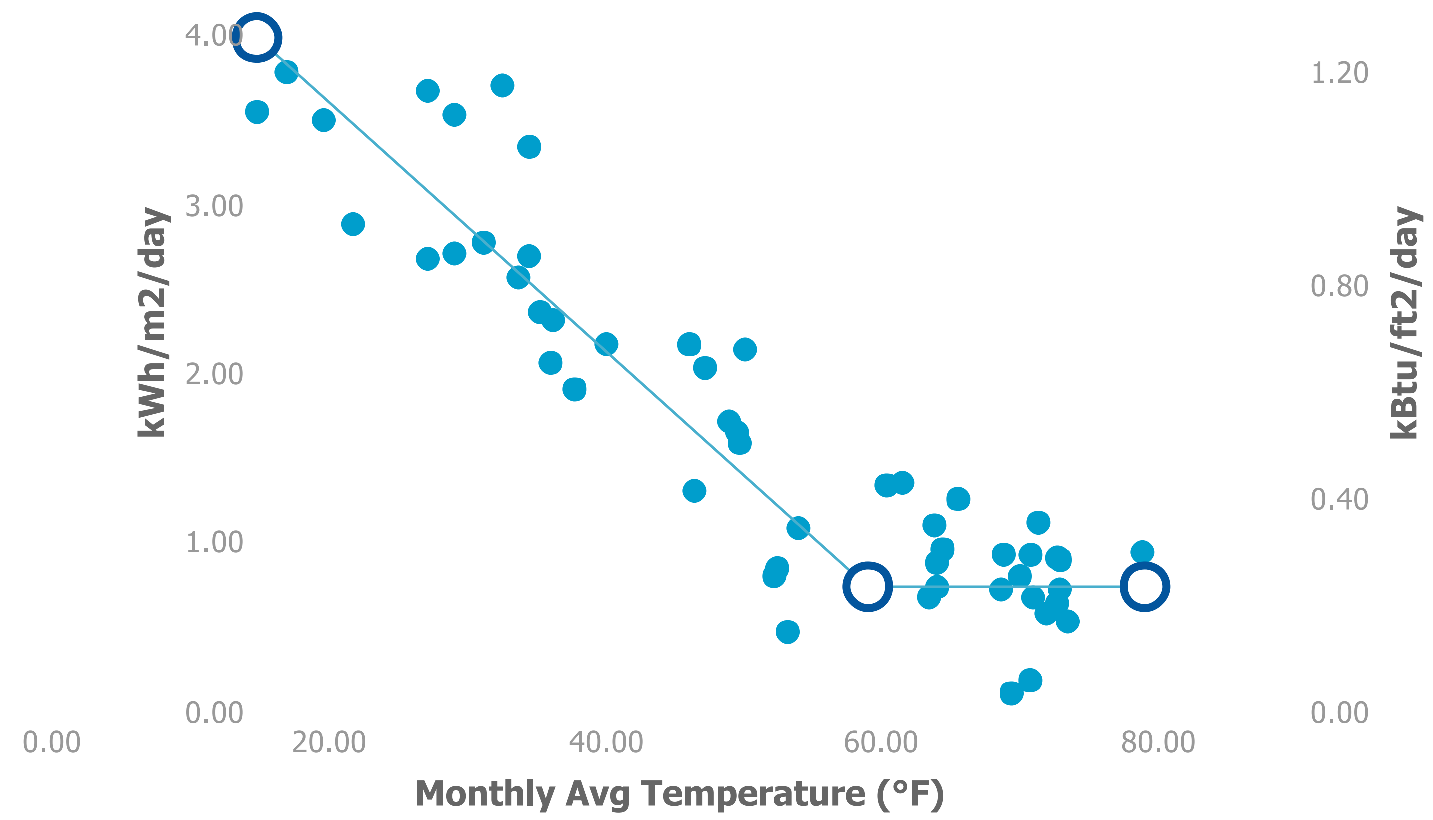
- Increase heating system efficiency
- Check fossil fuel base load



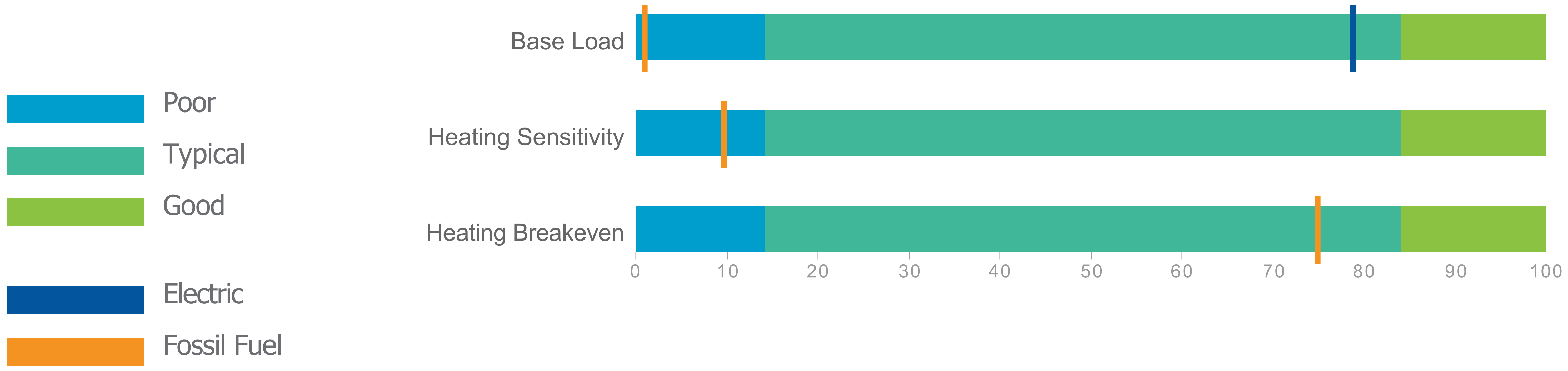
Electric



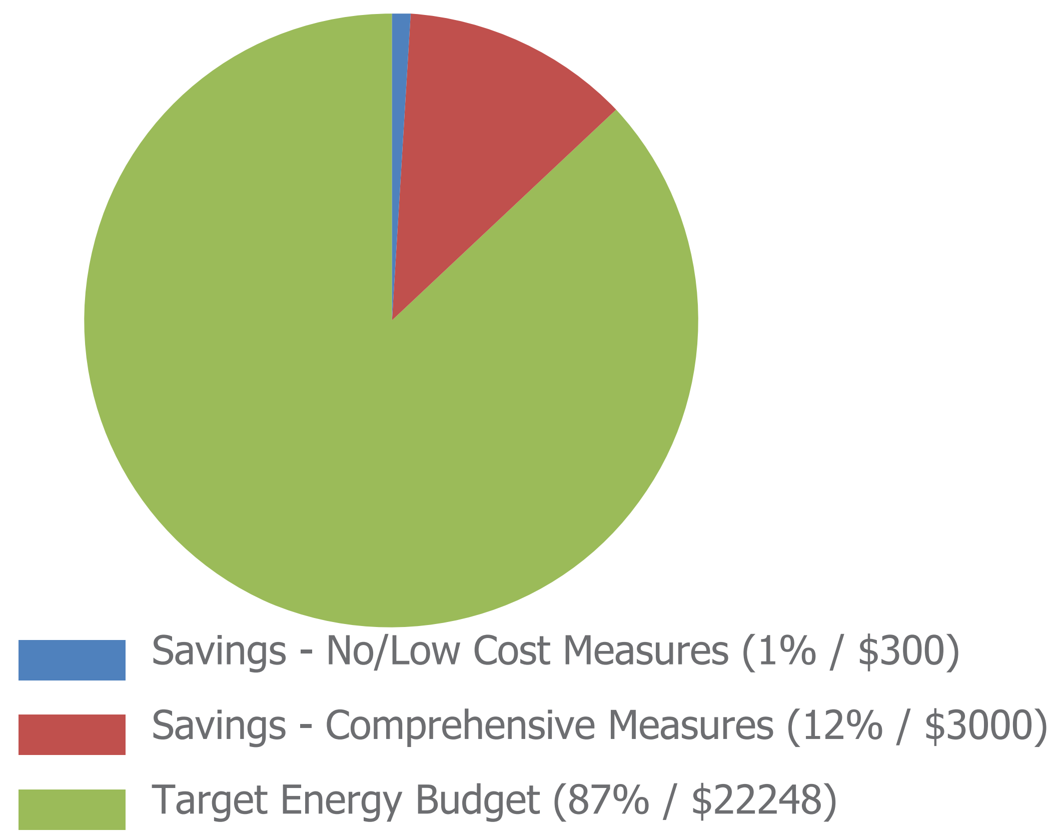
Fossil Fuel



Benchmark Metrics

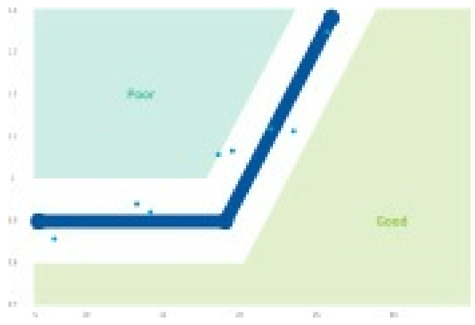


Savings Breakdown



Trotter William Monroe House

Recommendations



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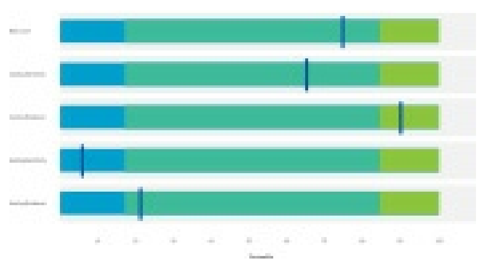

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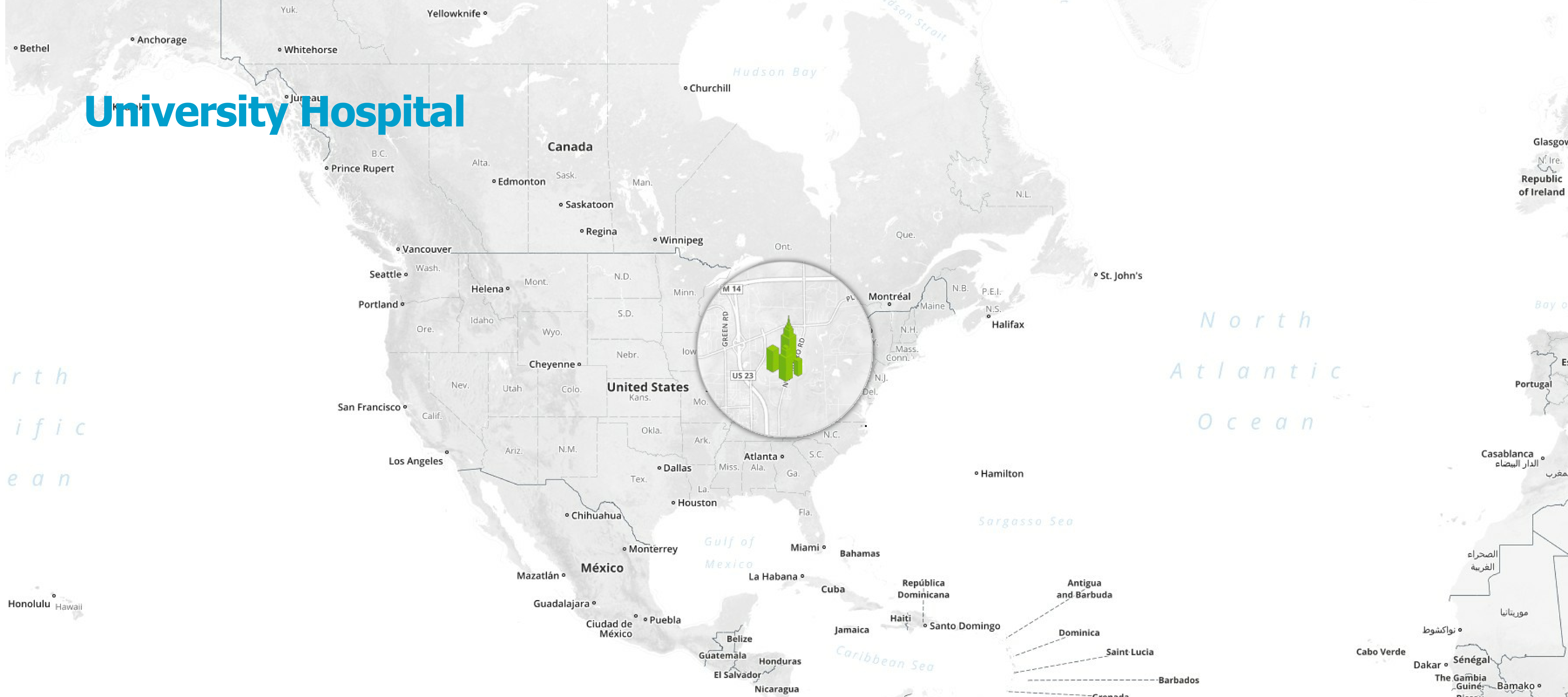
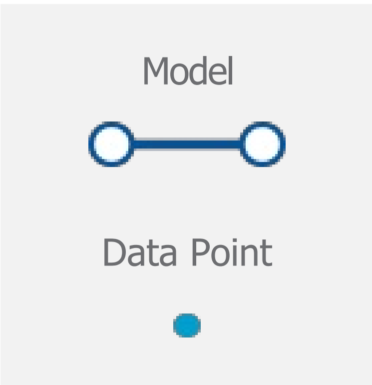
University Hospital

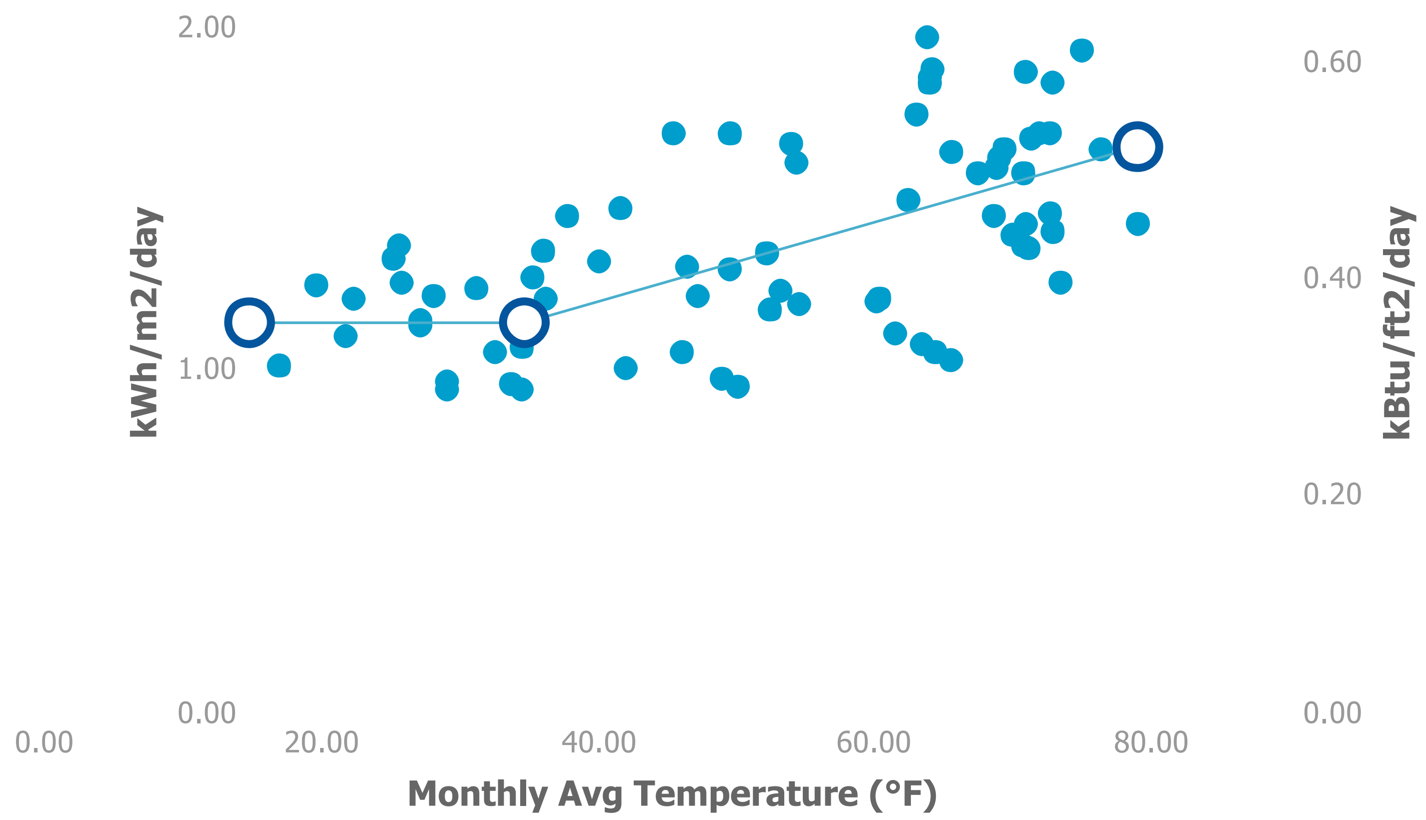


University Hospital

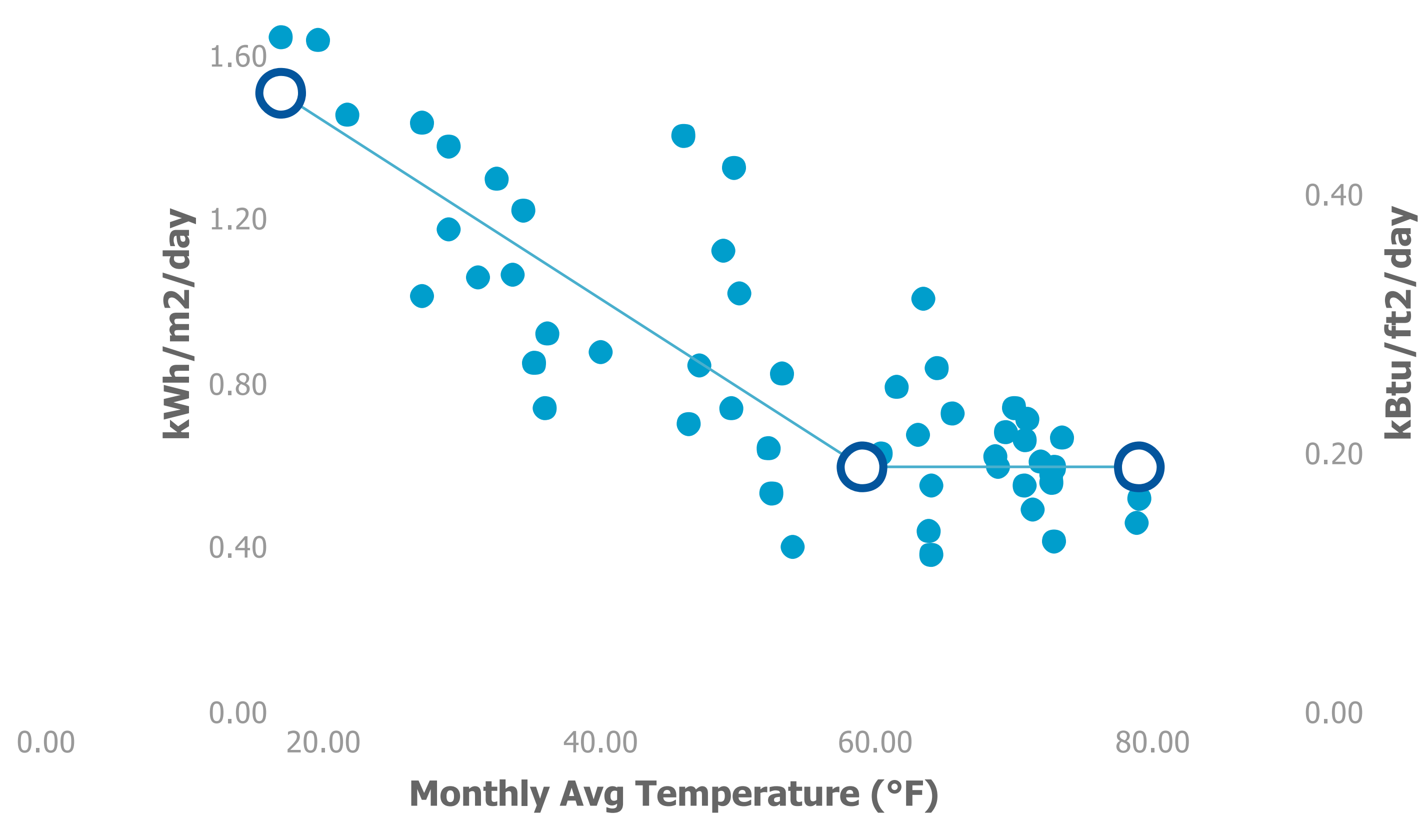
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$700,000

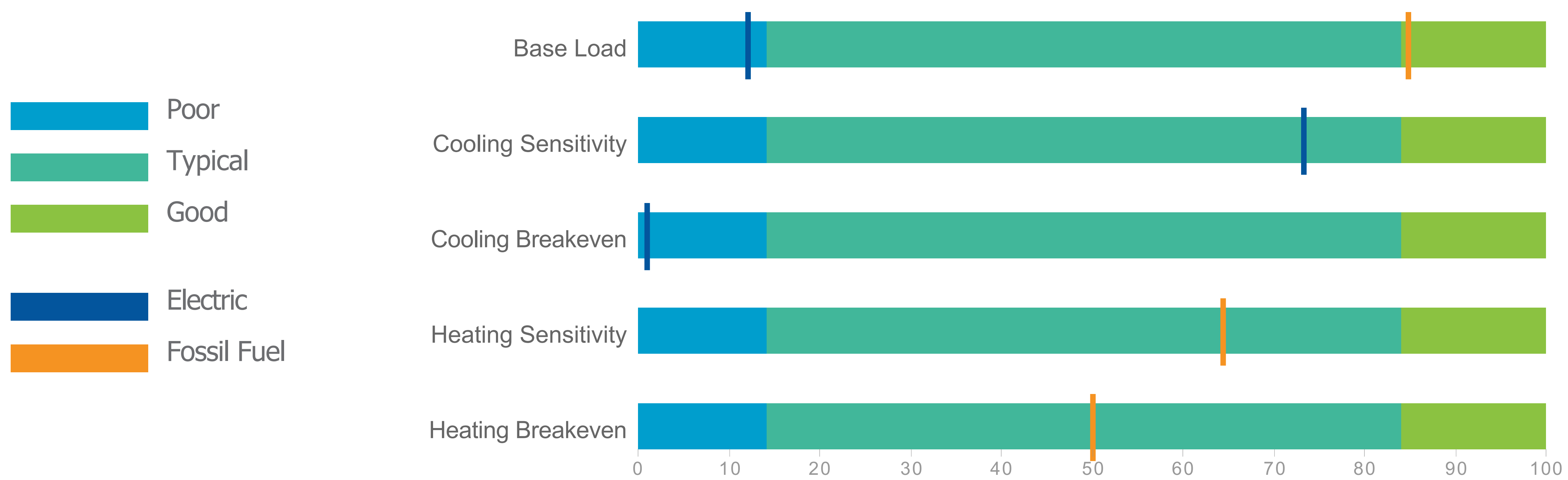
Total Potential Percentage Savings

9%

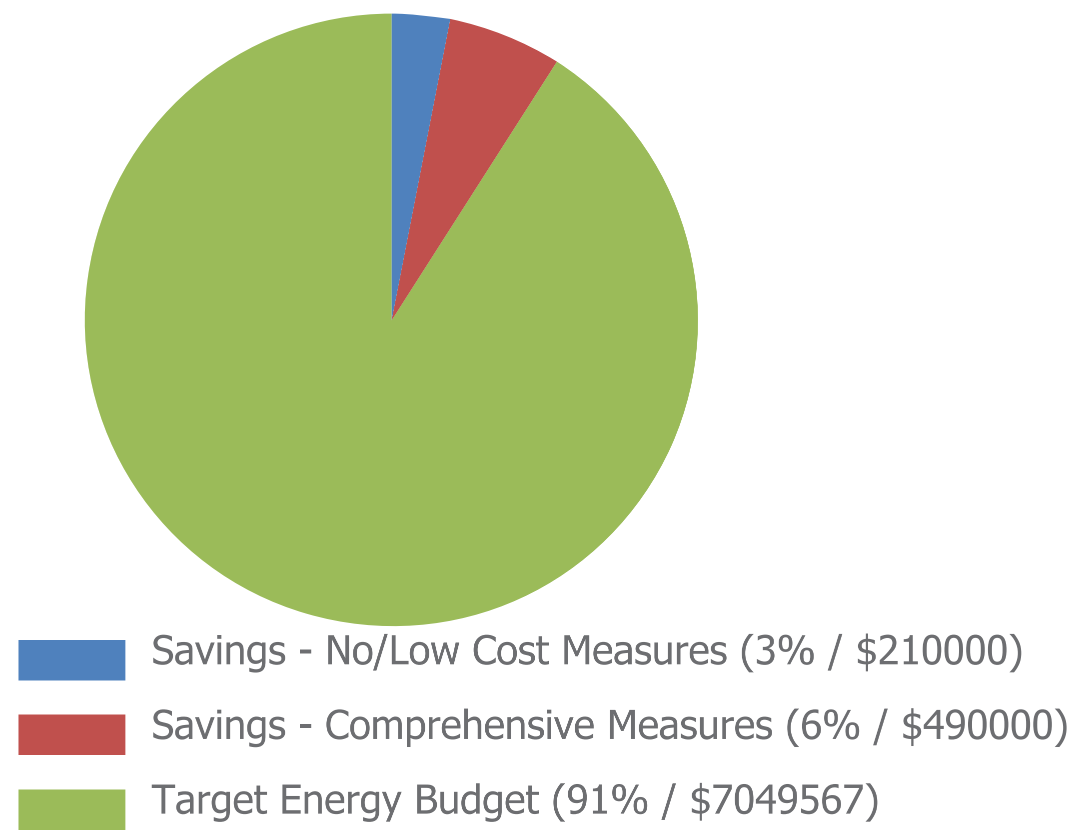
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Decrease heating setpoints
- Decrease ventilation
- Decrease infiltration
- Increase heating system efficiency
- Add wall ceiling insulation

Benchmark Metrics

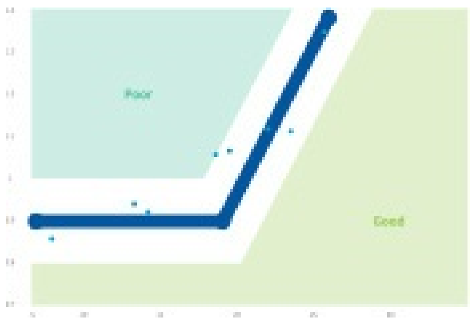


Savings Breakdown



University Hospital

Recommendations



Weather Sensitivity

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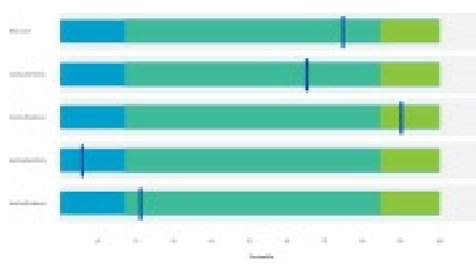

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Increase Cooling Setpoints

Both the occupied and unoccupied setpoints used during the cooling season or on zones that require cooling year round should be checked for opportunities to increase them. Increasing cooling setpoints will reduce the cooling loads of the building and the energy usage of cooling equipment and systems serving them.

Reduce Equipment Schedules

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Reduce Lighting Load

Lighting loads are reduced by improving both the control and efficiency of the lighting and by taking advantagve of natural daylighting whenever possilble. Existing or upgraded controls are used to dim and turn-off the lights appropriately; and lighting efficiency is improved by upgrading the bulbs and fixtures. Daylight utililtzation can be improved with better control of lights that are near existing windows and skylights, and with renovations to the building envelope and internal space configurations.

Reduce Plug Loads

Plug loads include anything that is plugged into standard electric recpetecals or outlets (e.g. personal computers, printers, coffee-makers, other office/lab/light-mfg equipment). Plug load reductions are accomplished by controlling/scheduling them where possible and upgrading the plugged in equipment to newer, more-efficient models.

Add Fix Economizers

Fixing or installing air-side conomizers can significantly reduce the energy used to cool a building by bringing in outside air that is cooler and/or dryer than the inside air. This is often referred to as free cooling because there is little to no additional energy needed to use outside air to condition a building. Existing economizers should be checked for proper and efficient operations.

Decrease Heating Setpoints

Both the occupied and unoccupied setpoints used during the heating season should be checked for opportunities to decrese them. Decreasing heating setpoints will reduce the heating loads of the building and the energy usage of heating equipment and systems serving them.

Decrease Ventilation

Ventilation is the amount of fresh outside air that is brought into a building to provide comfortable and safe conditions for it's occupants. Look for opportunities to reduce the amount of ventilation air, thereby reducing the energy used to to condition and distribute it. Make sure to understand and follow all related building codes.

Decrease Infiltration

Infiltration is the amount of uncontrolled outside air that is brought into a building. Unlike ventilation, it is uncontrolled and generally adds to the overall building cooling and heating loads. Infiltration is reduced with caulking, weather stripping, and upgrades in envelope components (e.g. windows, doors, air intakes & exhausts).

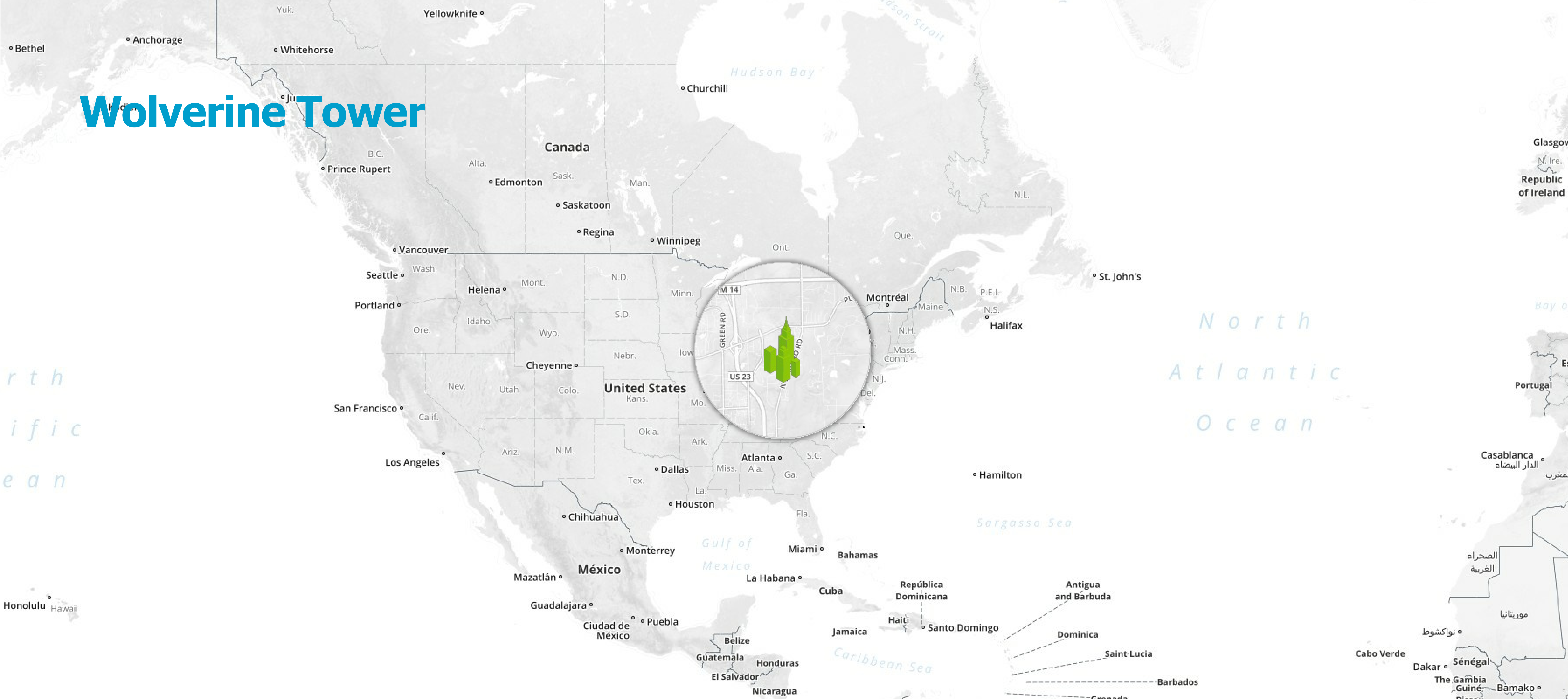
Increase Heating System Efficiency

The overall performance of the heating equipment and systems in this building is below the typical performance found in similar buildings. Check all heating related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Add Wall Ceiling Insulation

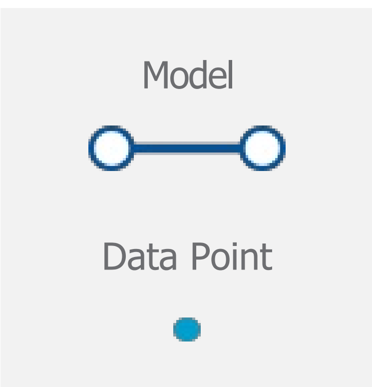
Heating and cooling loads are reduced by adding insulation to building walls, ceilings, and foundations.

Wolverine Tower

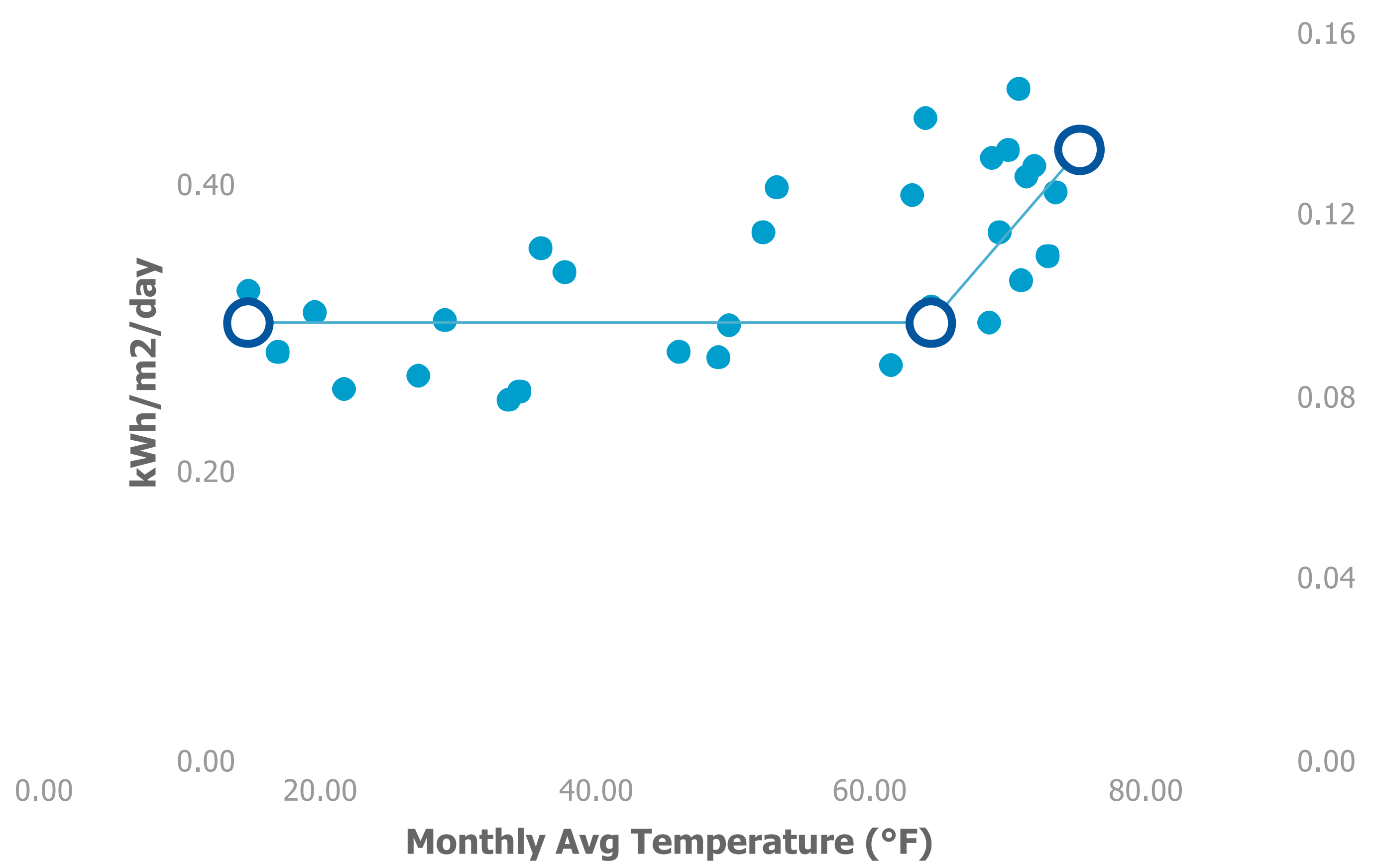


Wolverine Tower

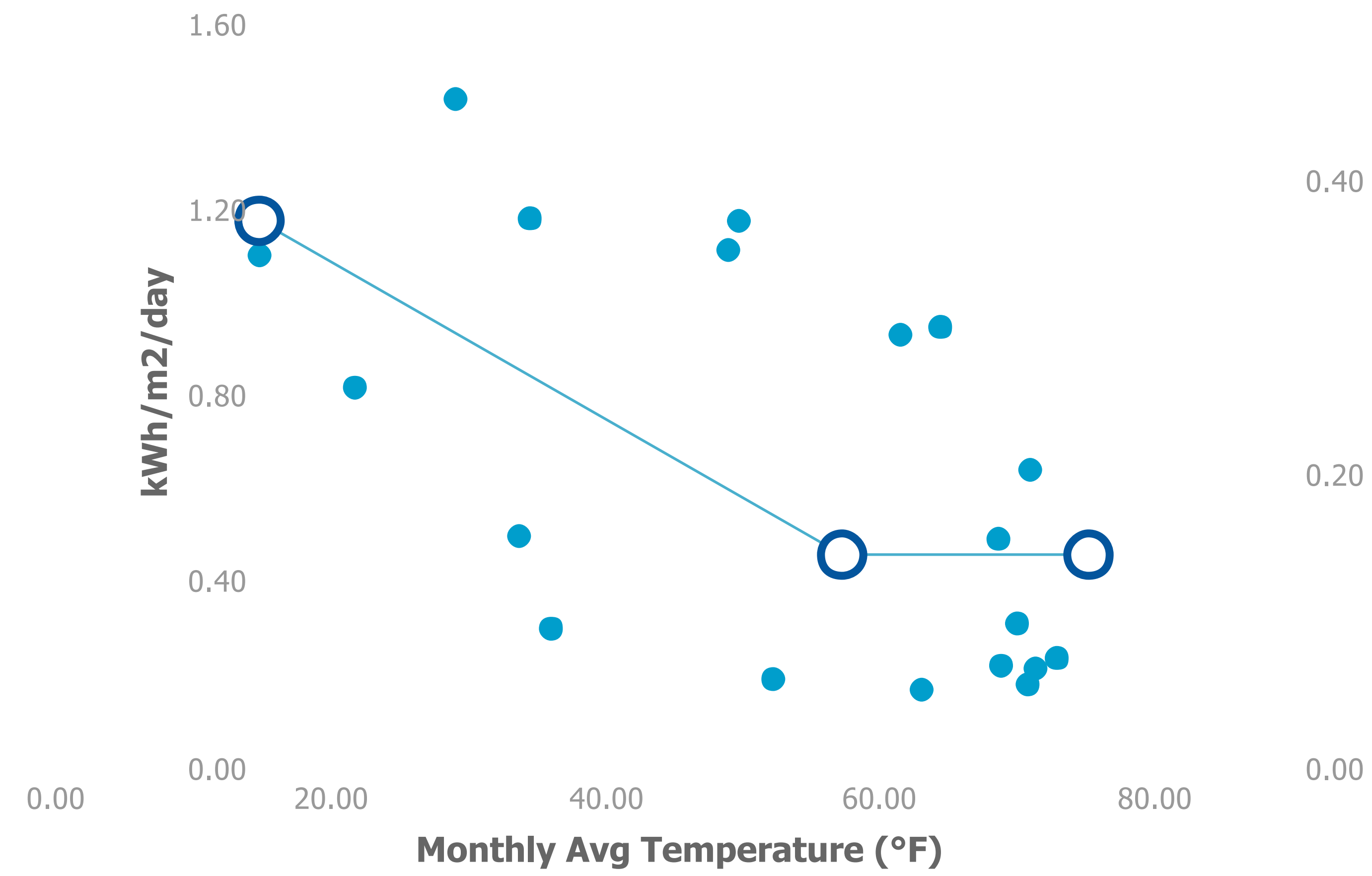
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$19,000

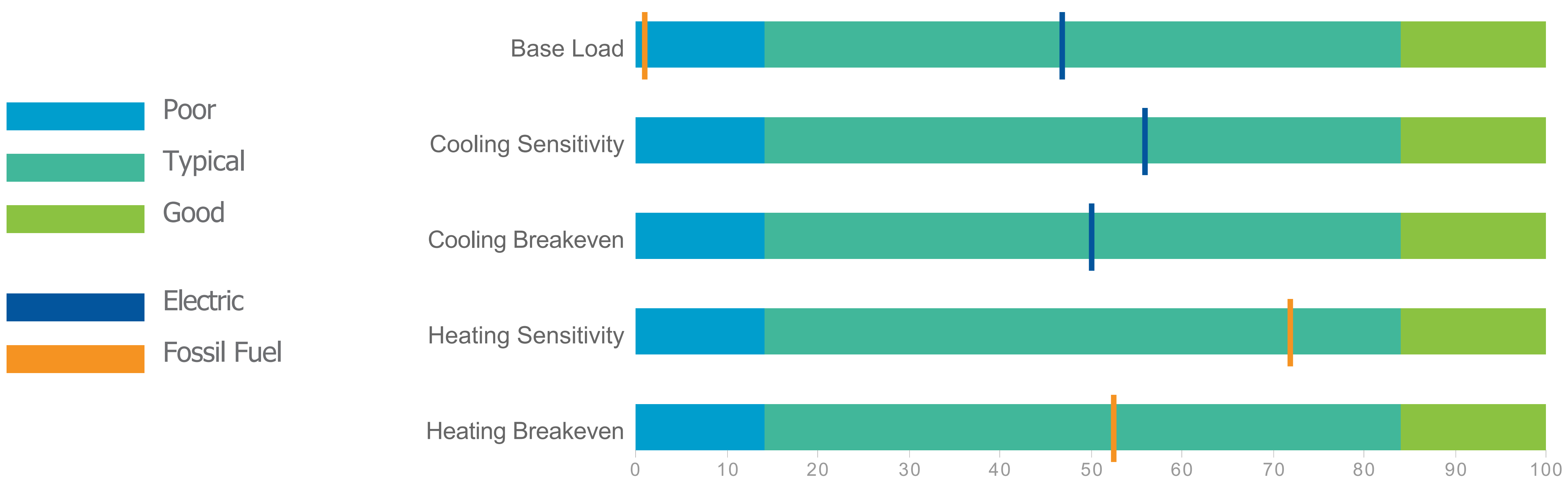
Total Potential Percentage Savings

5%

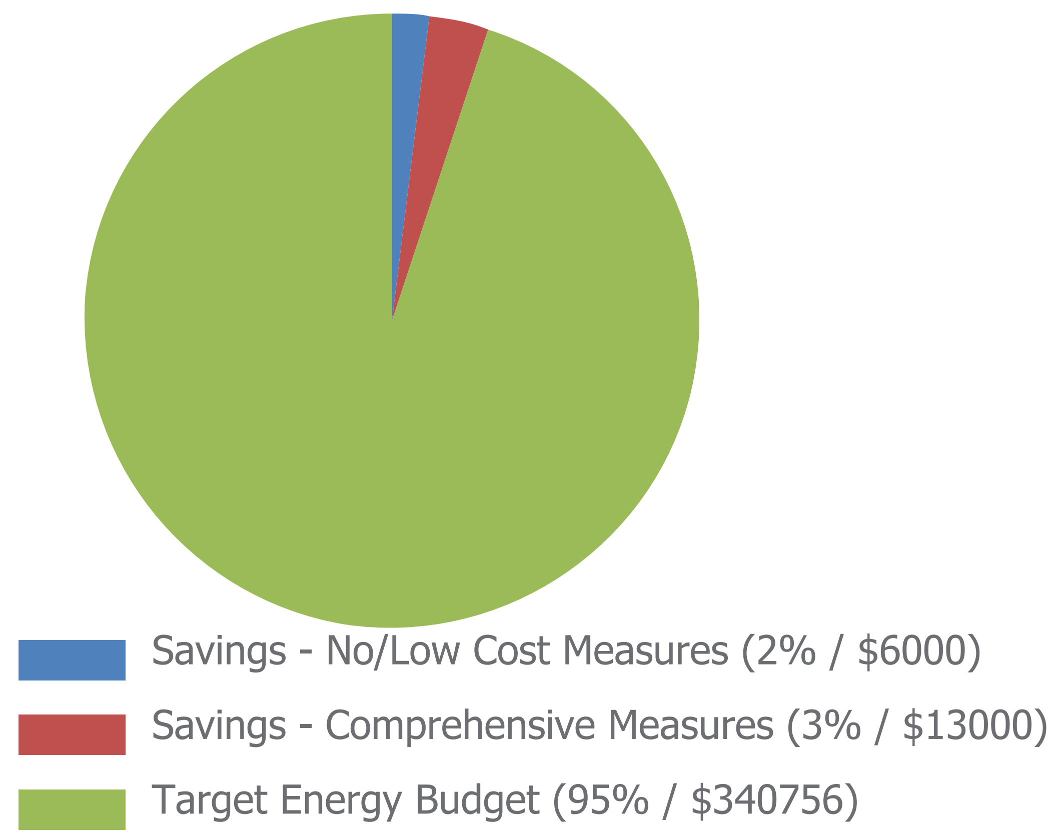
Recommendations

- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Check fossil fuel base load

Benchmark Metrics

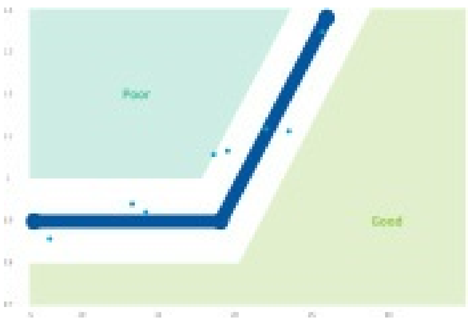


Savings Breakdown



Wolverine Tower

Recommendations



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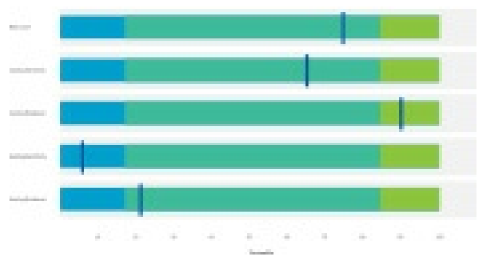

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Check Fossil Fuel Base Load

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Yost Ice Arena

Yost Ice Arena

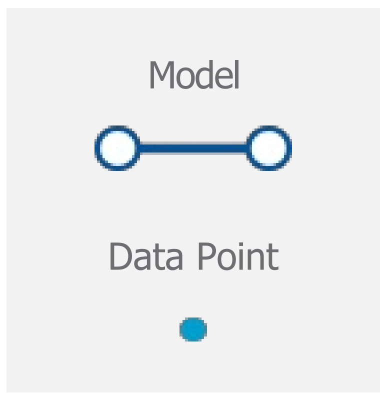
Weather Sensitivity

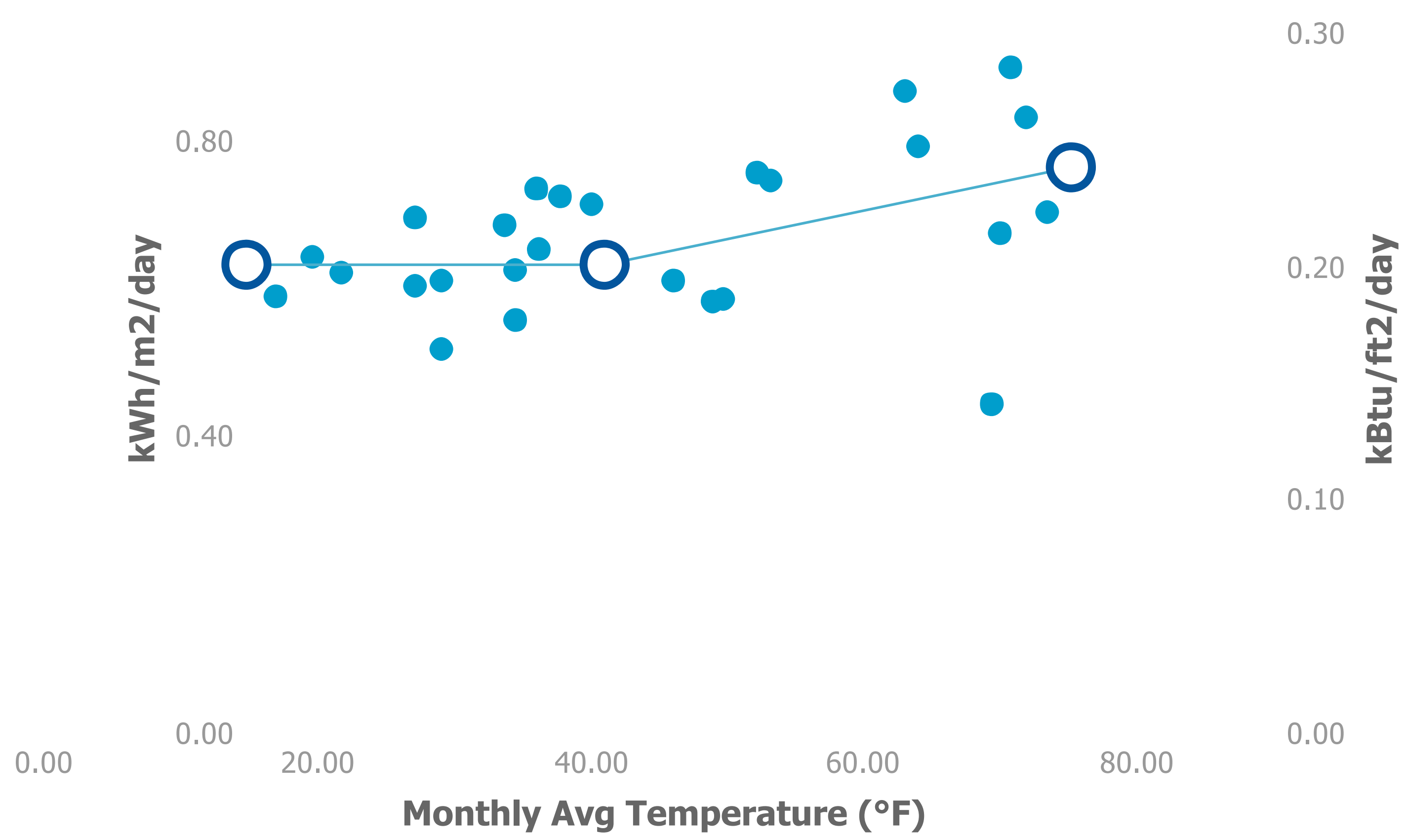
Total Potential Location Savings

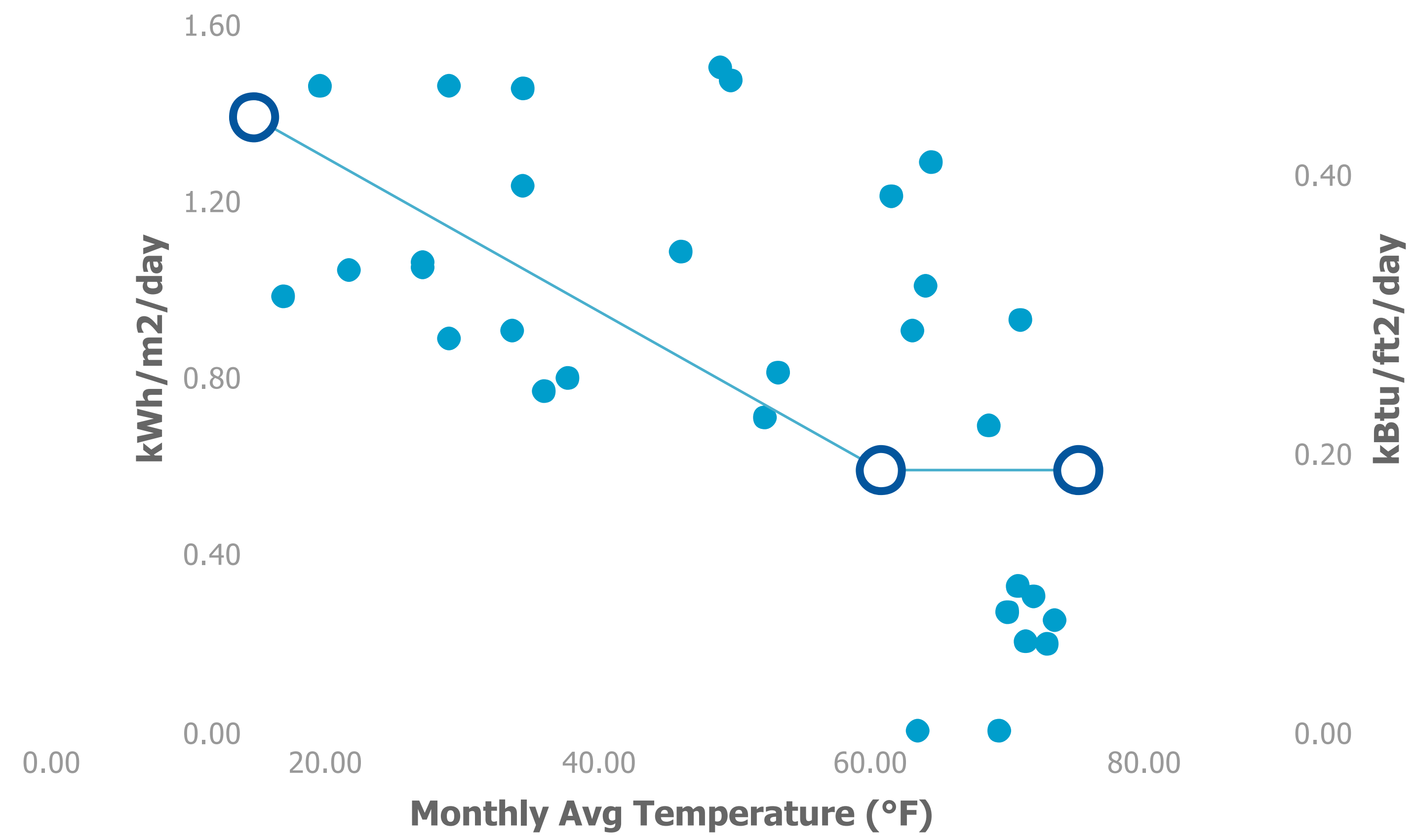
$16,000

Total Potential Percentage Savings

5%



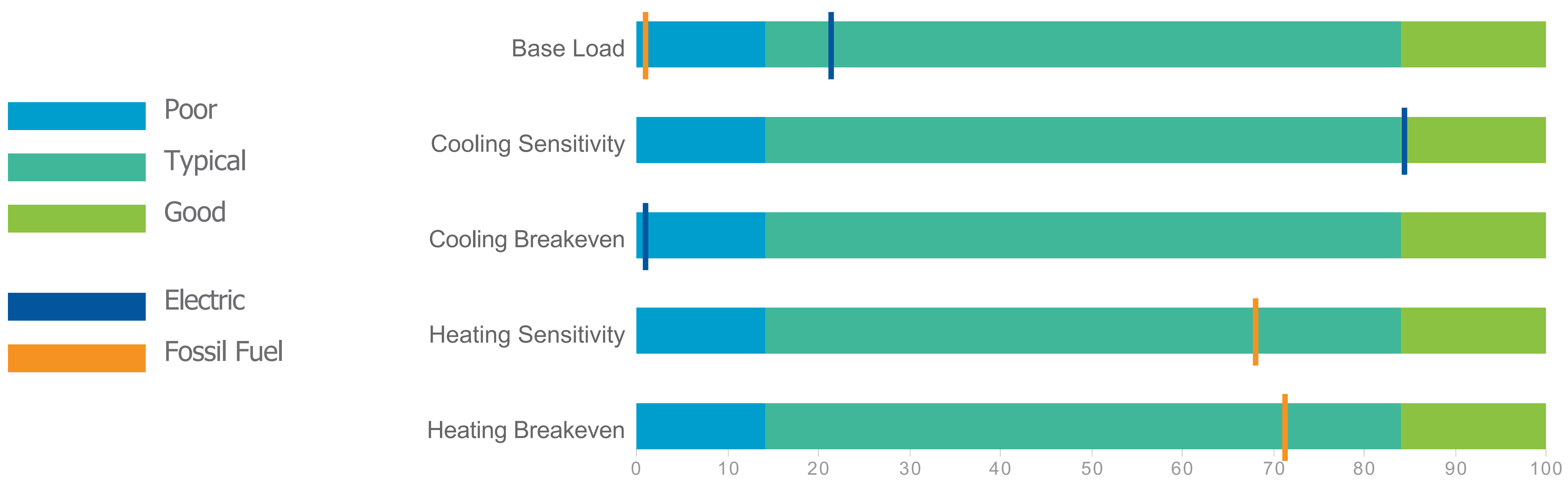




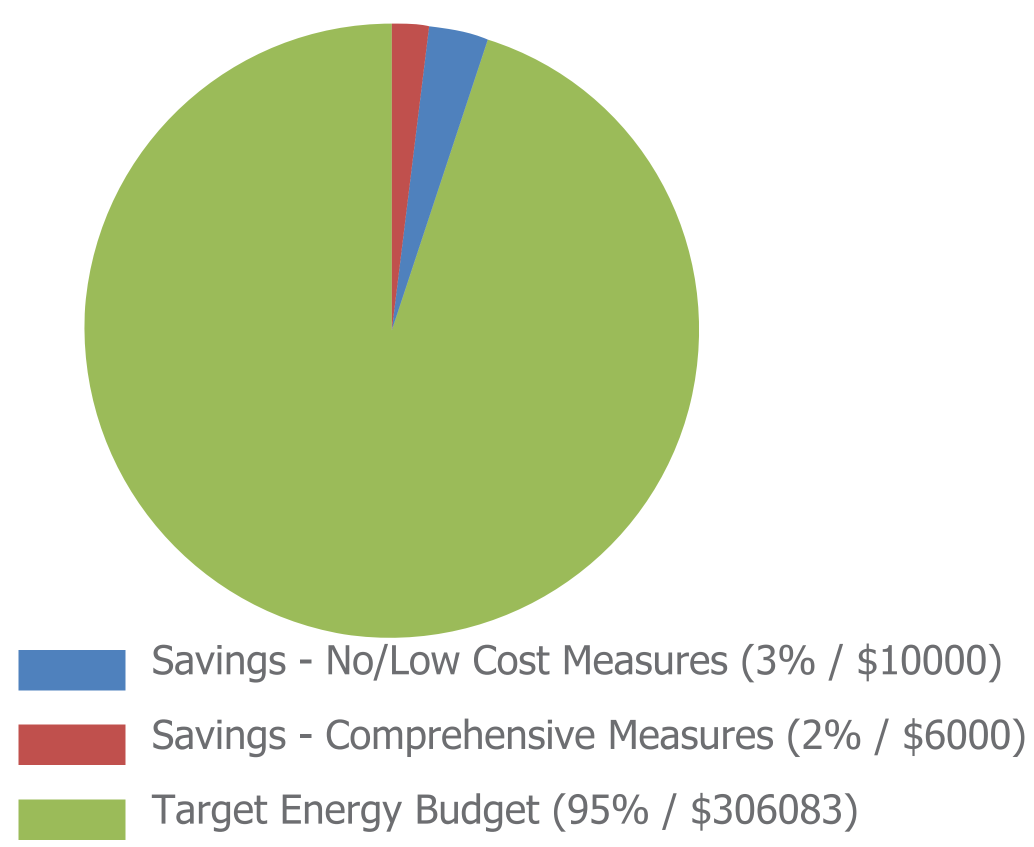
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

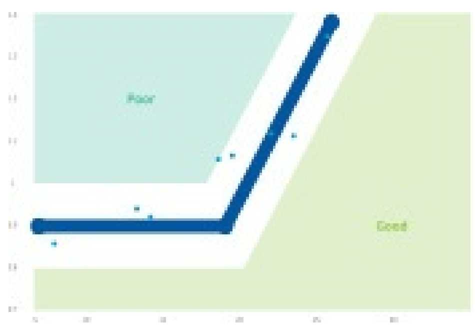


Savings Breakdown



Yost Ice Arena

Recommendations



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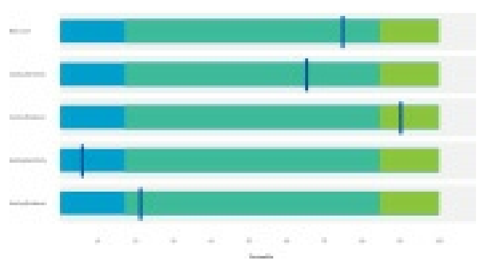

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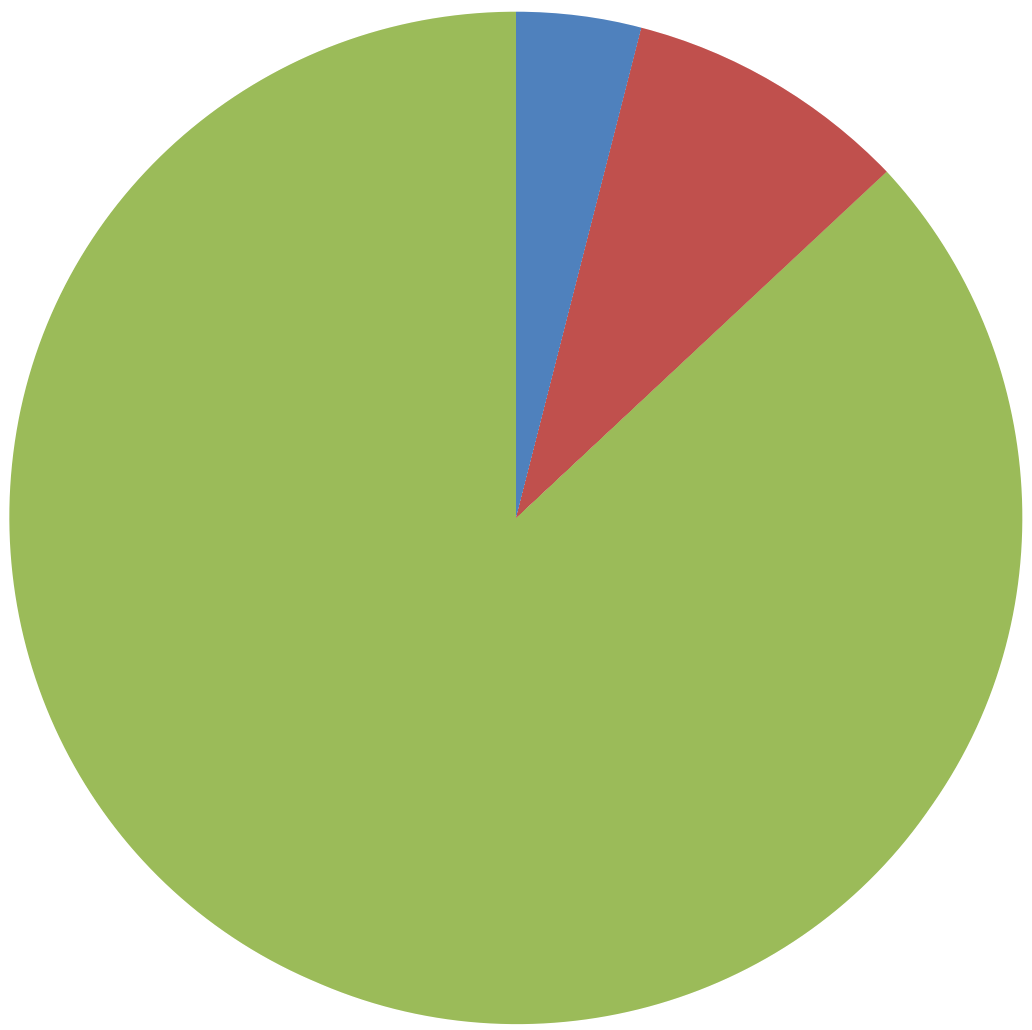
IV. Recommendations

Recommendations

Overall Cost/Low Cost Breakdown



Our LEAN Energy Analysis outlines recommended improvement measures. As the world's leading energy services company, Johnson Controls has the engineering expertise and operational excellence to retrofit your buildings with a customized approach. Where applicable, we identify grants, rebates or utility incentives and, if necessary, leverage financing vehicles to apply to your efficiency project. There is a wide spectrum of improvements reviewed with this analysis, ranging from low cost operational adjustment like decreasing setpoints, to improvements requiring construction-related activity like adding insulation and economizers. Additionally, while some recommendations are specific, others are more general, like reducing plug loads. Johnson Controls has the expertise to address any and all improvements. We want to help you engage and educate your building occupants because we know they can make a real difference in your energy efficiency success.

http://www.johnsoncontrols.com/content/us/en/products/building_efficiency/building/contact_us.html

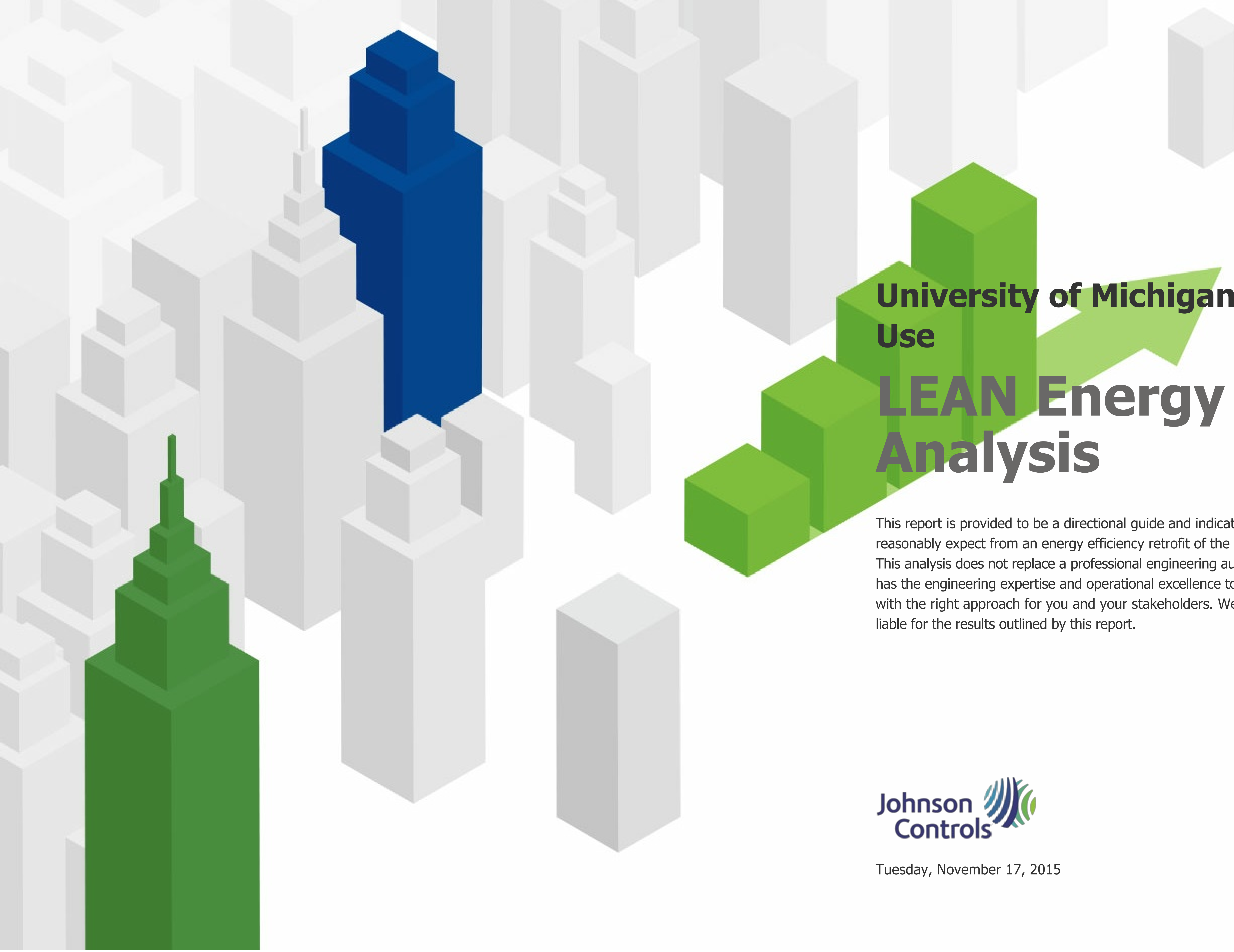
Overall Potential Savings

$1,630,300

Overall Potential Percentage Savings

13%

APPENDIX G-2: Lean Analysis Results from Mixed-Use Buildings at University



University of Michigan - Mixed Use

LEAN Energy Analysis

This report is provided to be a directional guide and indication of what you could reasonably expect from an energy efficiency retrofit of the identified buildings. This analysis does not replace a professional engineering audit. Johnson Controls has the engineering expertise and operational excellence to retrofit your buildings with the right approach for you and your stakeholders. We should not be held liable for the results outlined by this report.

Tuesday, November 17, 2015

Overview

Individual Facilities

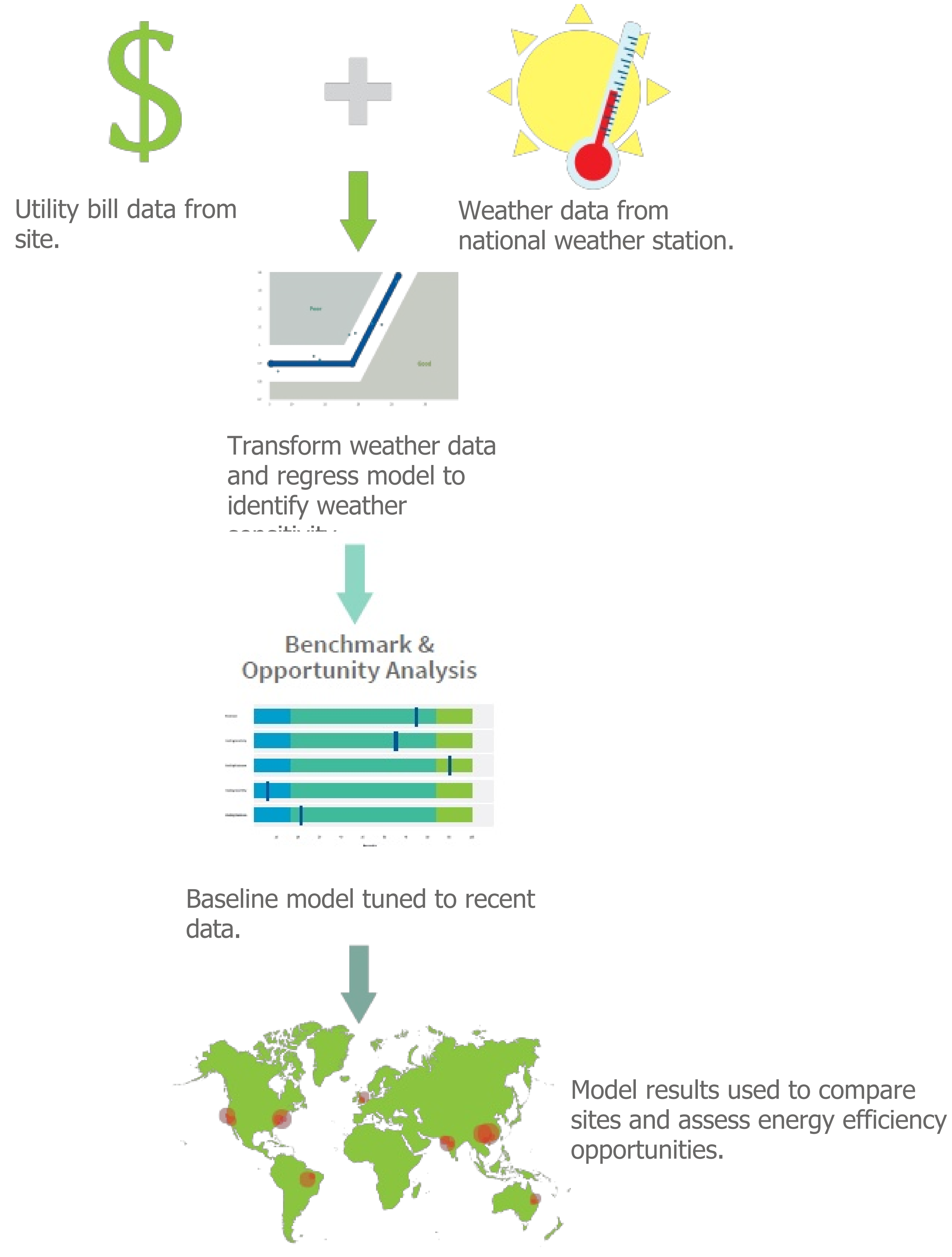
I. Introduction

What is LEAN Energy Analysis?

LEAN Energy Analysis provides building owners and managers visibility into the performance of their buildings and information to make informed decisions on where to target energy efficiency efforts. The performance of each building is benchmarked against similar buildings to identify energy efficiency opportunities. Results from a LEAN Energy Analysis help to target and focus further energy audits and studies.

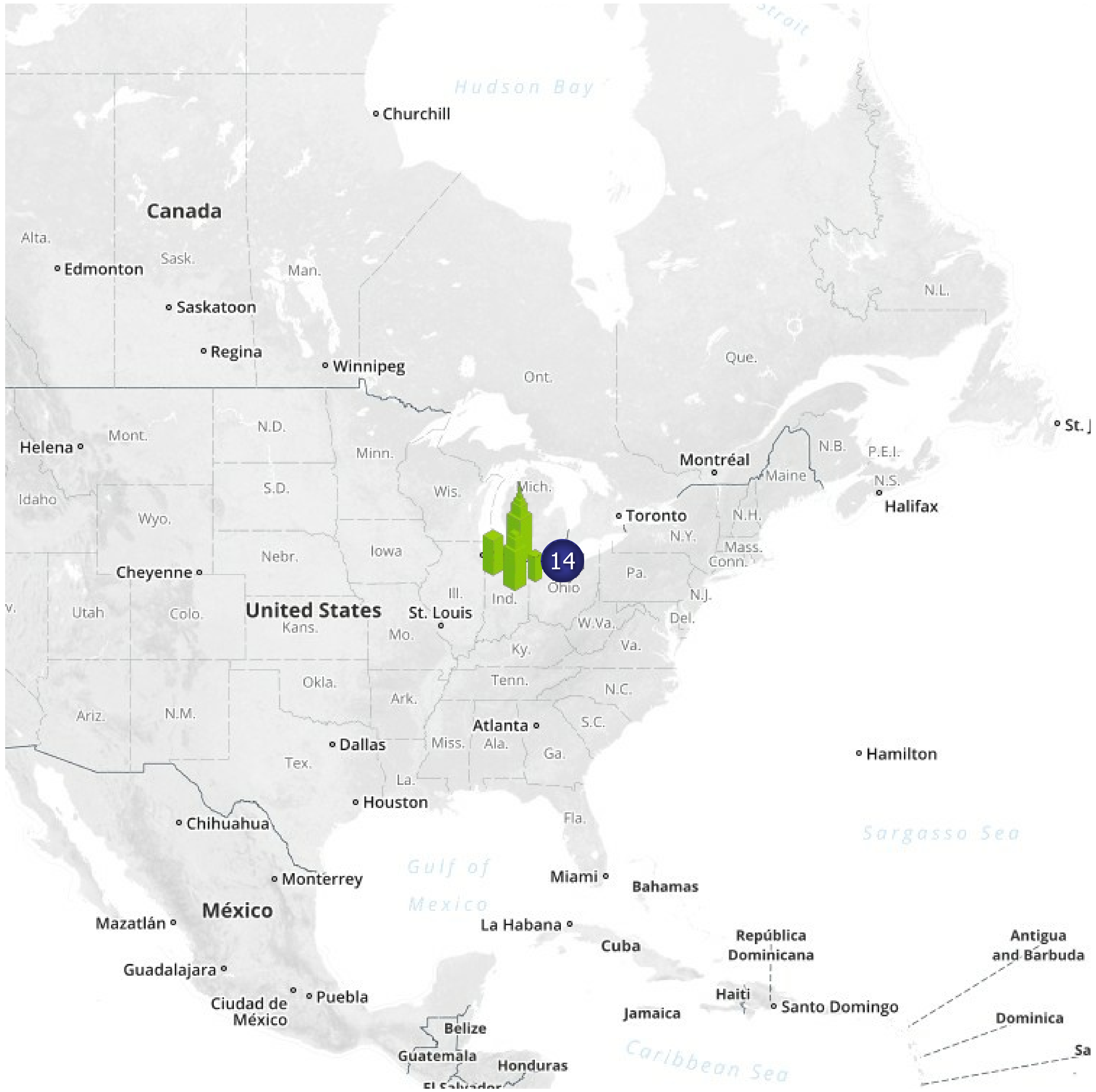
How does it work?

LEAN creates models of building energy usage from utility data and utilizes them to identify trends and benchmark performance. The models are built using sophisticated regression techniques that correlate energy usage to weather and other factors that influence energy usage. The models provide detailed insight into the physical and operational characteristics of each building and allow the performance and operating characteristics to be benchmarked and compared to populations of similar buildings.



II. Summary

Executive Summary of Opportunity



Highest Savings

2 facilities at this savings level

Life Sciences Institute Building - Lab

Chemistry - Lab

Medical Sciences Research Building III - Lab

Randall Harrison M Laboratory - Lab

Biomedical Science Research Building - Other

2 facilities at this savings level

5 facilities at this savings level

Lowest Savings

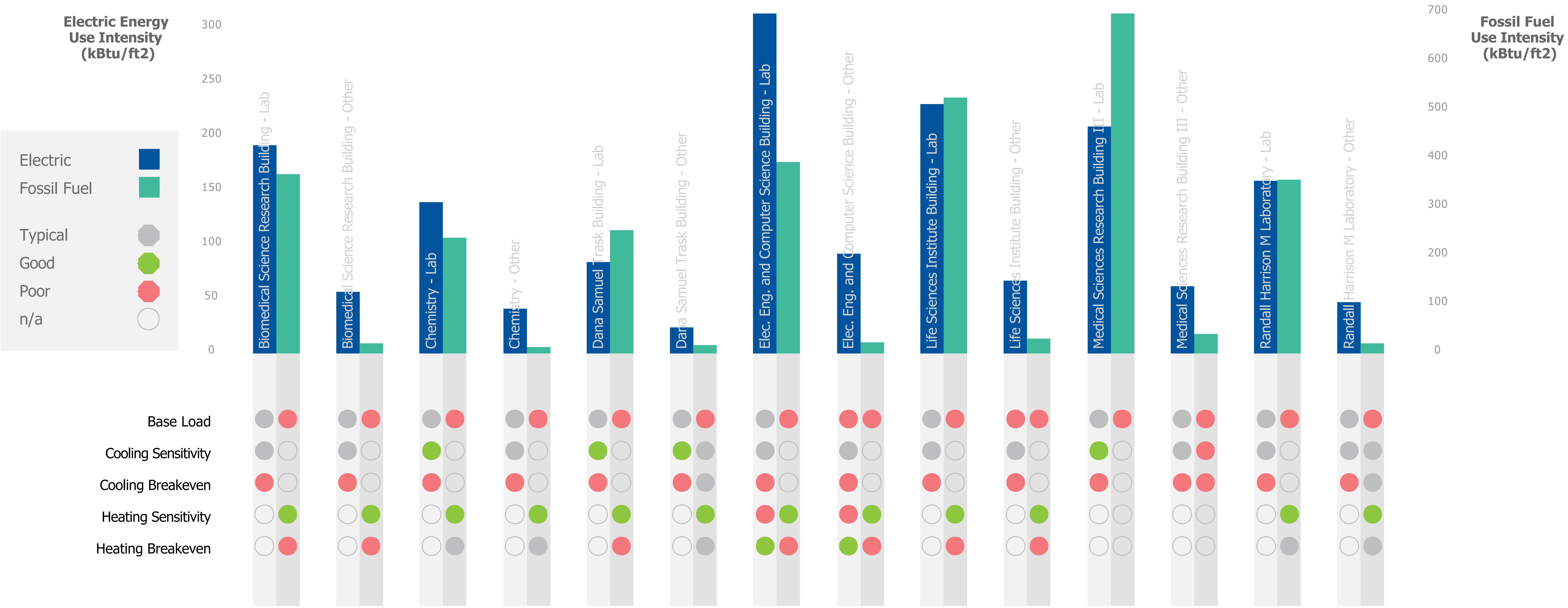
Total Potential Savings

$2,784,000

Top Individual Potential Savings

Biomedical Science Research Building - Lab	
Savings	500,000
Elec. Eng. and Computer Science Building - Lab	
Savings	500,000
Life Sciences Institute Building - Lab	
Savings	440,000
Chemistry - Lab	
Savings	370,000
Medical Sciences Research Building III - Lab	
Savings	290,000

Summary of Performance Benchmarks for Electricity and Fossil Fuels

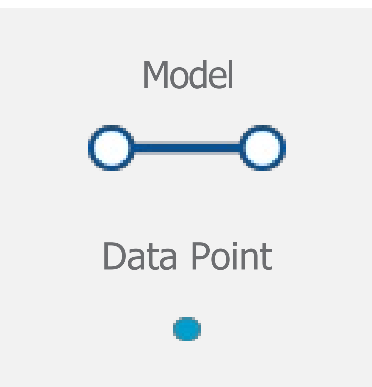


III. Individual Sites

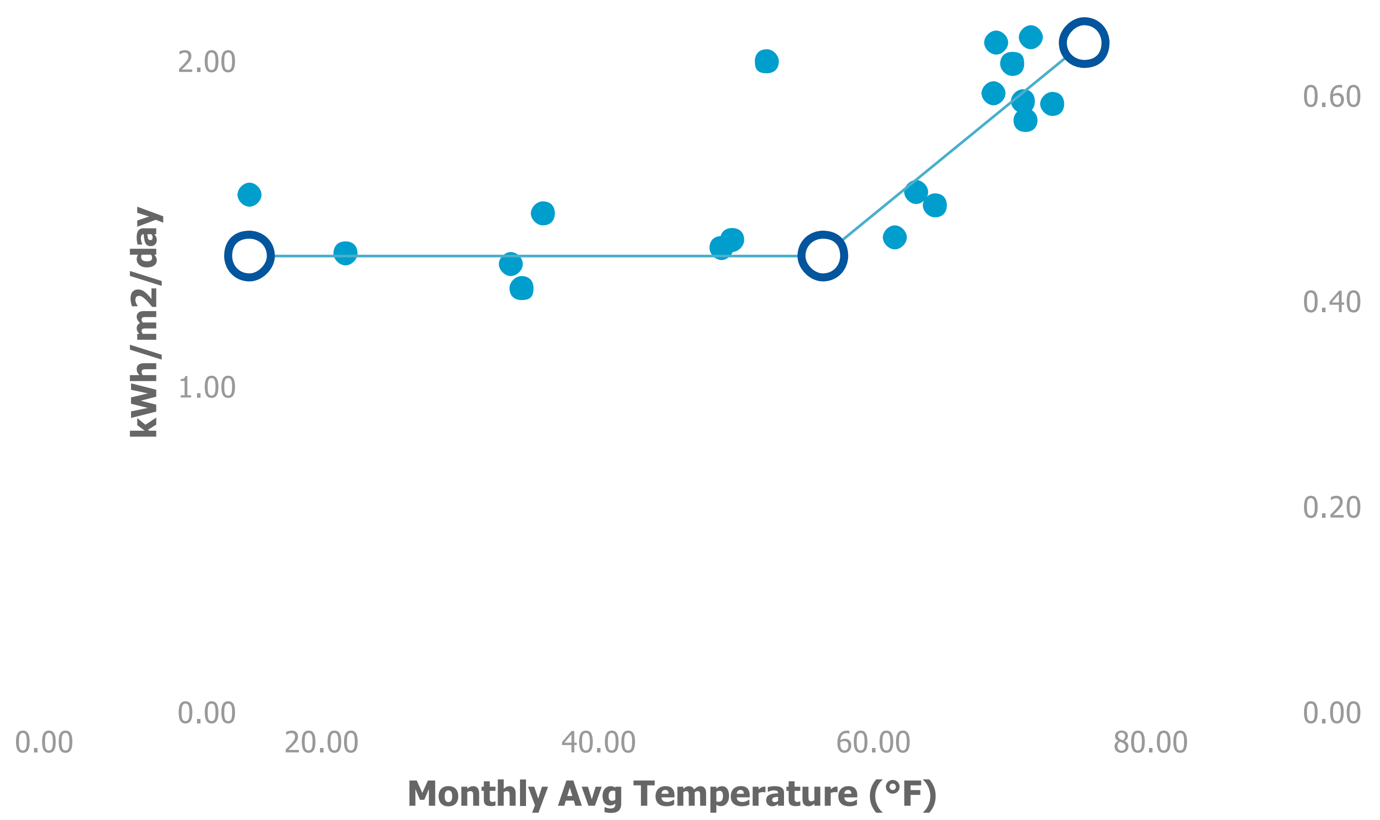
Biomedical Science Research Building - Lab

Biomedical Science Research Building - Lab

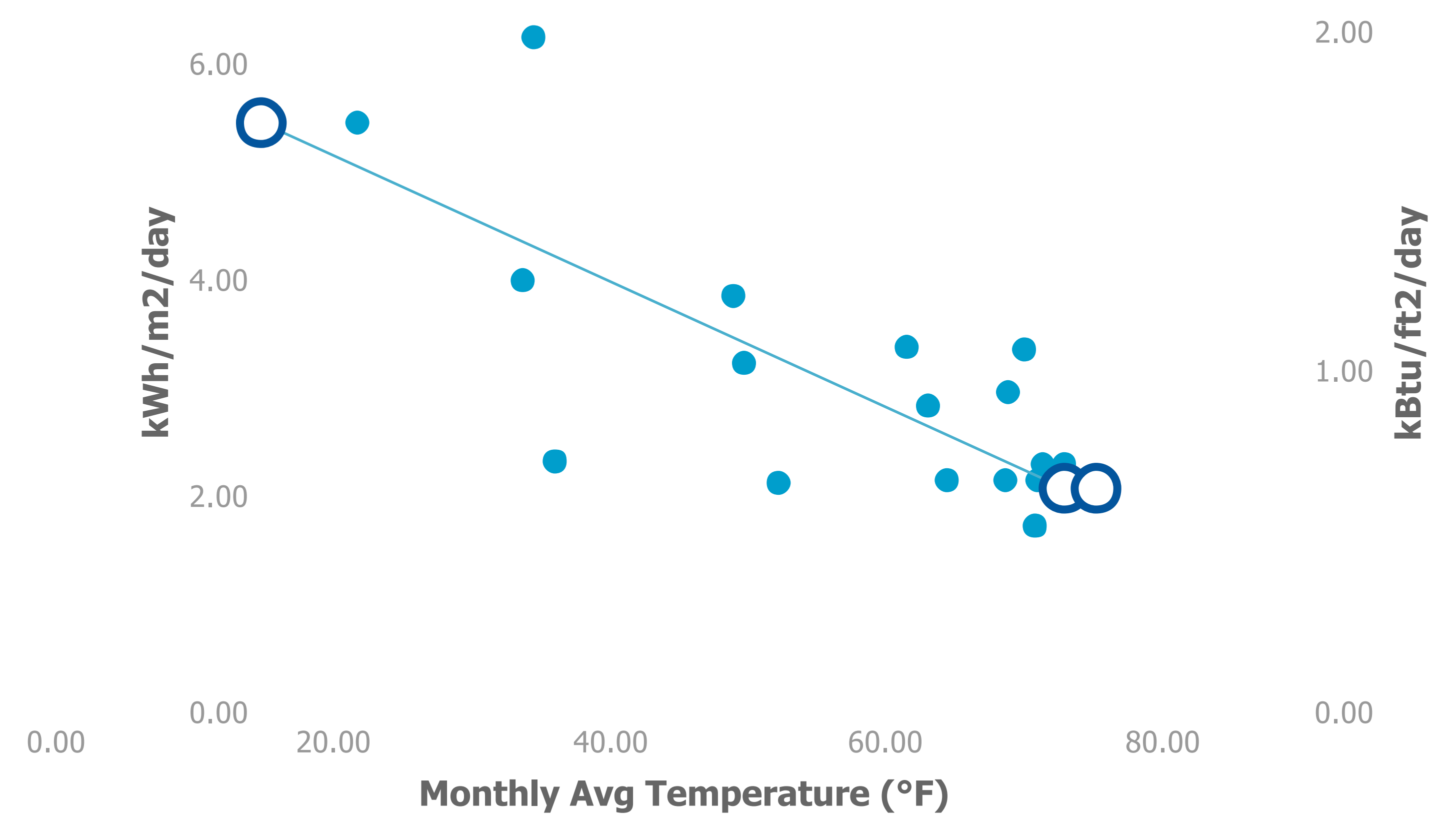
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$500,000

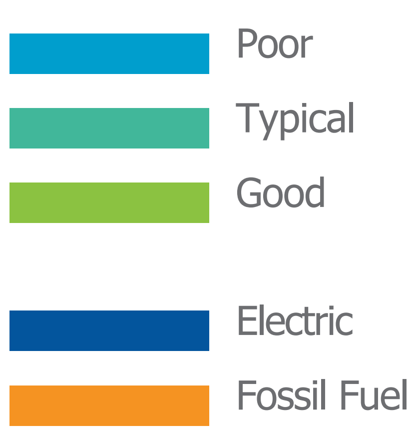
Total Potential Percentage Savings

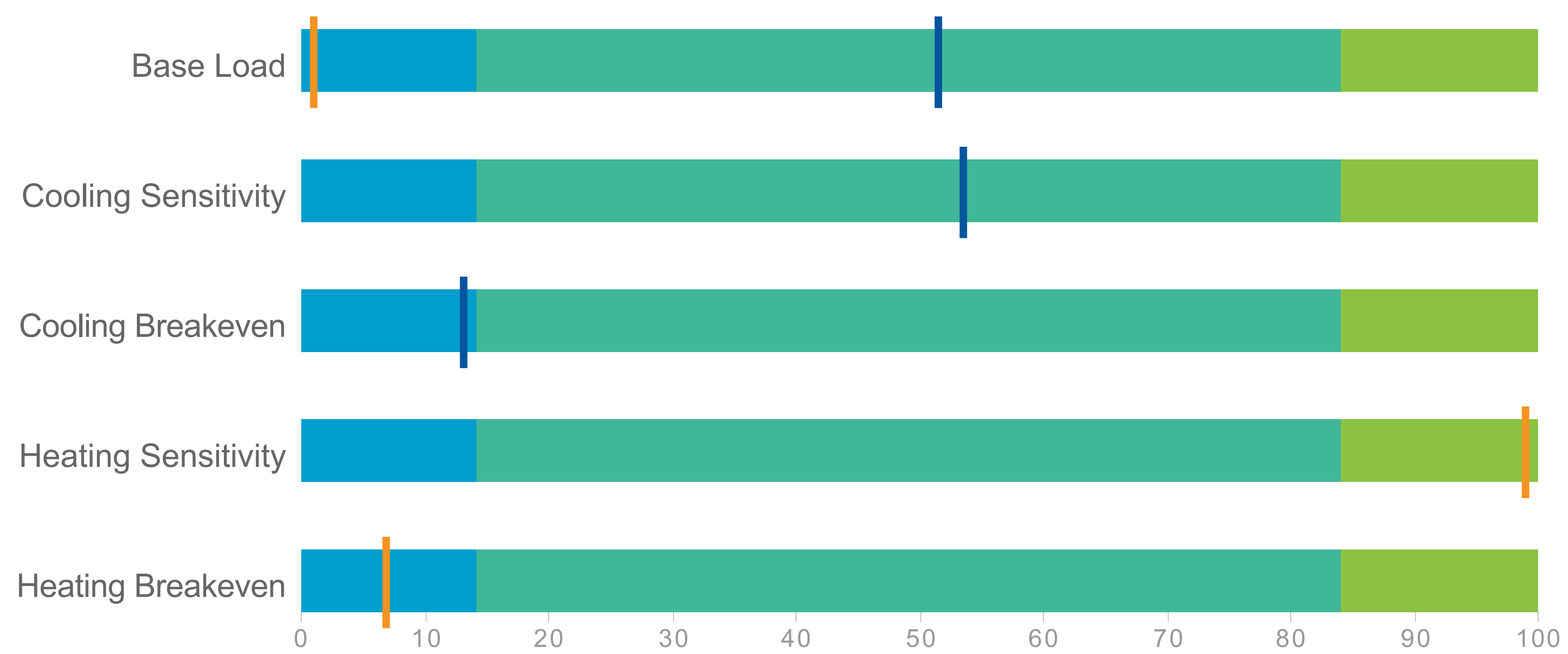
16%

Recommendations

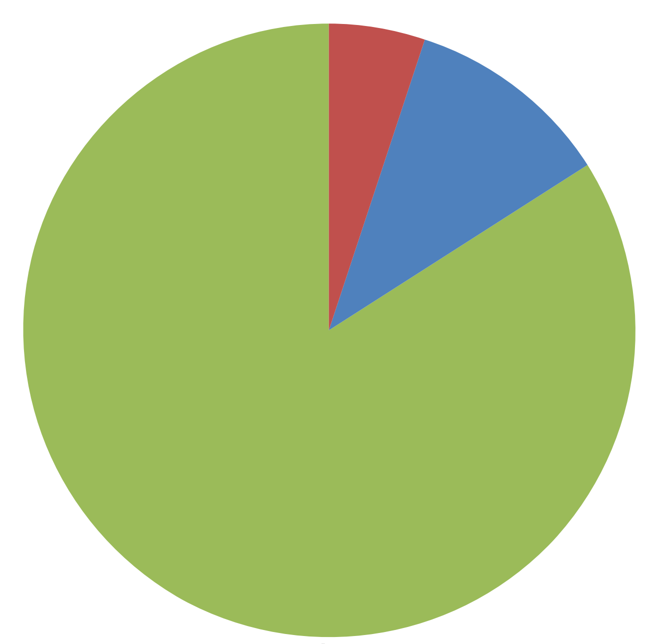
- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Decrease heating setpoints
- Check fossil fuel base load

Benchmark Metrics





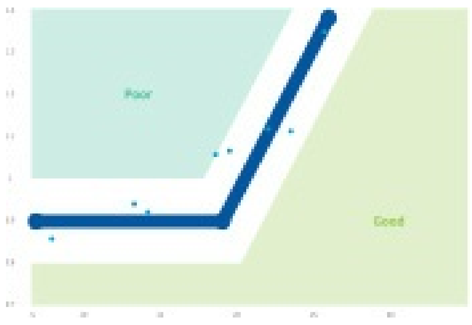
Savings Breakdown



Savings - No/Low Cost Measures (11% / $350000)
Savings - Comprehensive Measures (5% / $150000)
Target Energy Budget (84% / $2586581)

Biomedical Science Research Building - Lab

Recommendations



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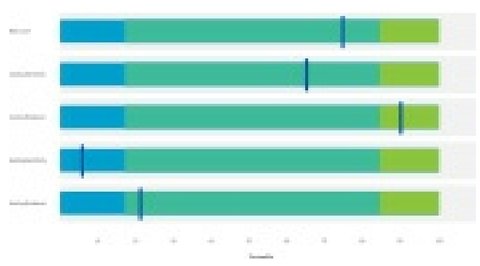

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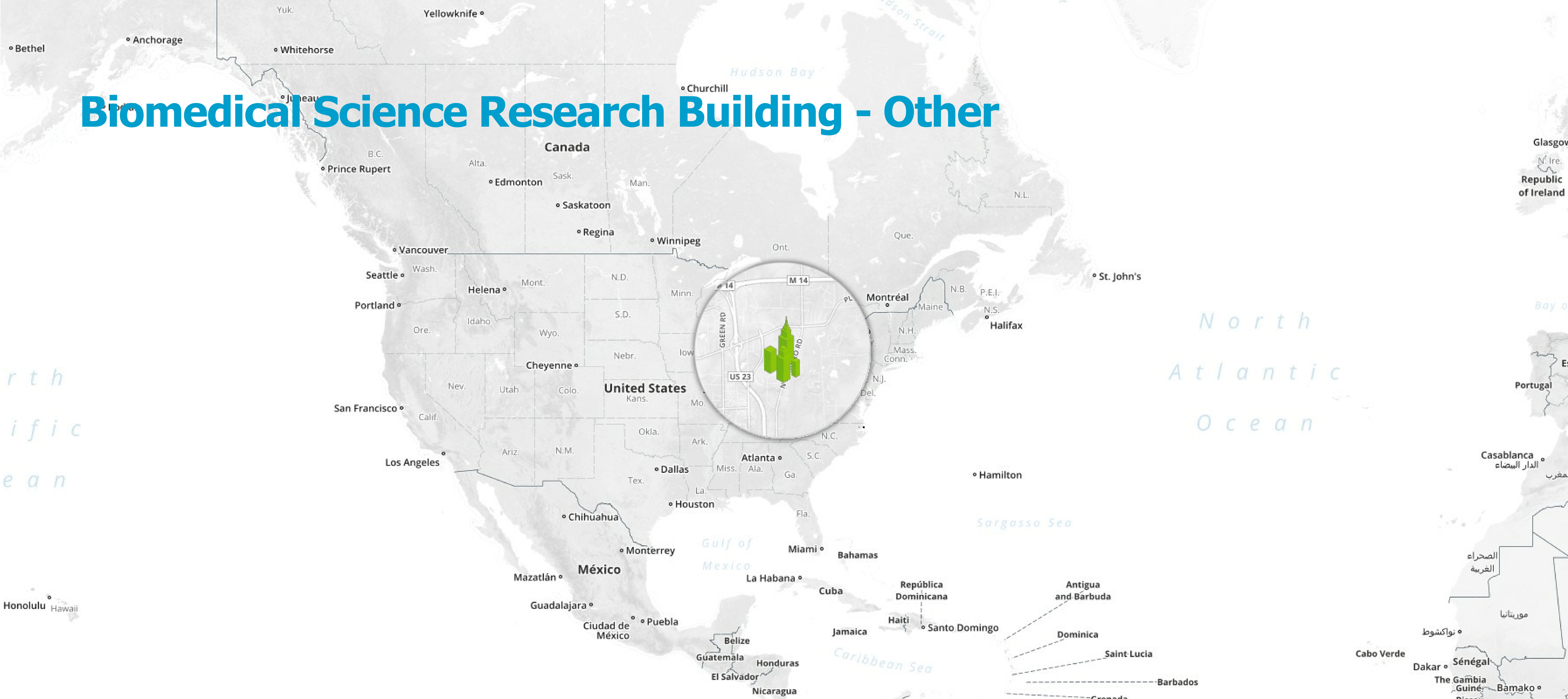
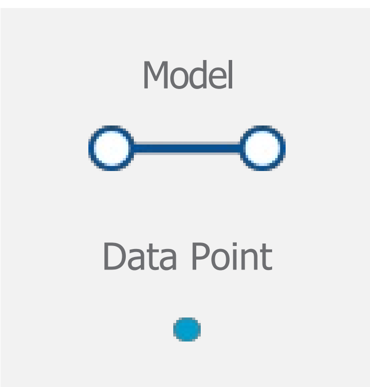
Biomedical Science Research Building - Other

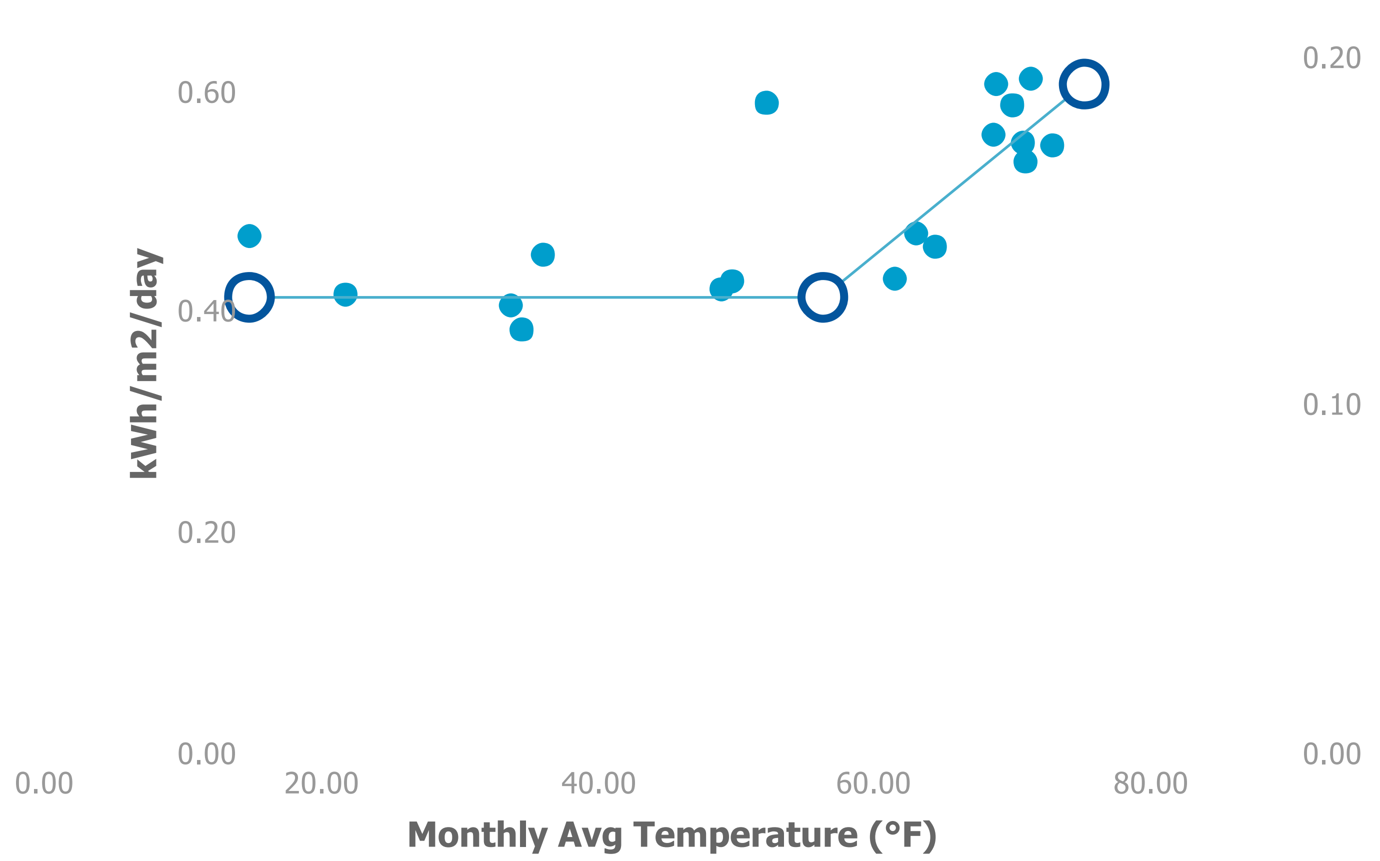


Biomedical Science Research Building - Other

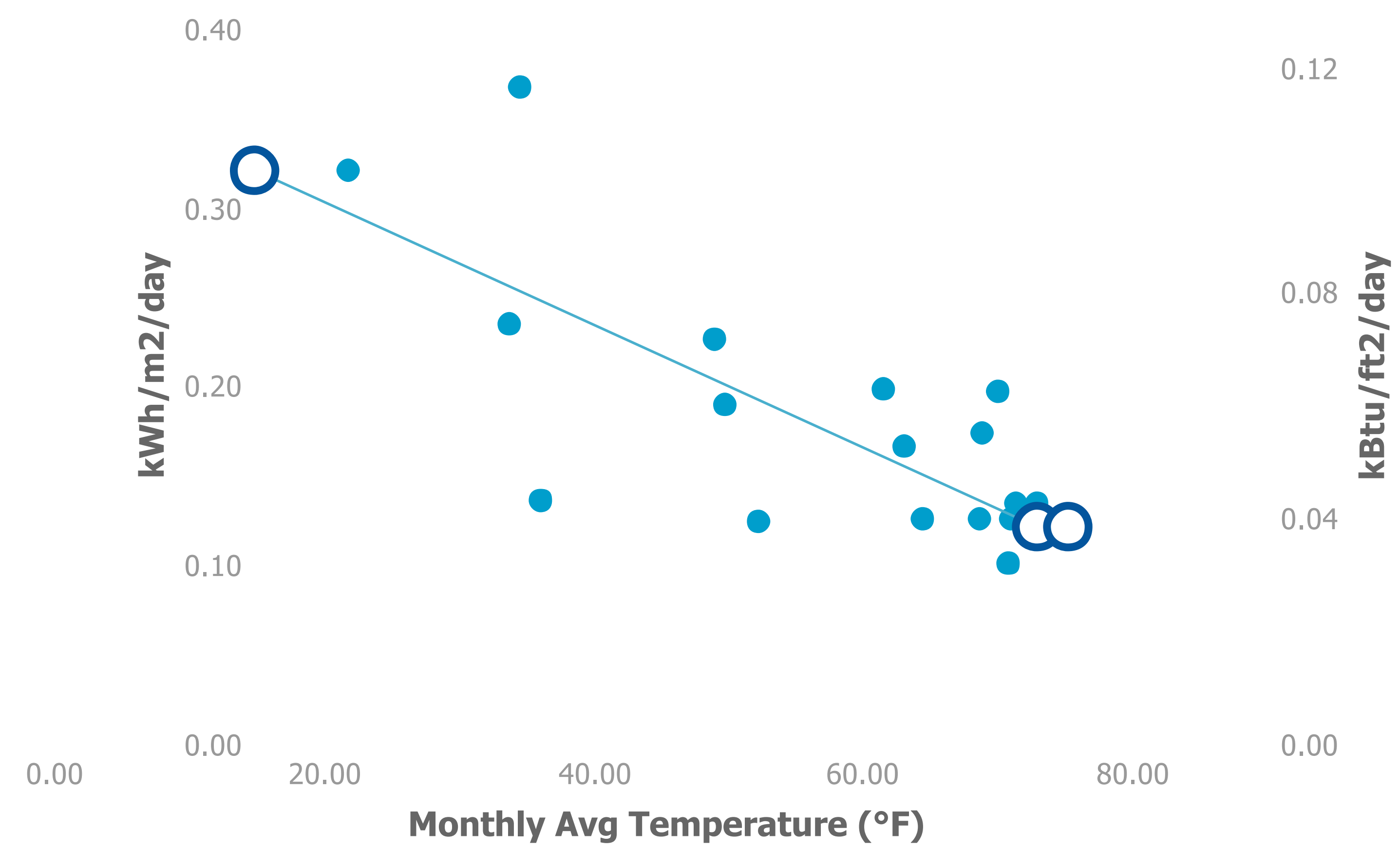
Weather Sensitivity

Electric





Fossil Fuel



Total Potential Location Savings

$140,000

Total Potential Percentage Savings

35%

Recommendations

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- Reduce plug loads
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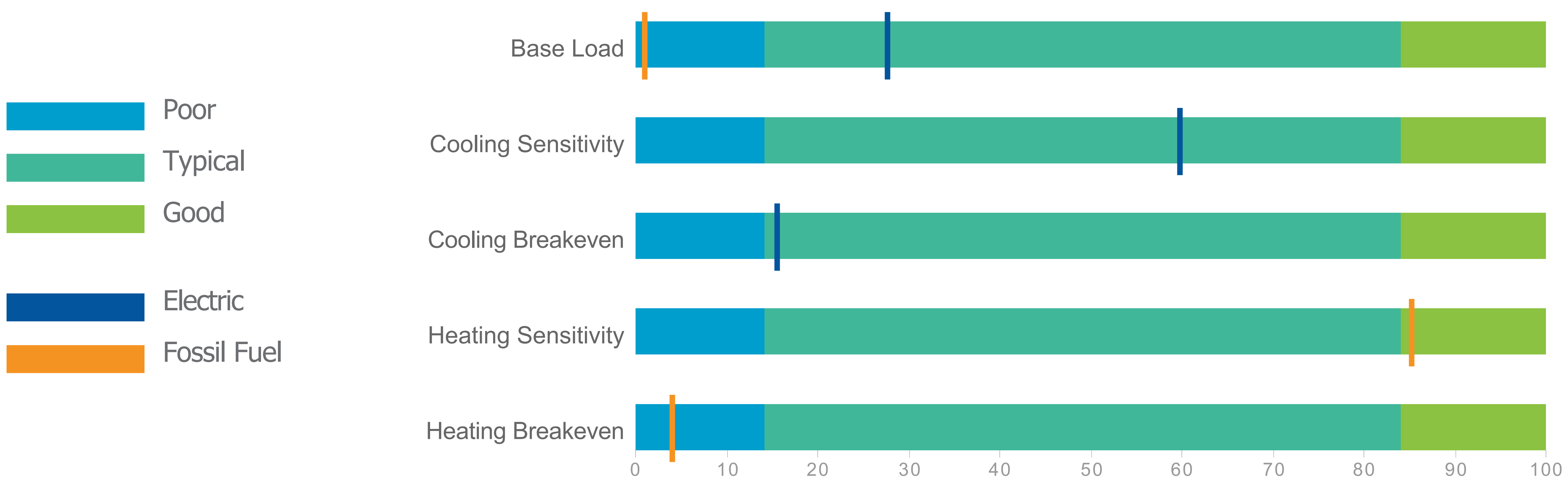

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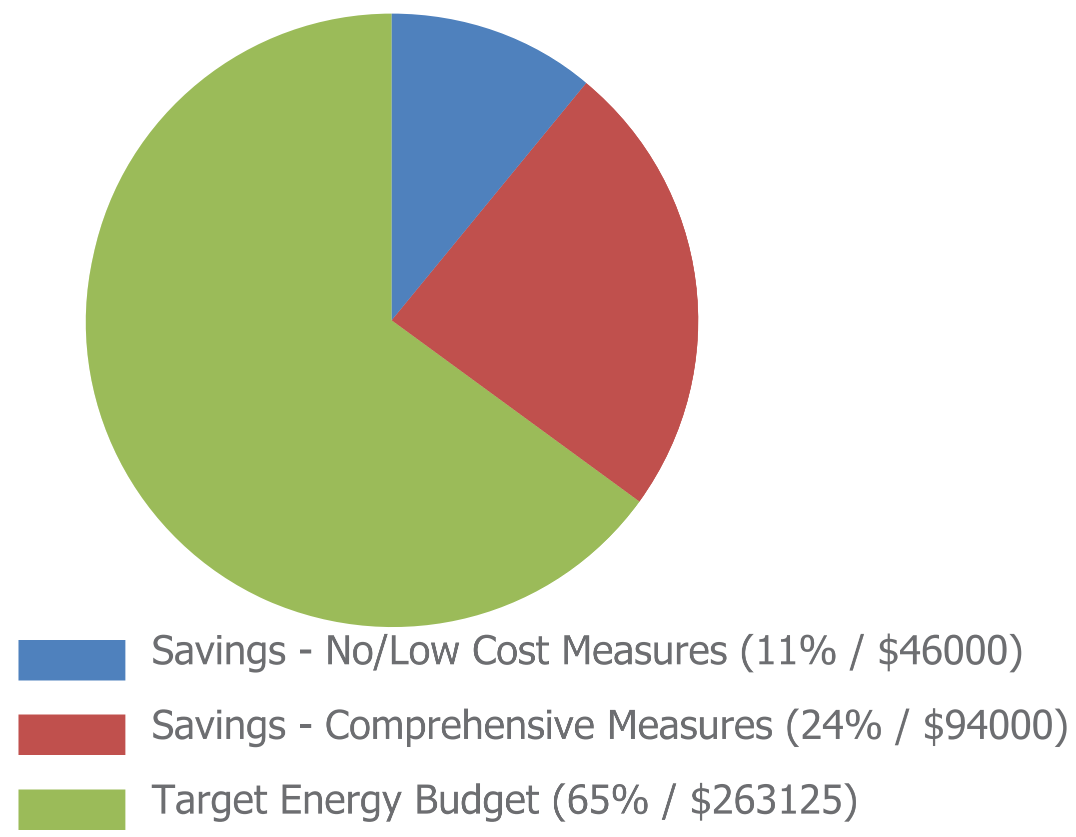

Biomedical Science Research Building - Other

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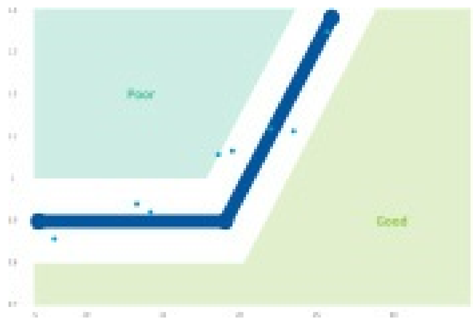

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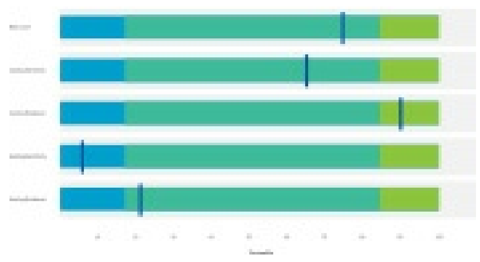

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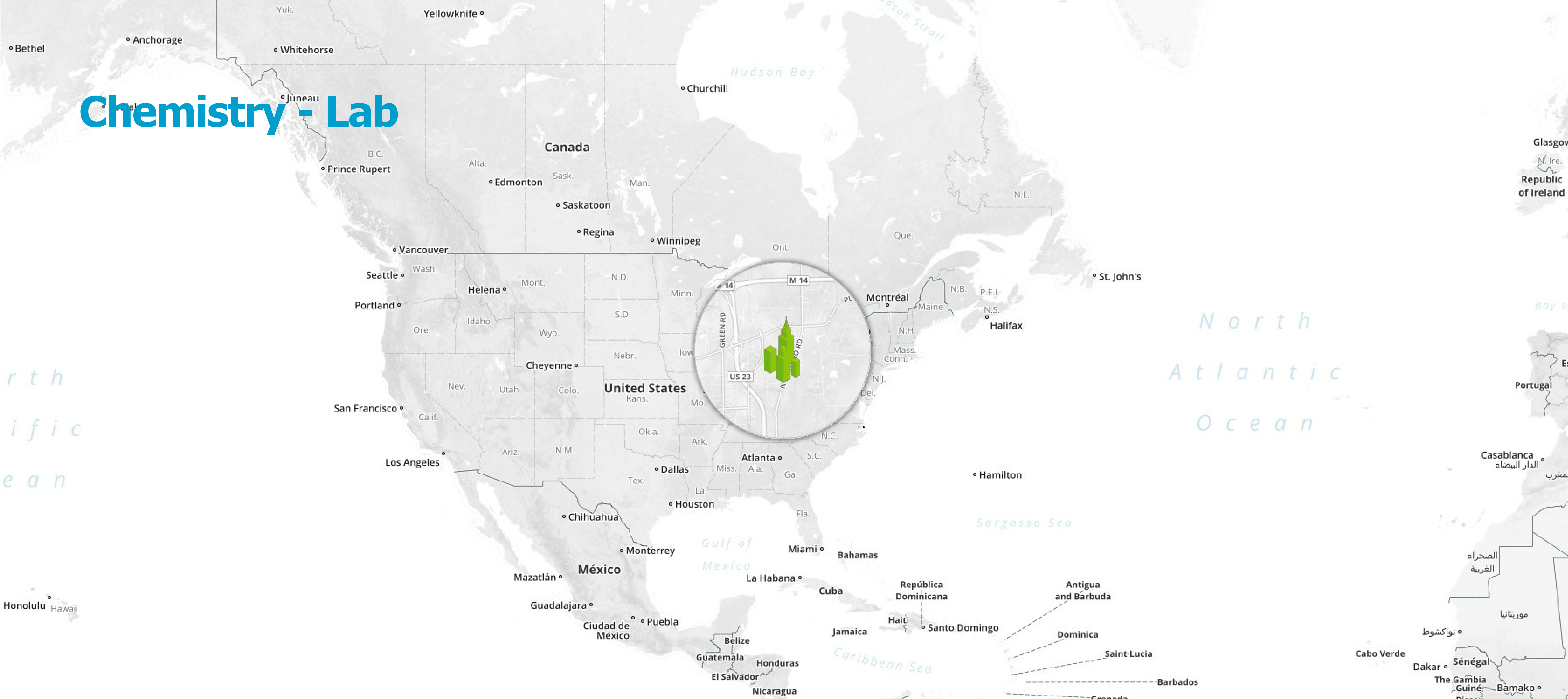
Both the occupied and unoccupied setpoints used during the heating season should be checked for opportunities to decrese them. Decreasing heating setpoints will reduce the heating loads of the building and the energy usage of heating equipment and systems serving them.

Check Fossil Fuel Base Load

The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Chemistry - Lab

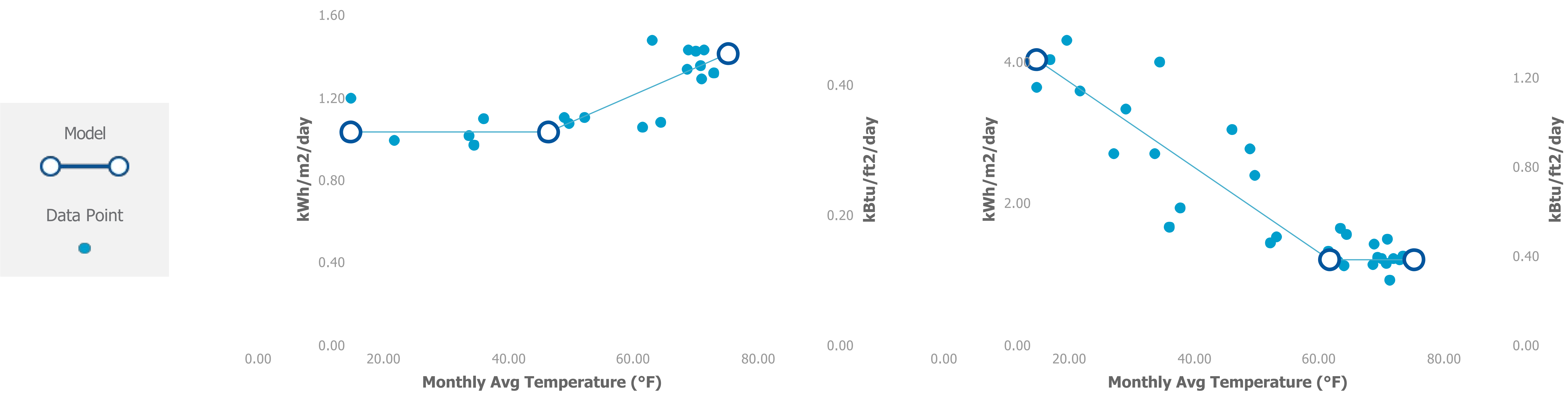


Chemistry - Lab

Weather Sensitivity

Electric

Fossil Fuel



Total Potential Location Savings

$370,000

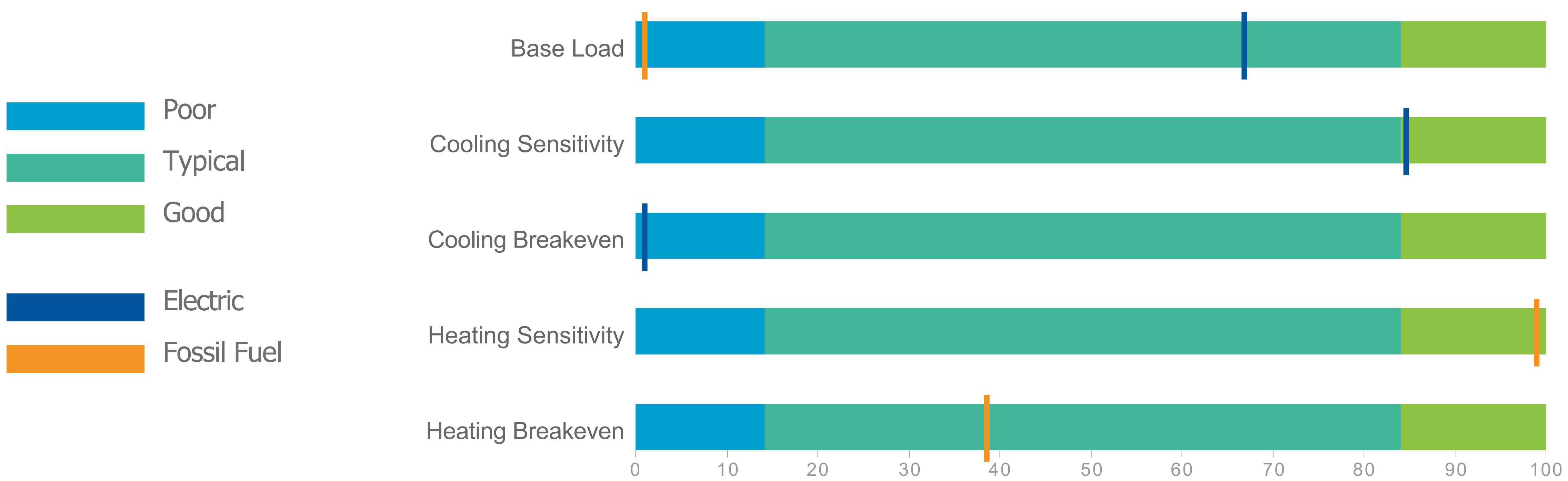
Total Potential Percentage Savings

16%

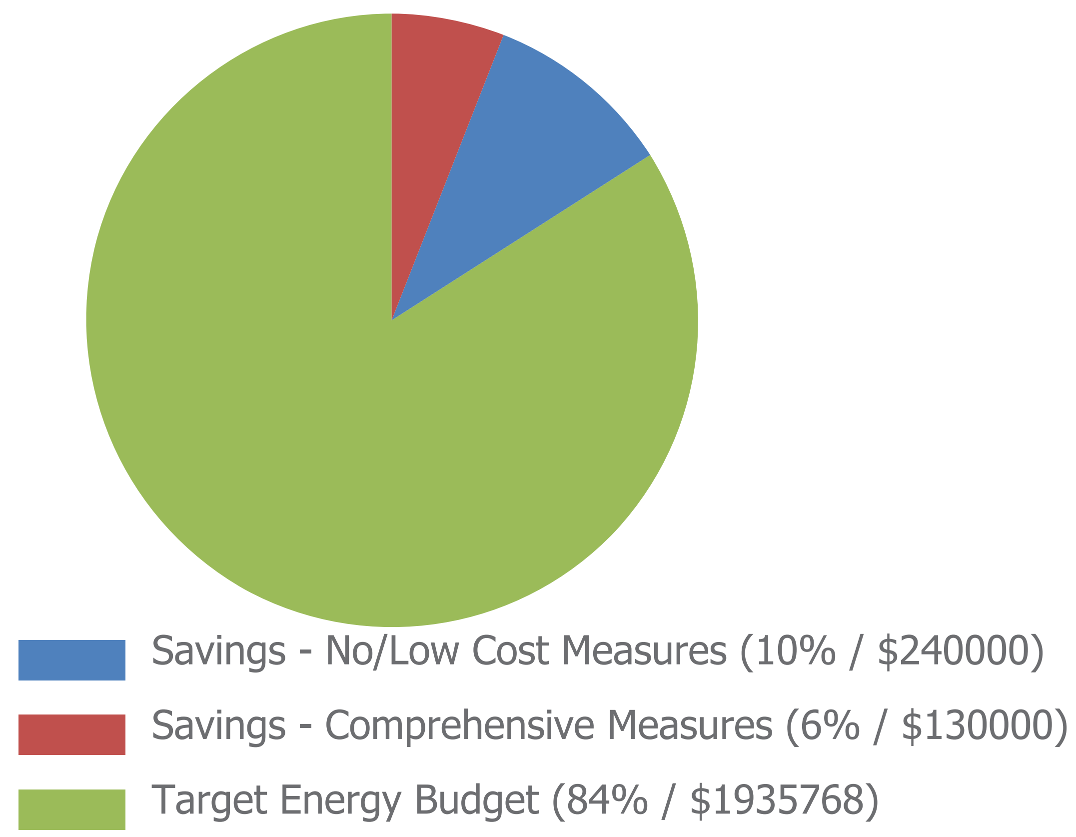
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

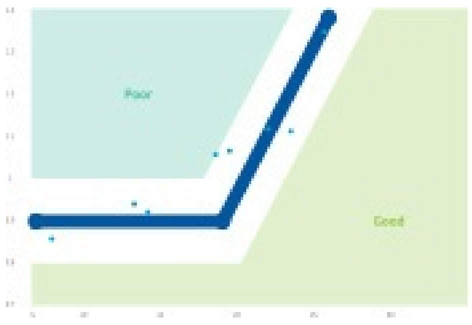


Savings Breakdown



Chemistry - Lab

Recommendations



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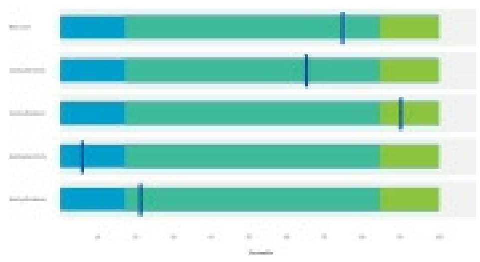

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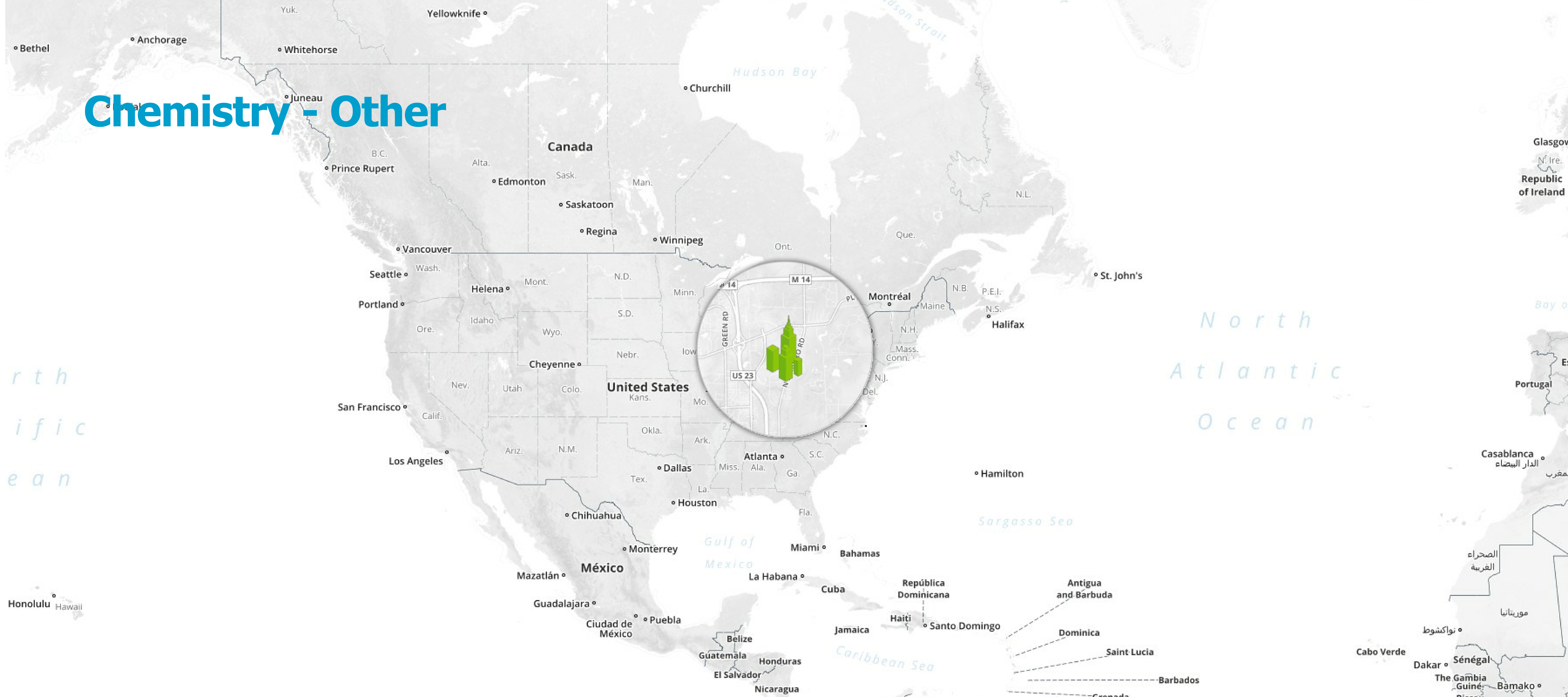
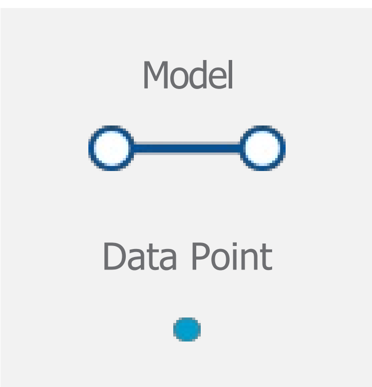
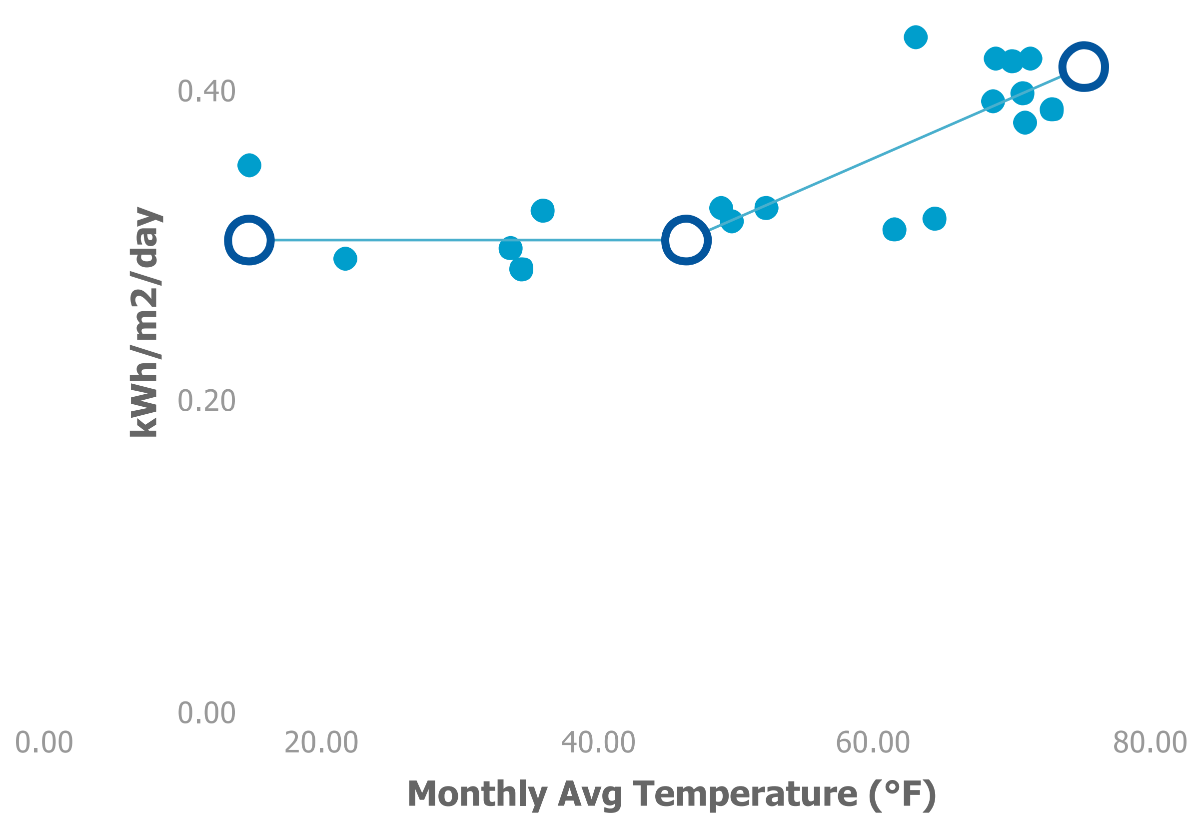


Chemistry - Other

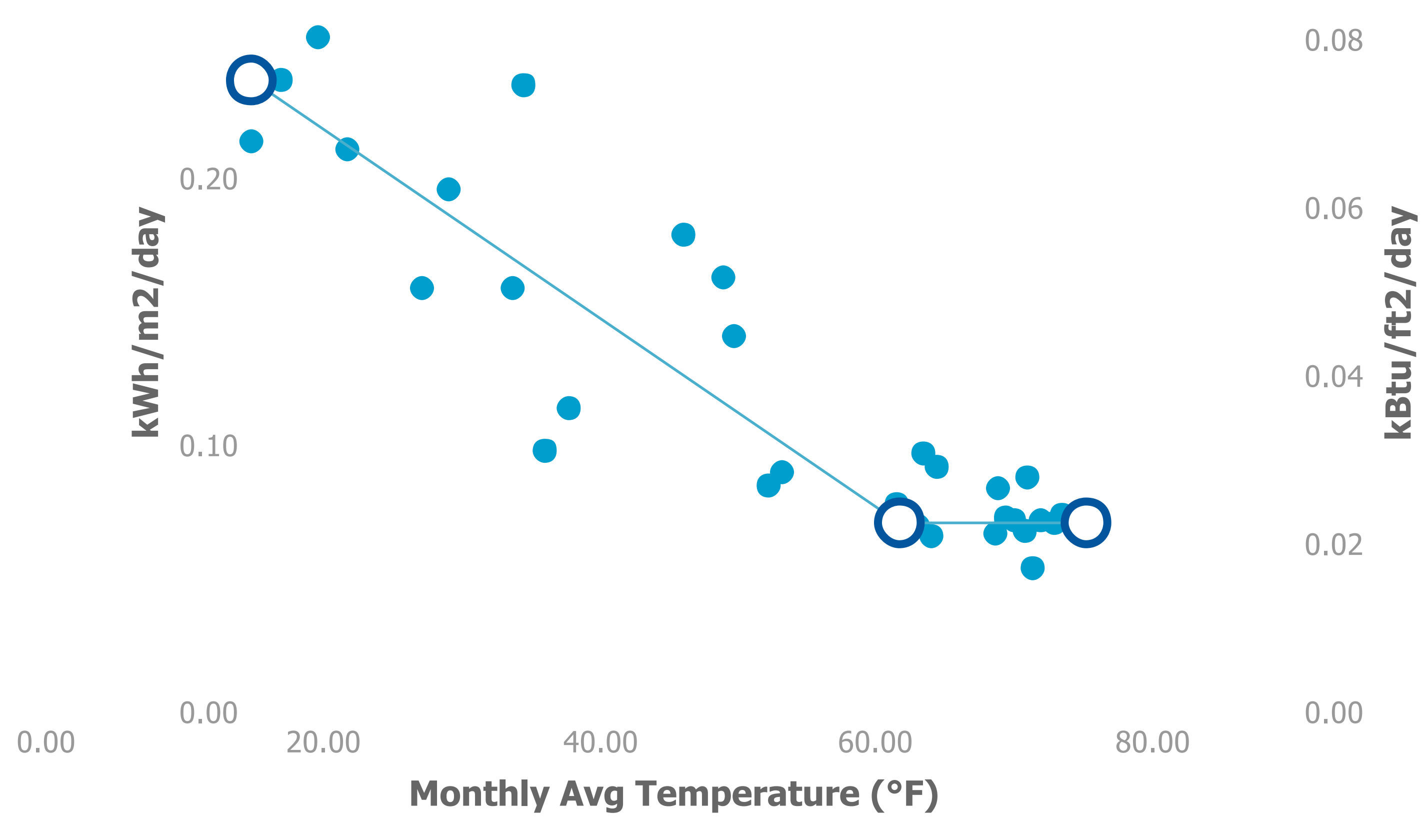
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$21,000

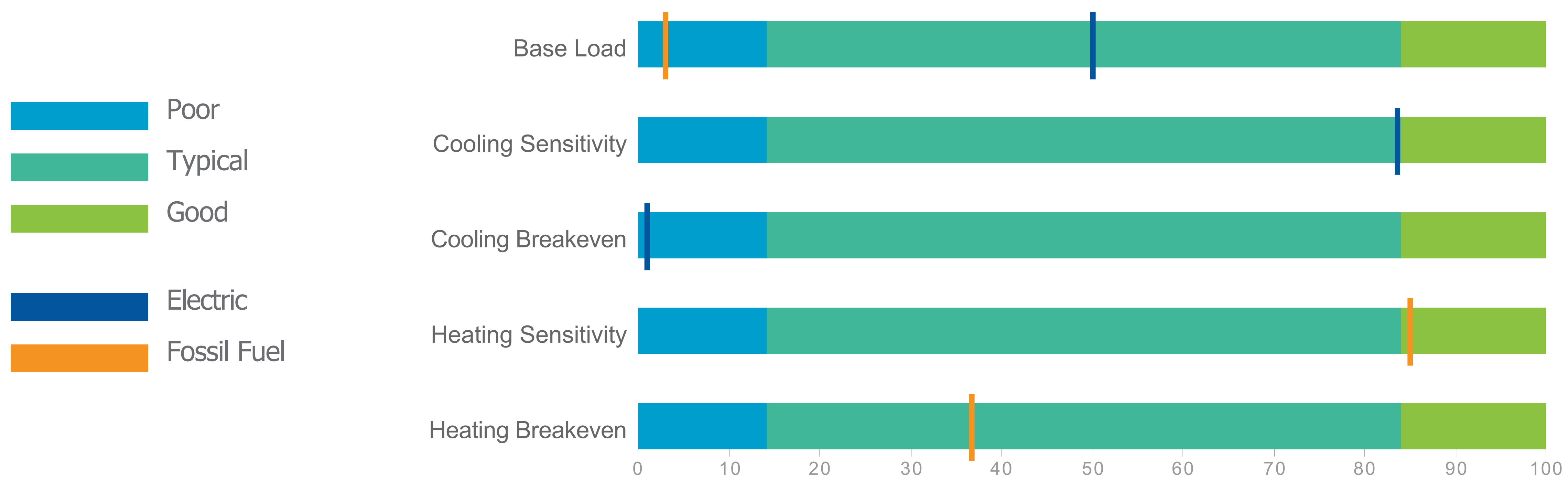
Total Potential Percentage Savings

11%

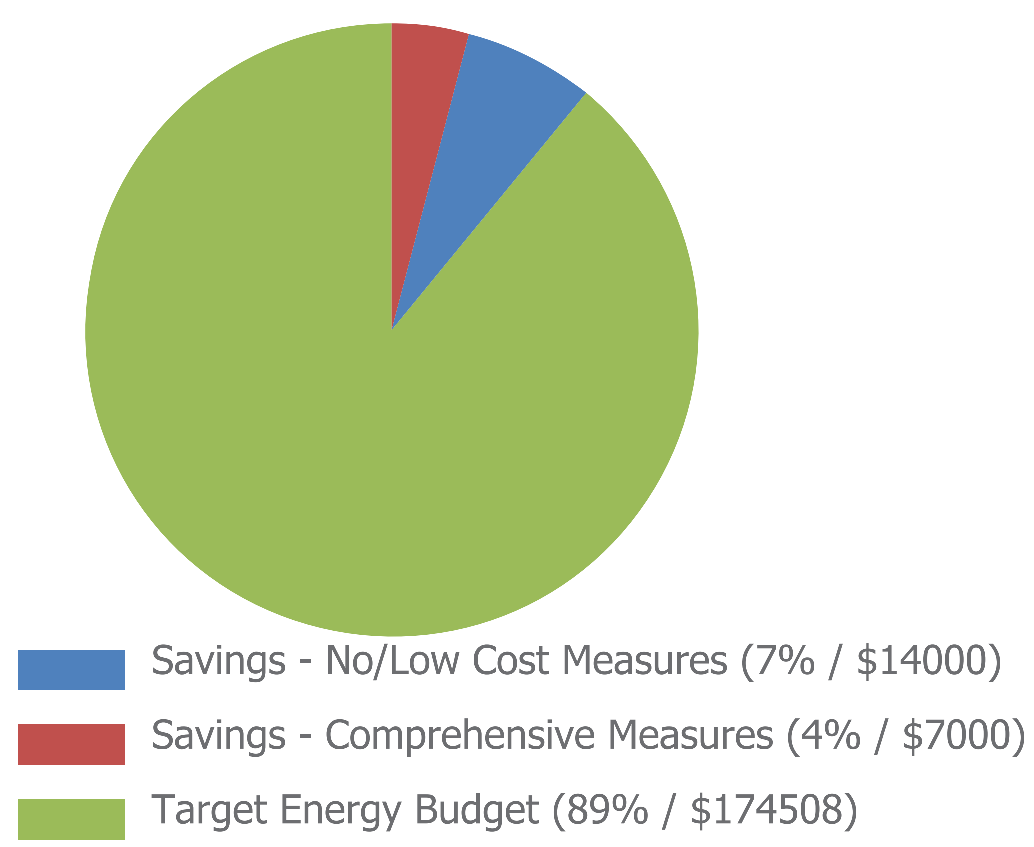
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

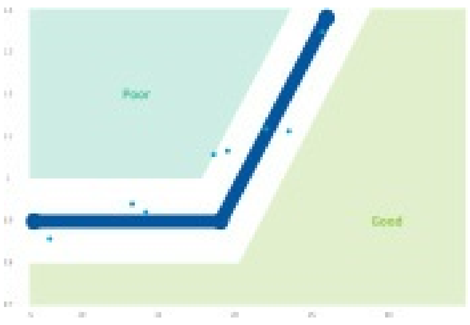


Savings Breakdown



Chemistry - Other

Recommendations



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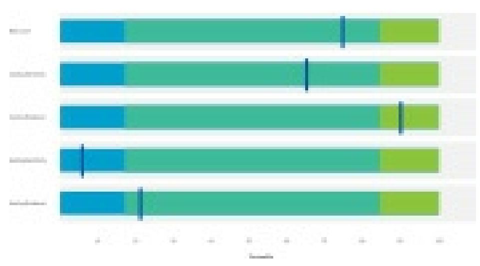

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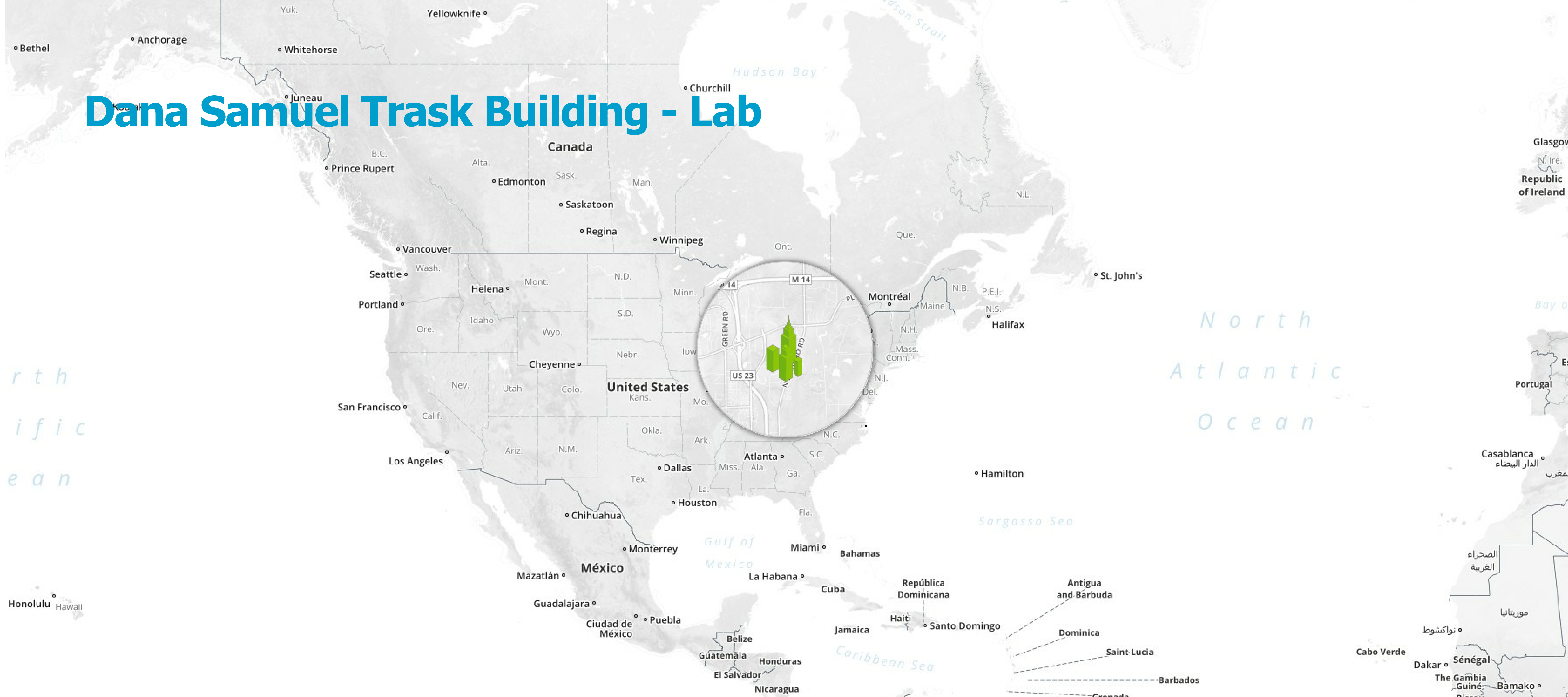
Dana Samuel Trask Building - Lab



Dana Samuel Trask Building - Lab

Weather Sensitivity

Total Potential Location Savings

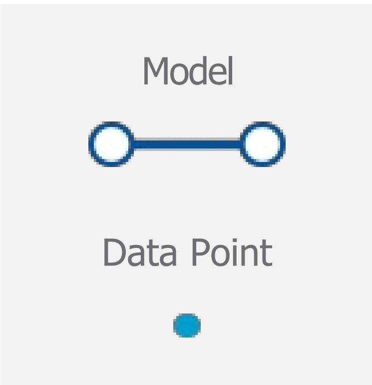
$60,000

Total Potential Percentage Savings

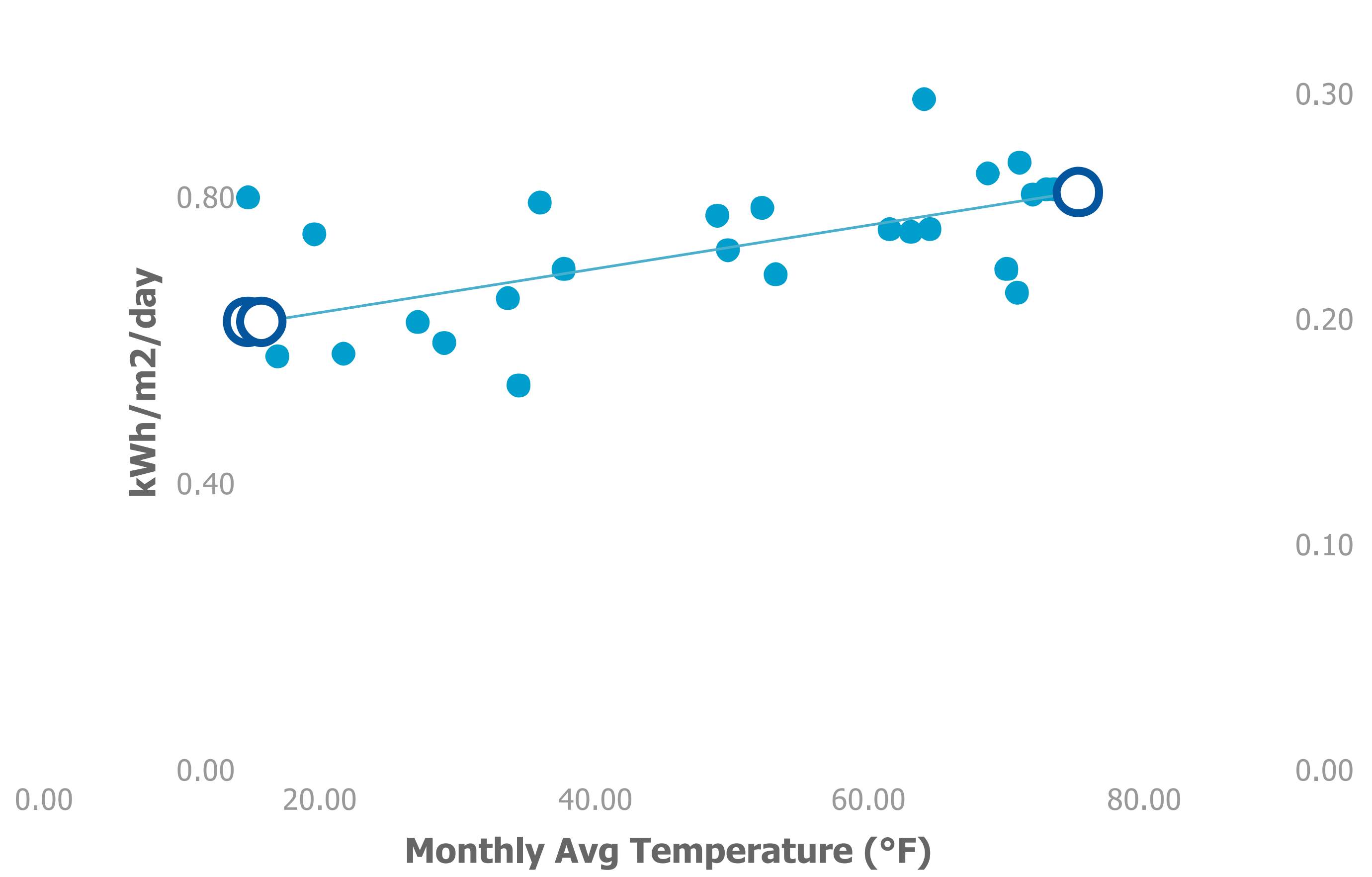
30%

Recommendations

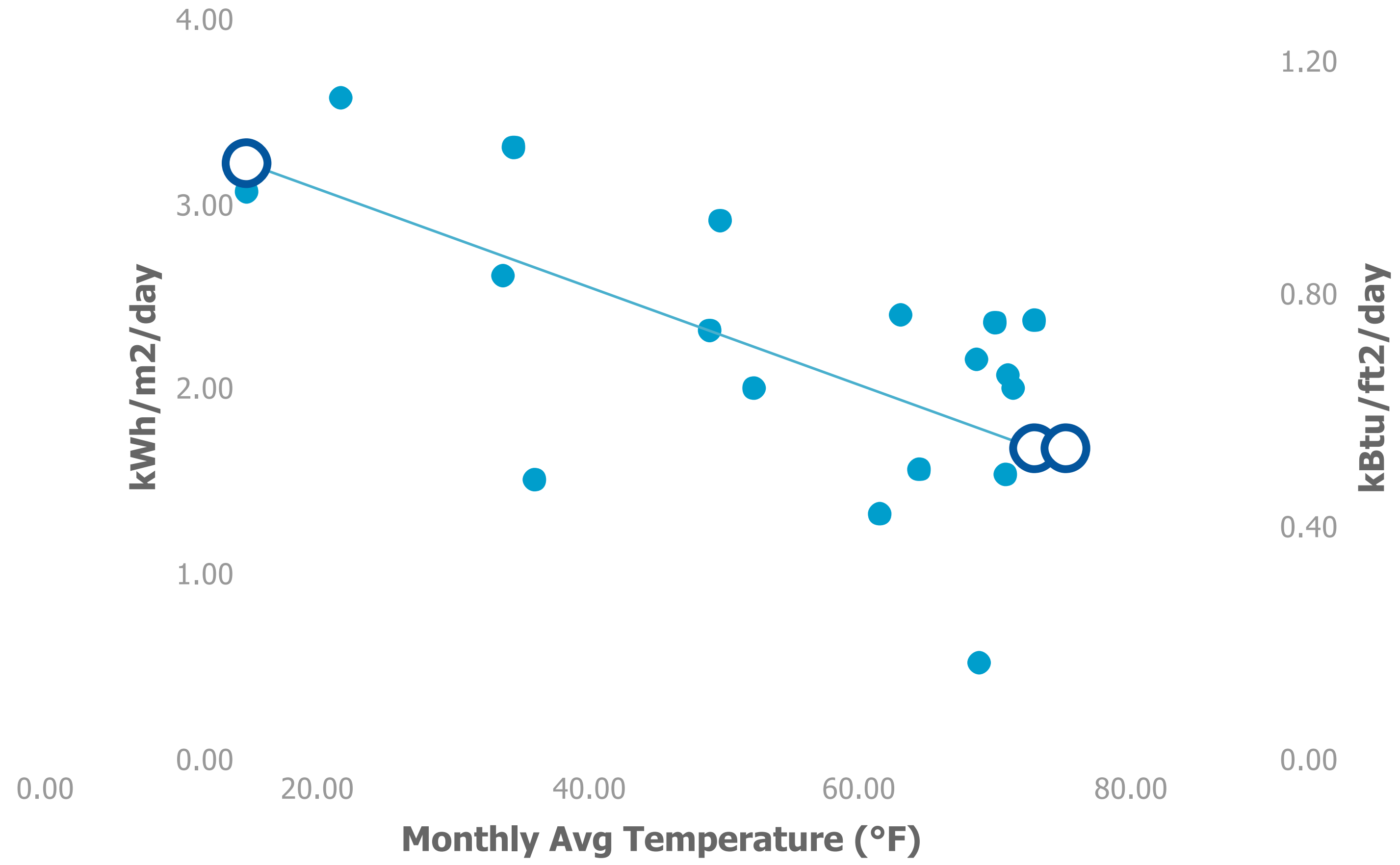
- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Decrease heating setpoints
- Check fossil fuel base load



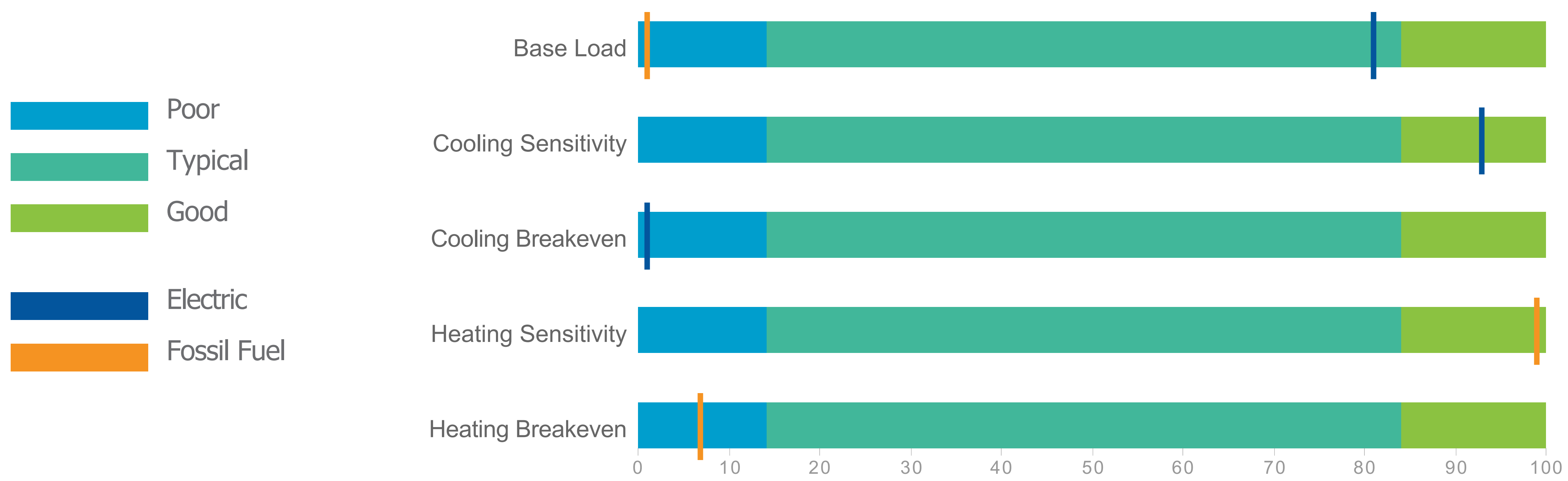
Electric



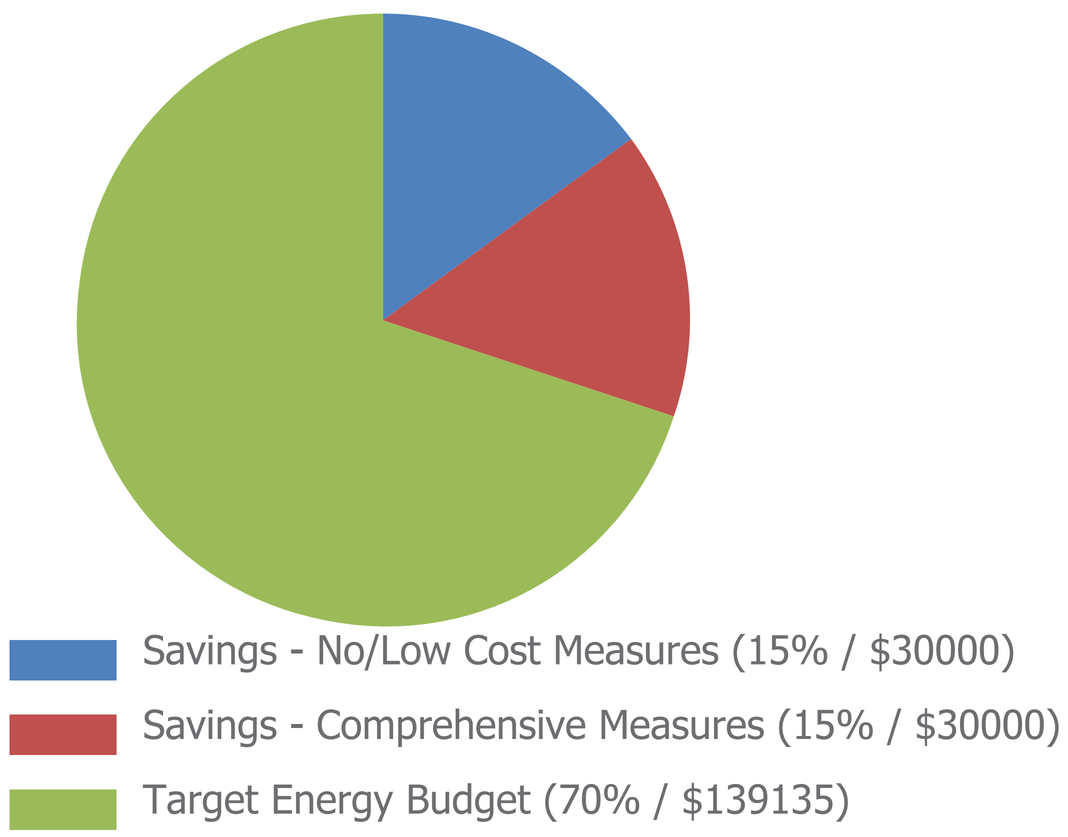
Fossil Fuel



Benchmark Metrics

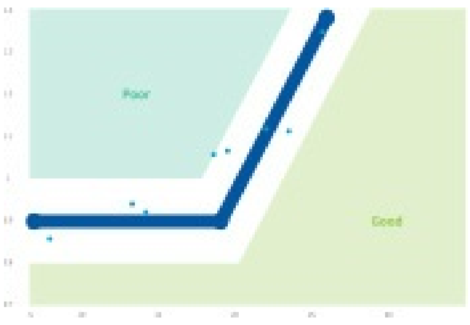


Savings Breakdown



Dana Samuel Trask Building - Lab

Recommendations



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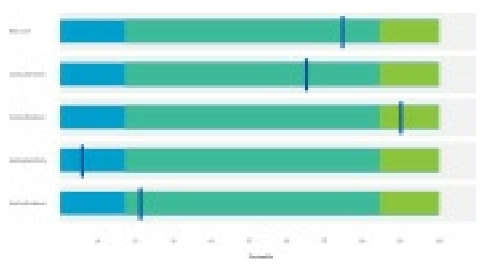

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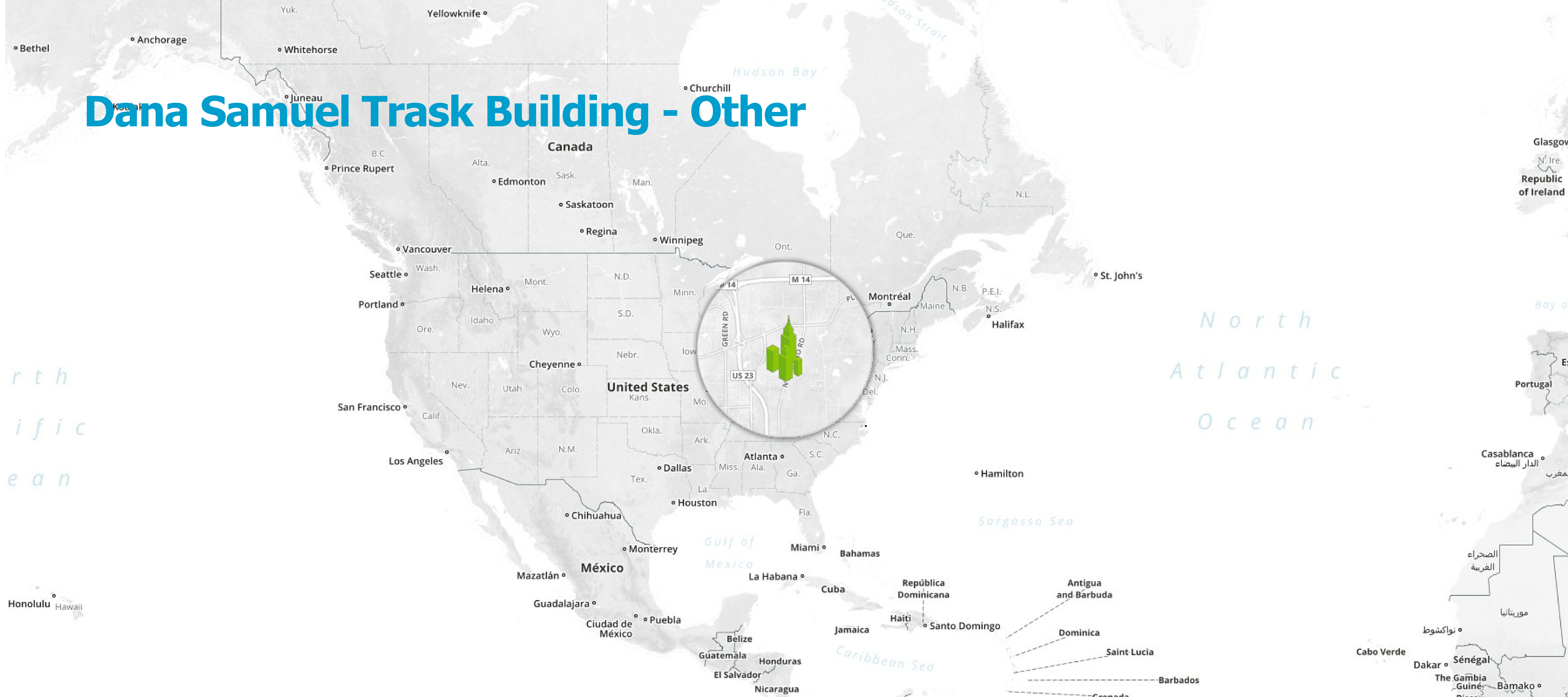
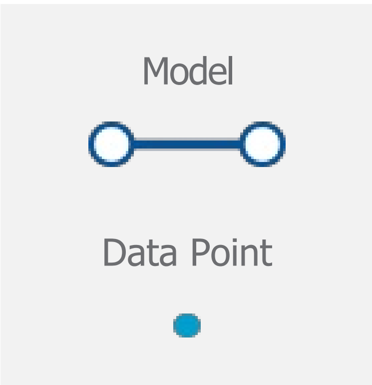
Dana Samuel Trask Building - Other

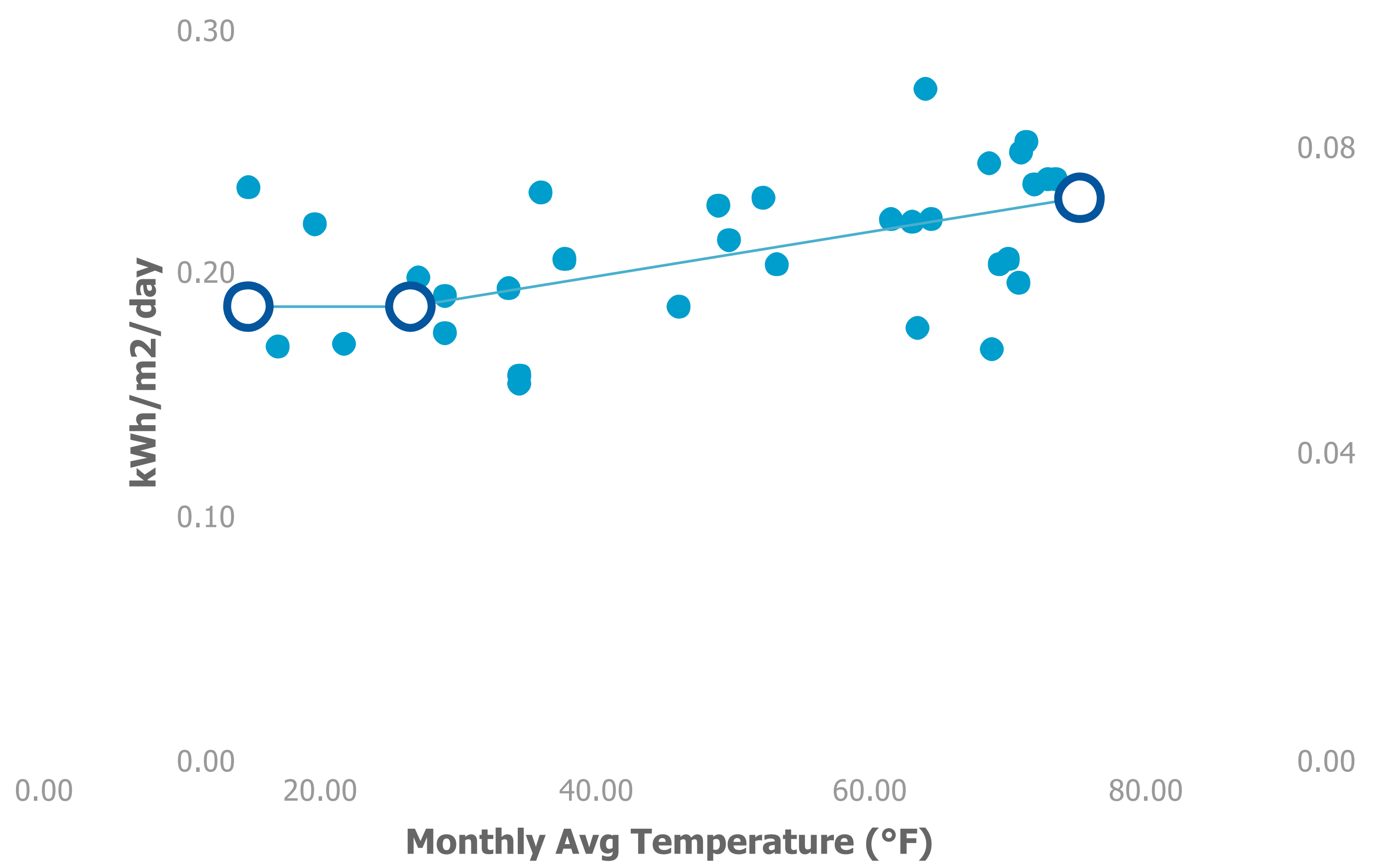


Dana Samuel Trask Building - Other

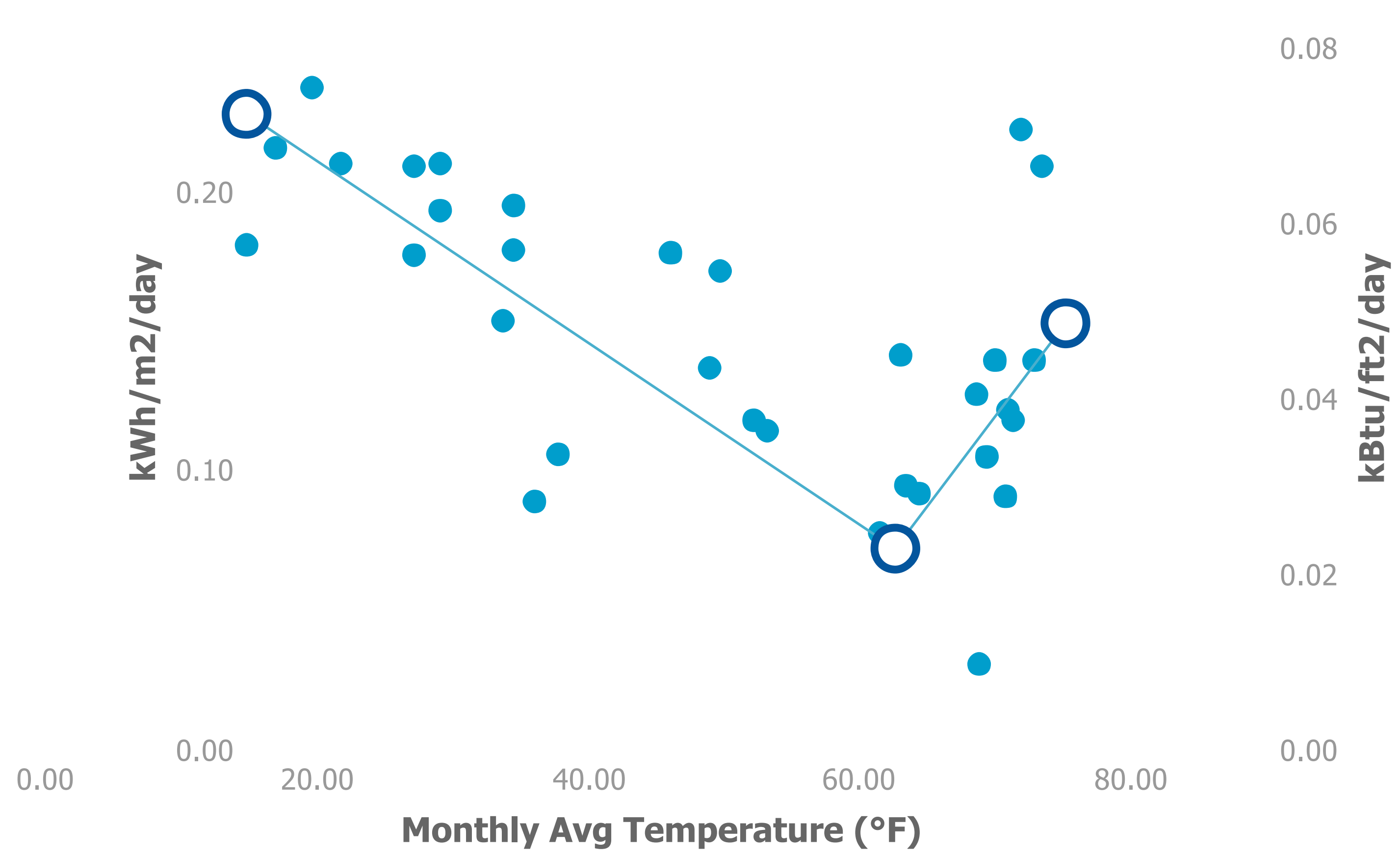
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$11,000

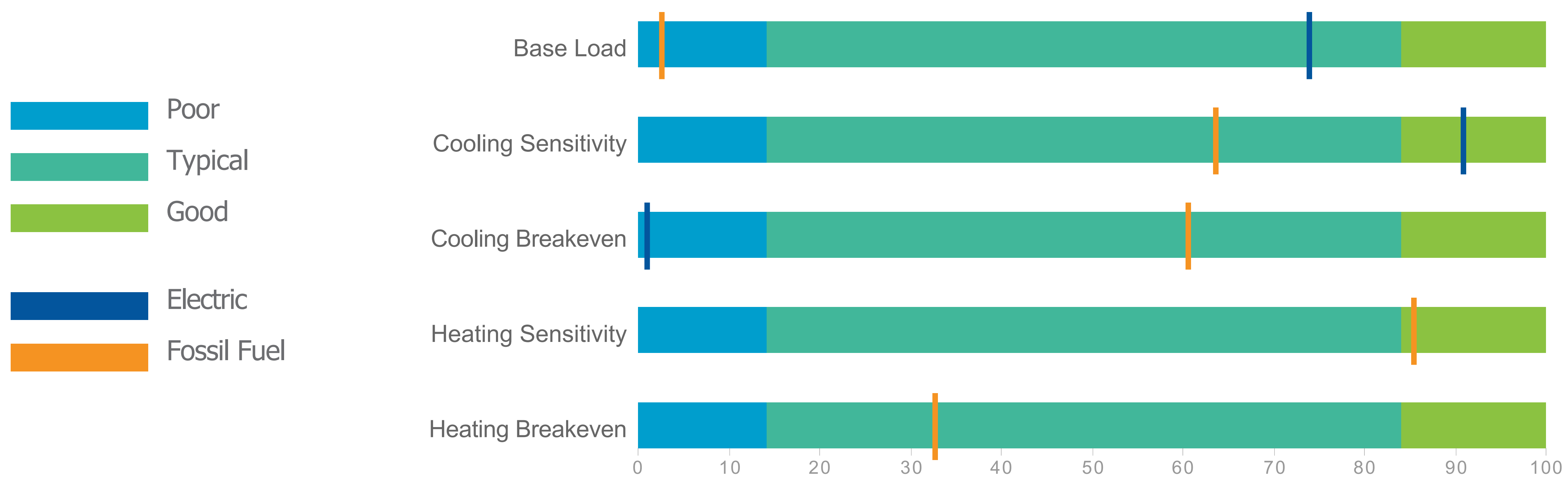
Total Potential Percentage Savings

18%

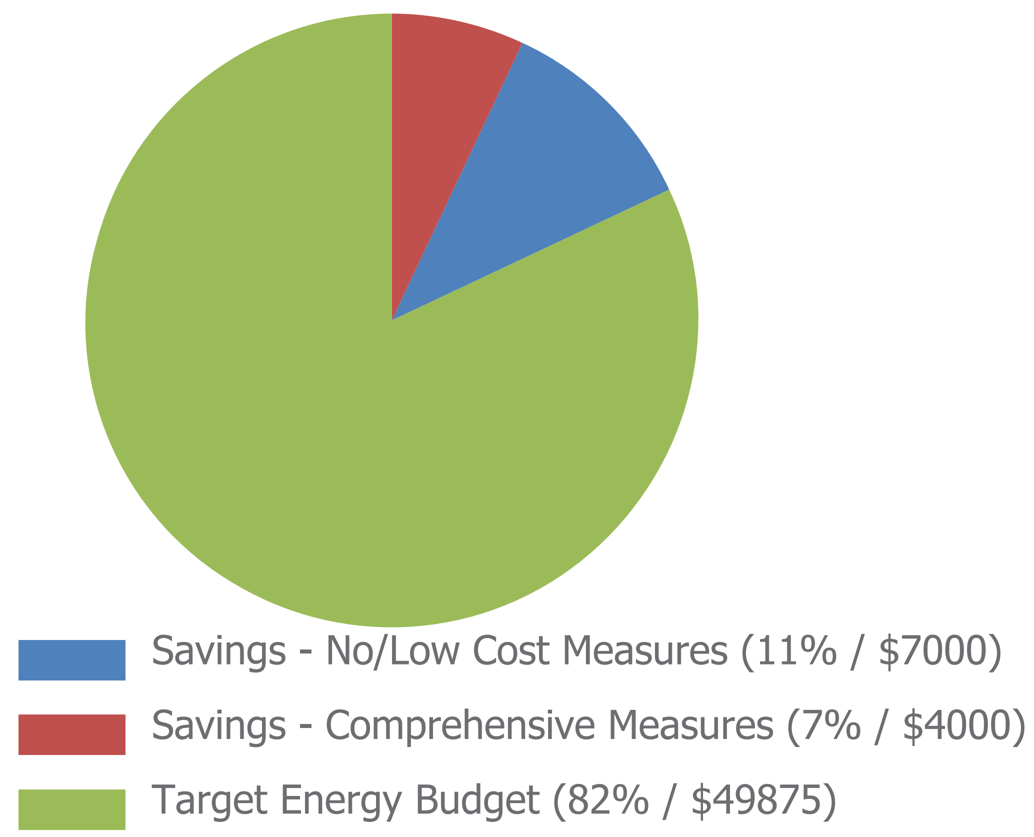
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Add fix economizers
- Decrease heating setpoints
- Check fossil fuel base load

Benchmark Metrics

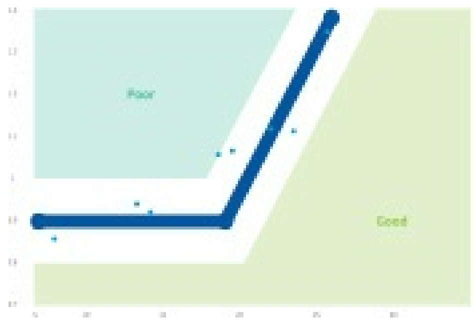


Savings Breakdown



Dana Samuel Trask Building - Other

Recommendations



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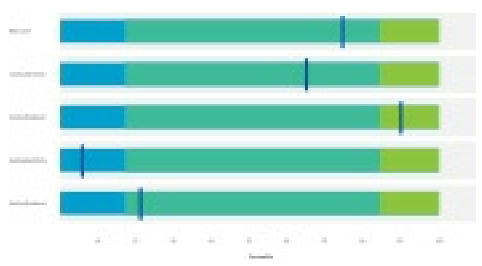

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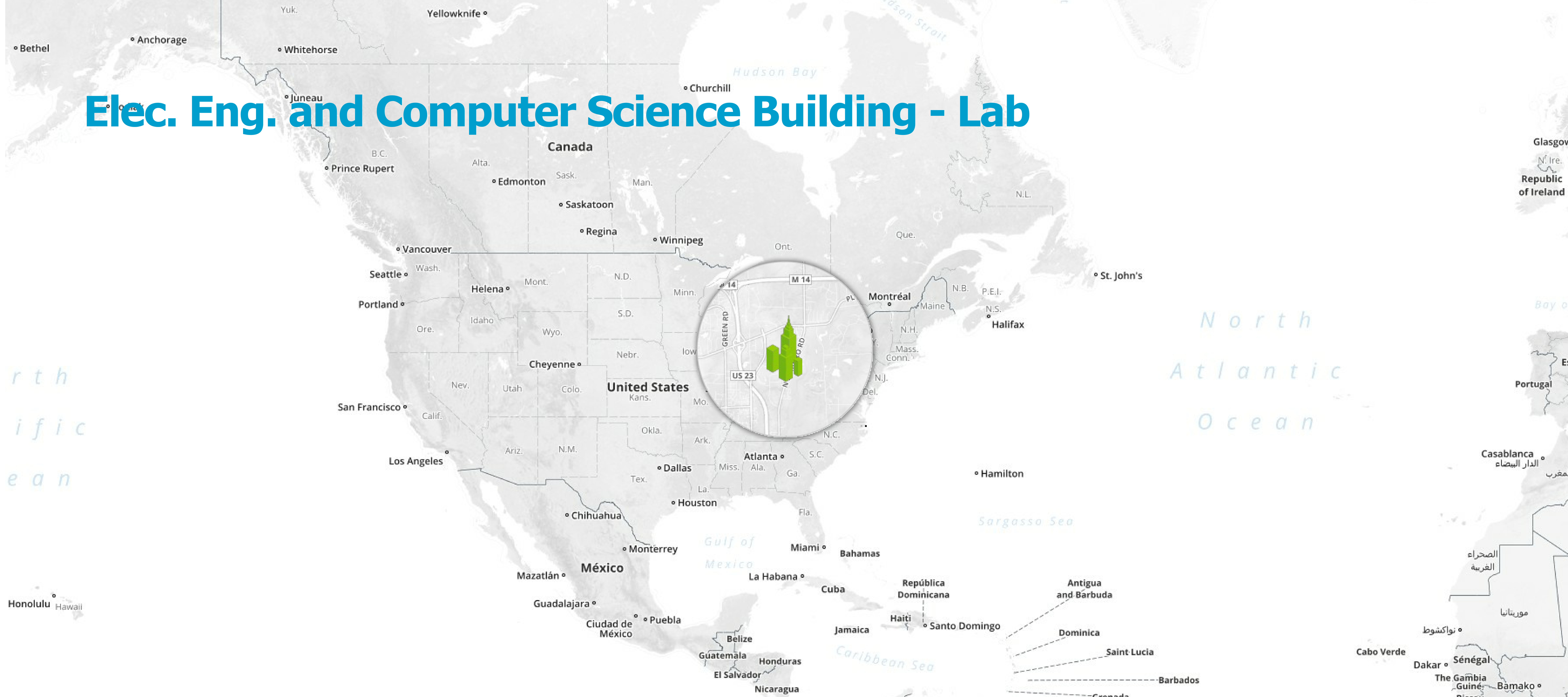
Elec. Eng. and Computer Science Building - Lab



Elec. Eng. and Computer Science Building - Lab

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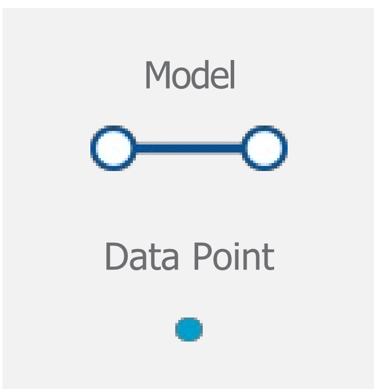
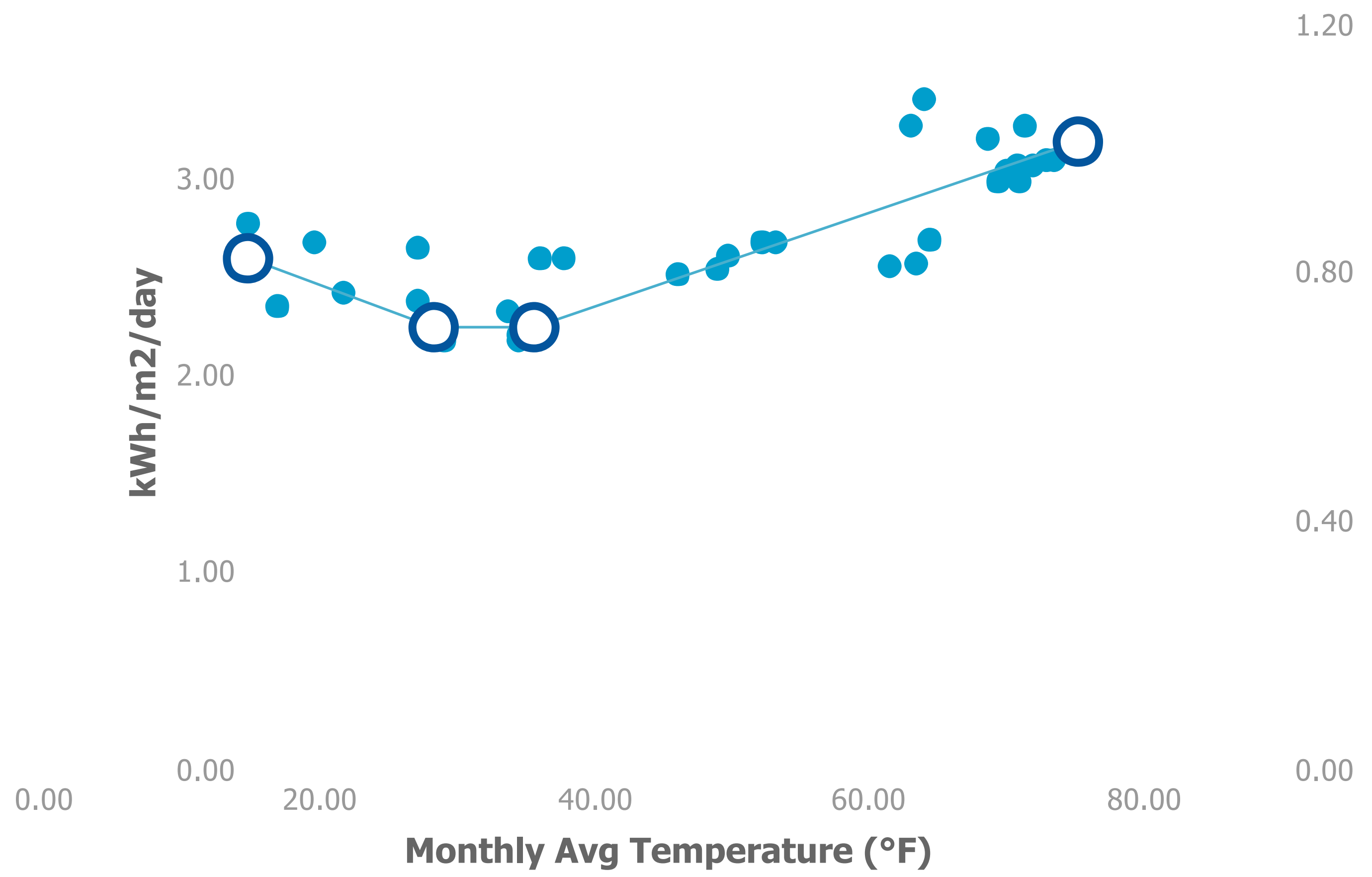
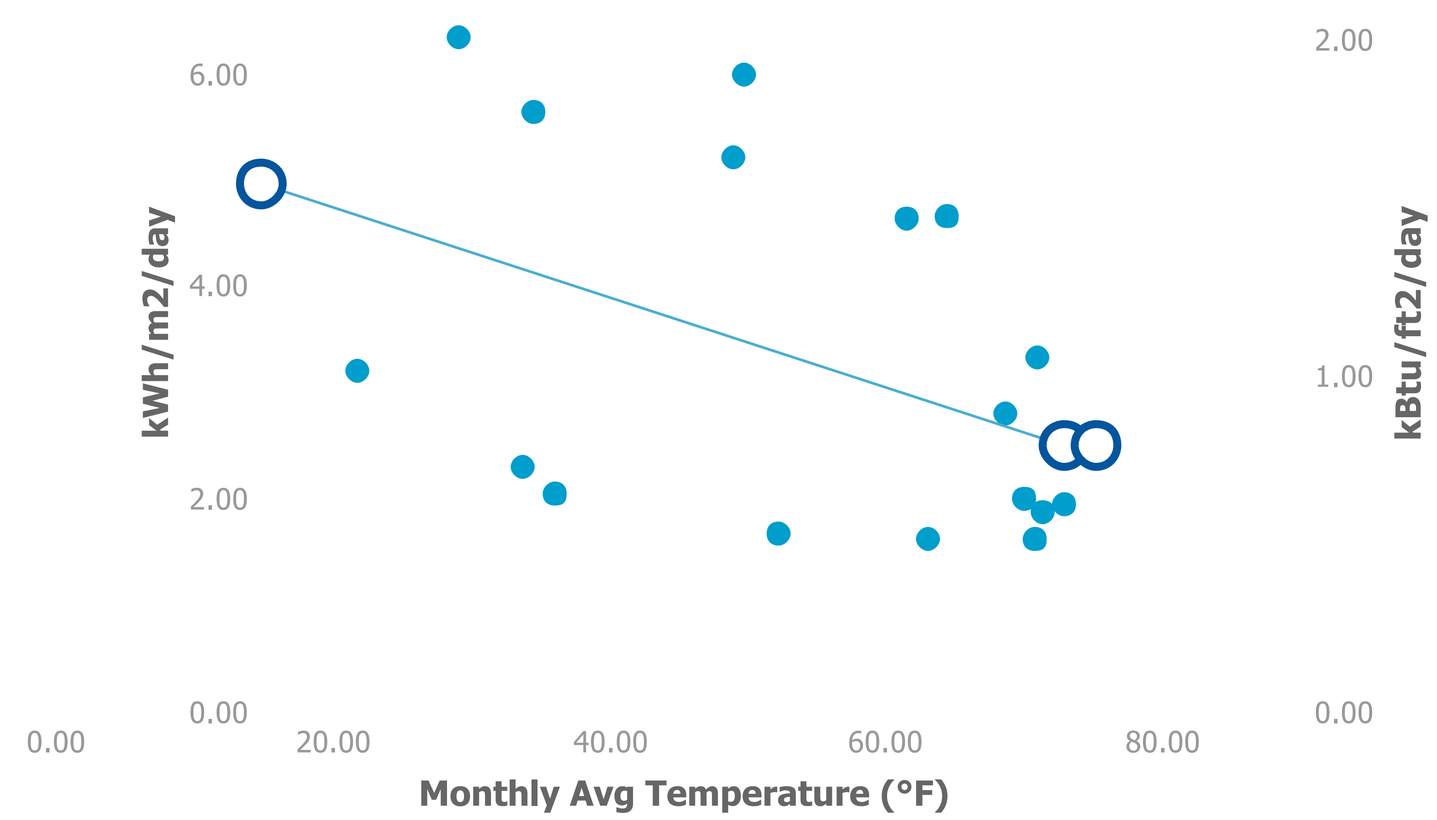


Electric



Fossil Fuel



Total Potential Location Savings

$500,000

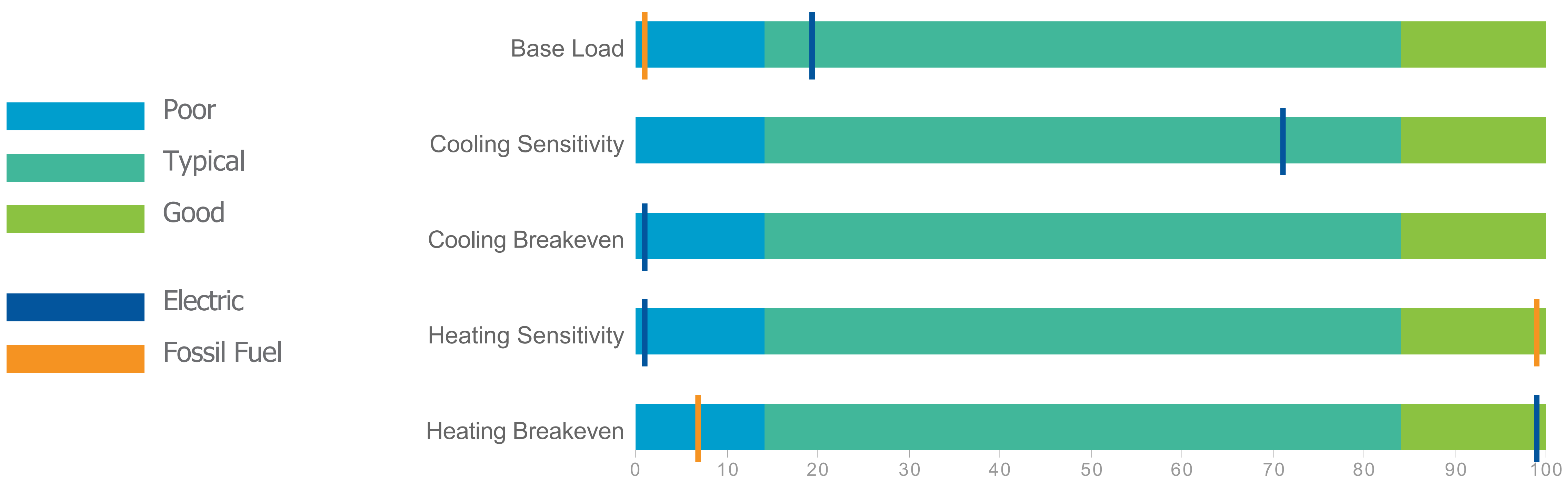
Total Potential Percentage Savings

37%

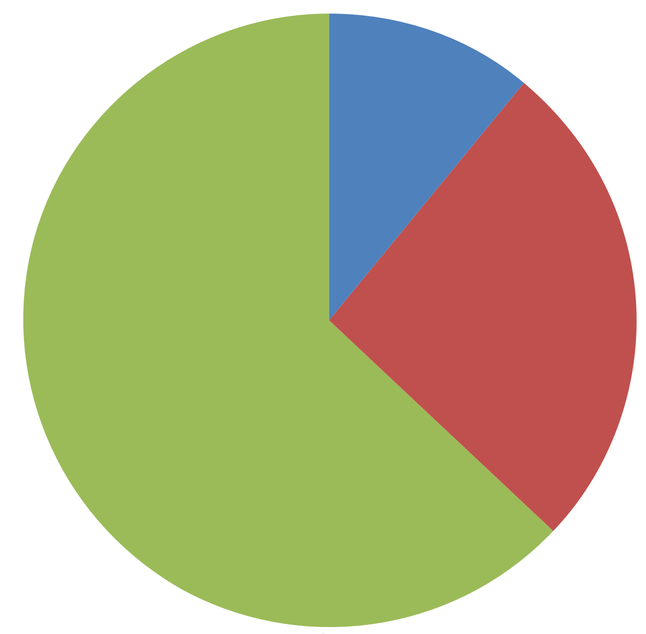
Recommendations

- Increase cooling setpoints
- Decrease heating setpoints
- Reduce equipment schedules
- Decrease ventilation
- Eliminate electric heating
- Decrease infiltration
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Increase heating system efficiency
- Add wall ceiling insulation
- Check fossil fuel base load

Benchmark Metrics



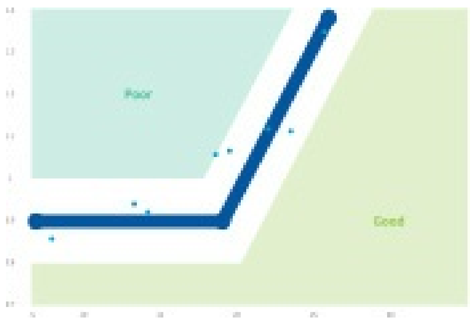
Savings Breakdown



Savings - No/Low Cost Measures (11% / $150000)
Savings - Comprehensive Measures (26% / $350000)
Target Energy Budget (63% / $864468)

Elec. Eng. and Computer Science Building - Lab

Recommendations



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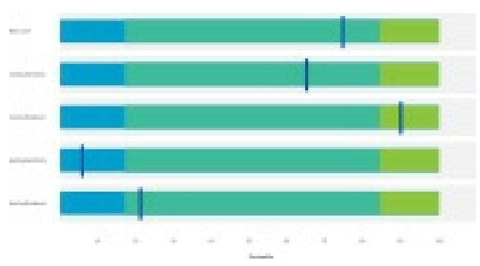

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Decrease Ventilation

Ventilation is the amount of fresh outside air that is brought into a building to provide comfortable and safe conditions for it's occupants. Look for opportunities to reduce the amount of ventilation air, thereby reducing the energy used to to condition and distribute it. Make sure to understand and follow all related building codes.

Eliminate Electric Heating

Check for any electric heating and re-heating of air delivered by air-handling and terminal units and for direct heating of building spaces. Where possible, eliminate or reduce these forms of heating and evaluate the economics of replacing them with fossil fuel based or other non-electric forms of heating.

Decrease Infiltration

Infiltration is the amount of uncontrolled outside air that is brought into a building. Unlike ventilation, it is uncontrolled and generally adds to the overall building cooling and heating loads. Infiltration is reduced with caulking, weather stripping, and upgrades in envelope components (e.g. windows, doors, air intakes & exhausts).

Reduce Lighting Load

Lighting loads are reduced by improving both the control and efficiency of the lighting and by taking advantagve of natural daylighting whenever possible. Existing or upgraded controls are used to dim and turn-off the lights appropriately; and lighting efficiency is improved by upgrading the bulbs and fixtures. Daylight utililtzation can be improved with better control of lights that are near existing windows and skylights, and with renovations to the building envelope and internal space configurations.

Reduce Plug Loads

Plug loads include anything that is plugged into standard electric recpetecals or outlets (e.g. personal computers, printers, coffee-makers, other office/lab/light-mfg equipment). Plug load reductions are accomplished by controlling/scheduling them where possible and upgrading the plugged in equipment to newer, more-efficient models.

Add Fix Economizers

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Increase Heating System Efficiency

The overall performance of the heating equipment and systems in this building is below the typical performance found in similar buildings. Check all heating related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Add Wall Ceiling Insulation

Heating and cooling loads are reduced by adding insulation to building walls, ceilings, and foundations.

Check Fossil Fuel Base Load

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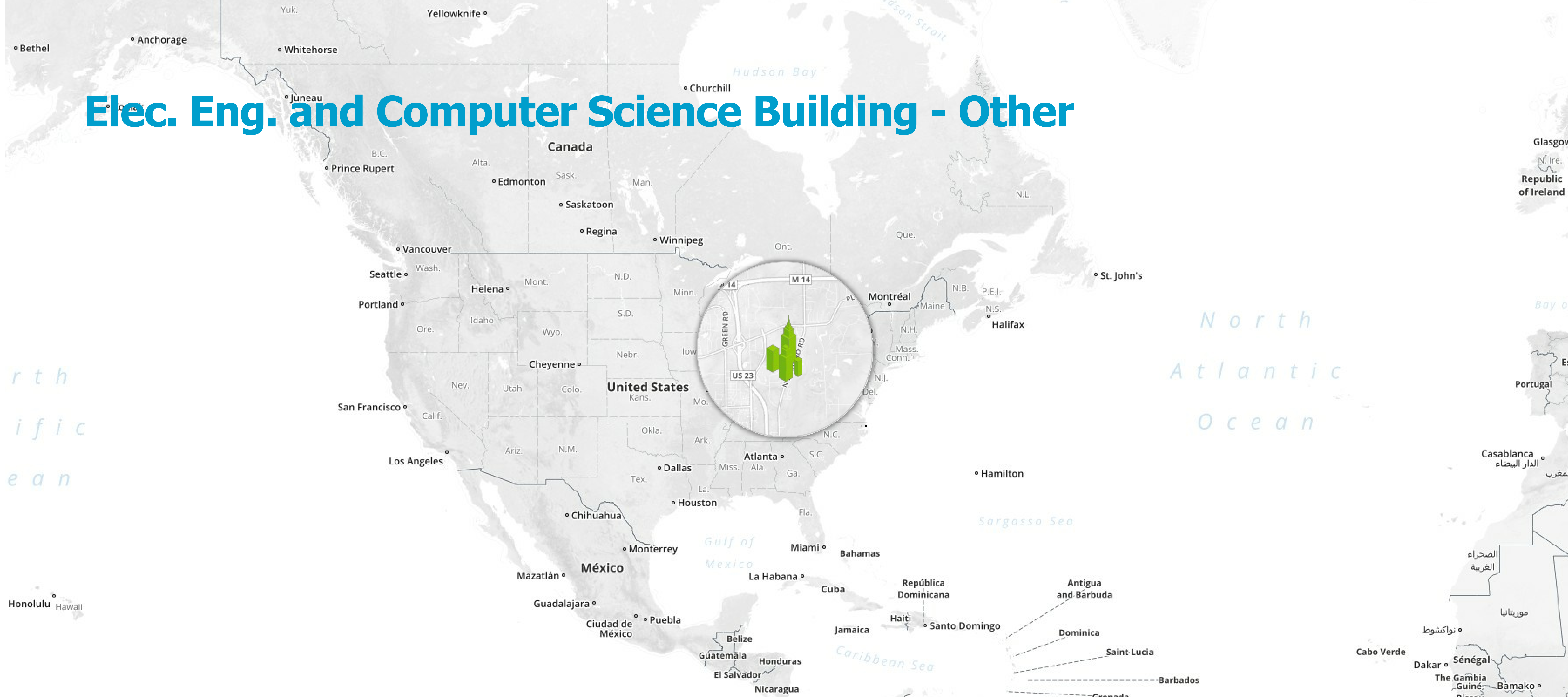
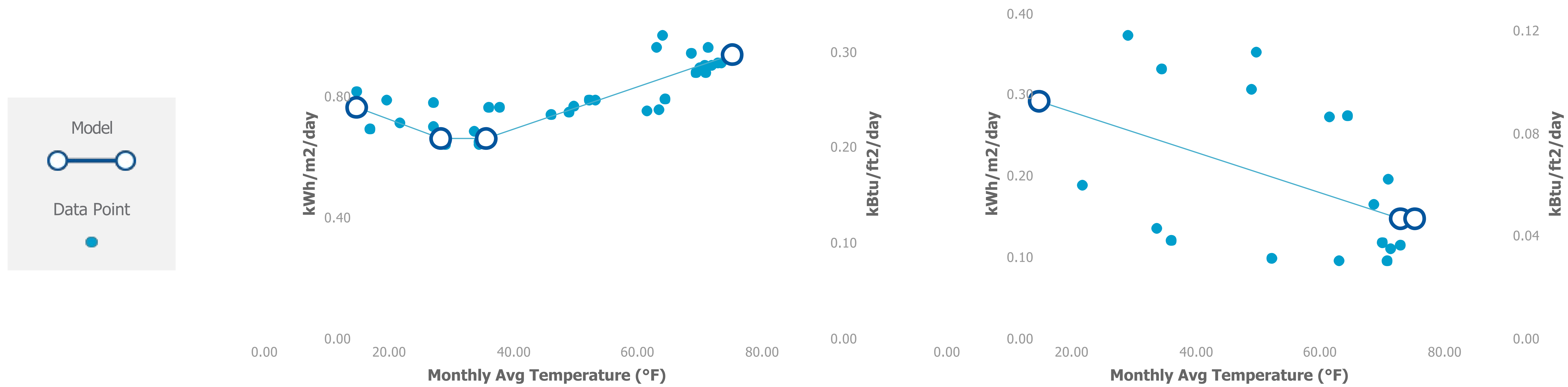
Elec. Eng. and Computer Science Building - Other



Elec. Eng. and Computer Science Building - Other

Weather Sensitivity



Total Potential Location Savings

$100,000

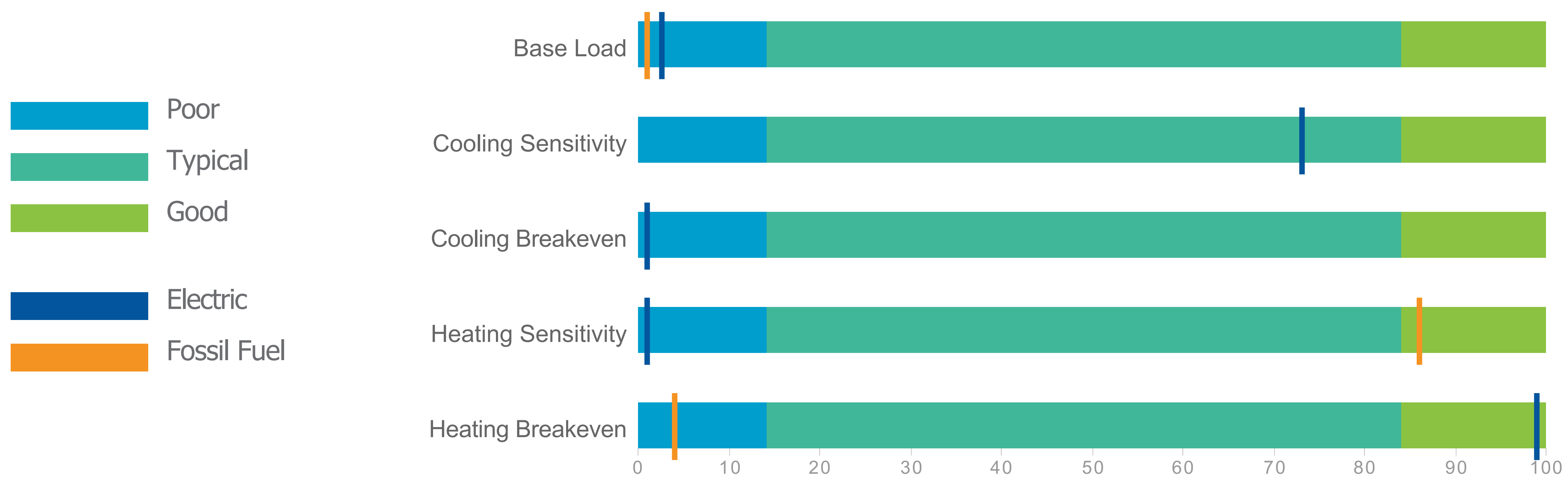
Total Potential Percentage Savings

28%

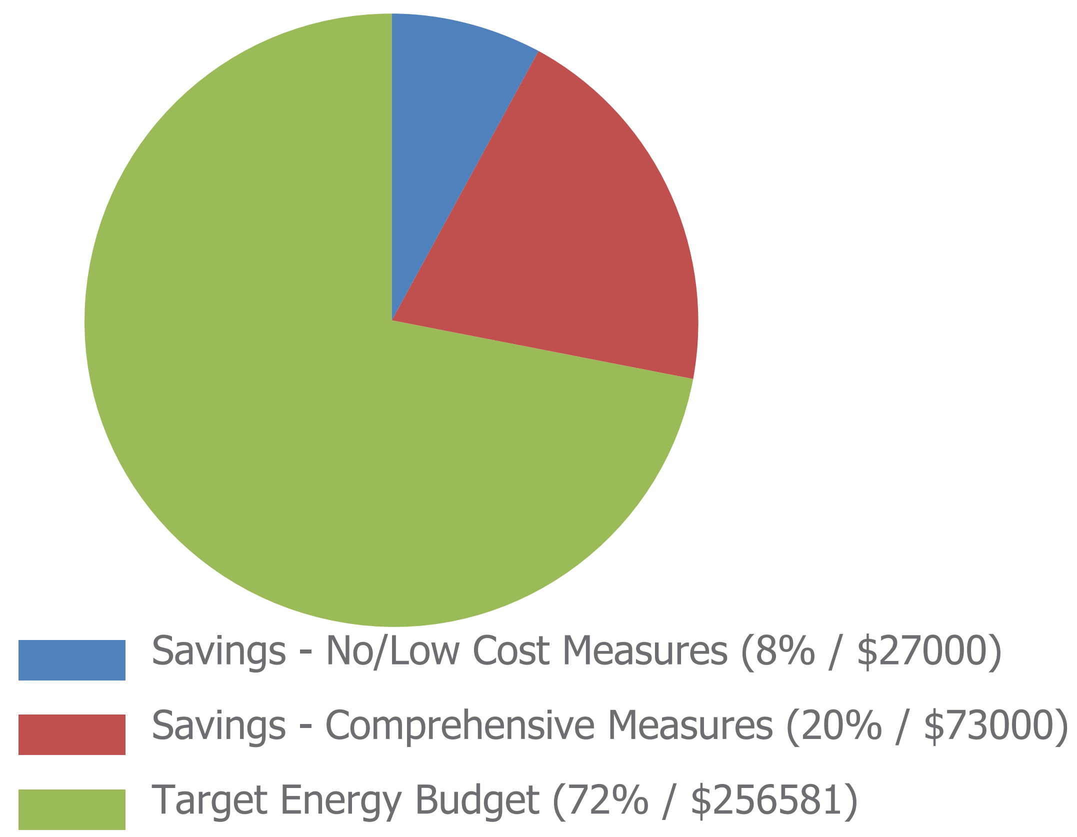
Recommendations

- Increase cooling setpoints
- Decrease heating setpoints
- Reduce equipment schedules
- Eliminate electric heating
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

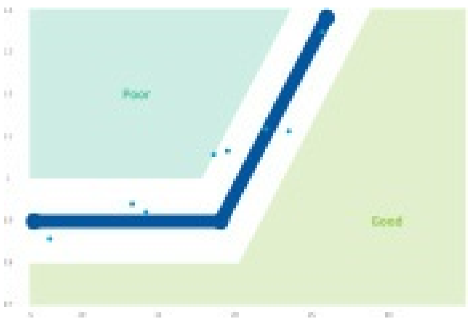


Savings Breakdown



Elec. Eng. and Computer Science Building - Other

Recommendations



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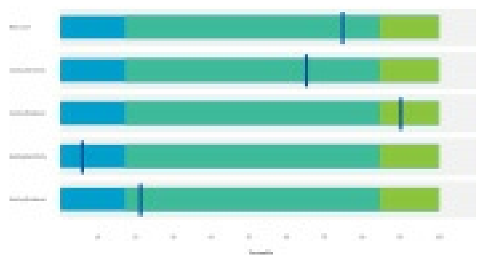

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Increase Cooling Setpoints

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Decrease Heating Setpoints

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Reduce Equipment Schedules

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Eliminate Electric Heating

Check for any electric heating and re-heating of air delivered by air-handling and terminal units and for direct heating of building spaces. Where possible, eliminate or reduce these forms of heating and evaluate the economics of replacing them with fossil fuel based or other non-electric forms of heating.

Reduce Lighting Load

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Add Fix Economizers

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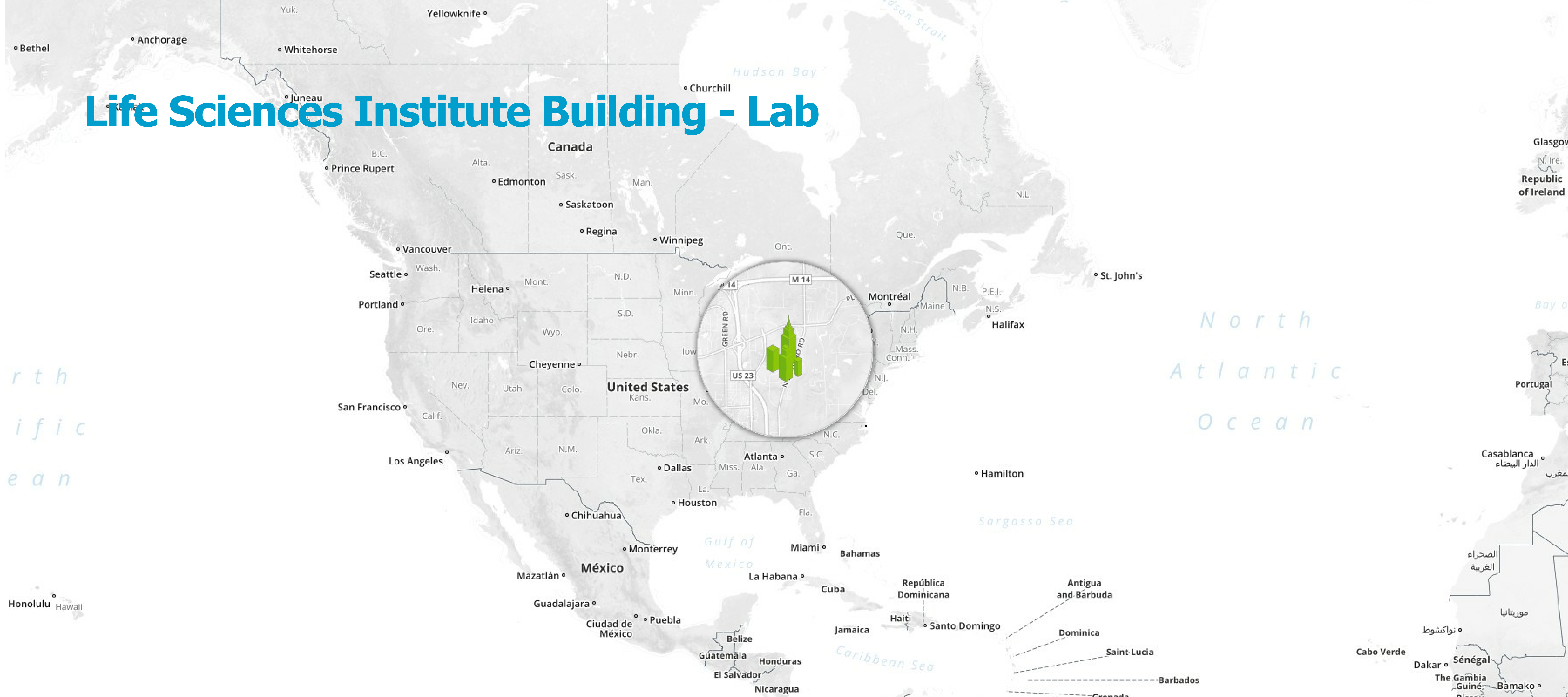
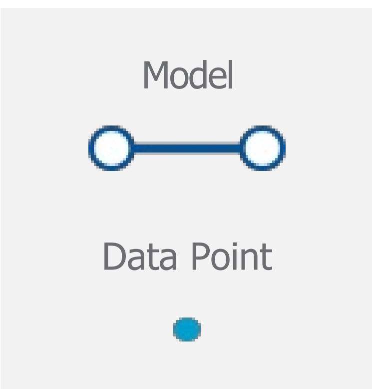
The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Life Sciences Institute Building - Lab

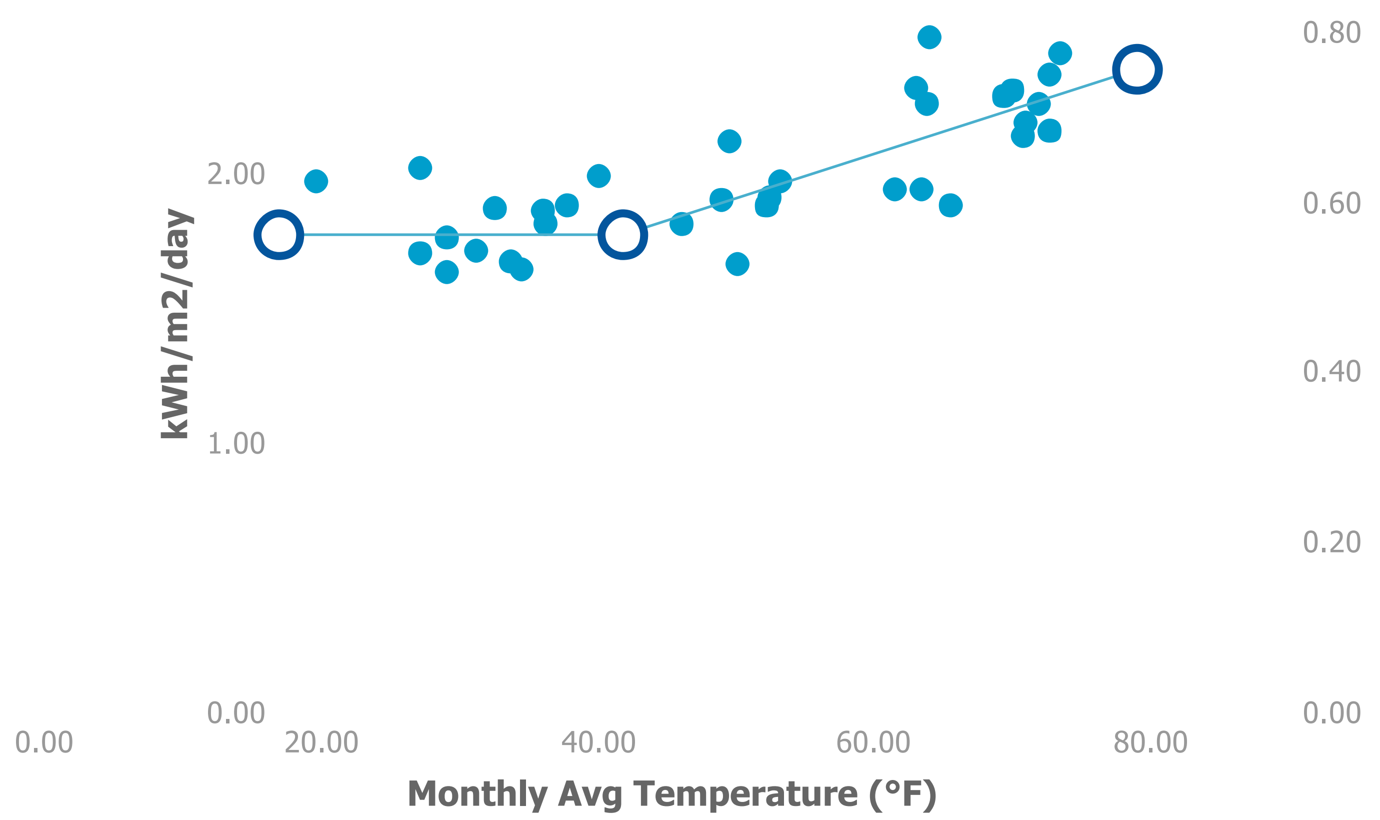


Life Sciences Institute Building - Lab

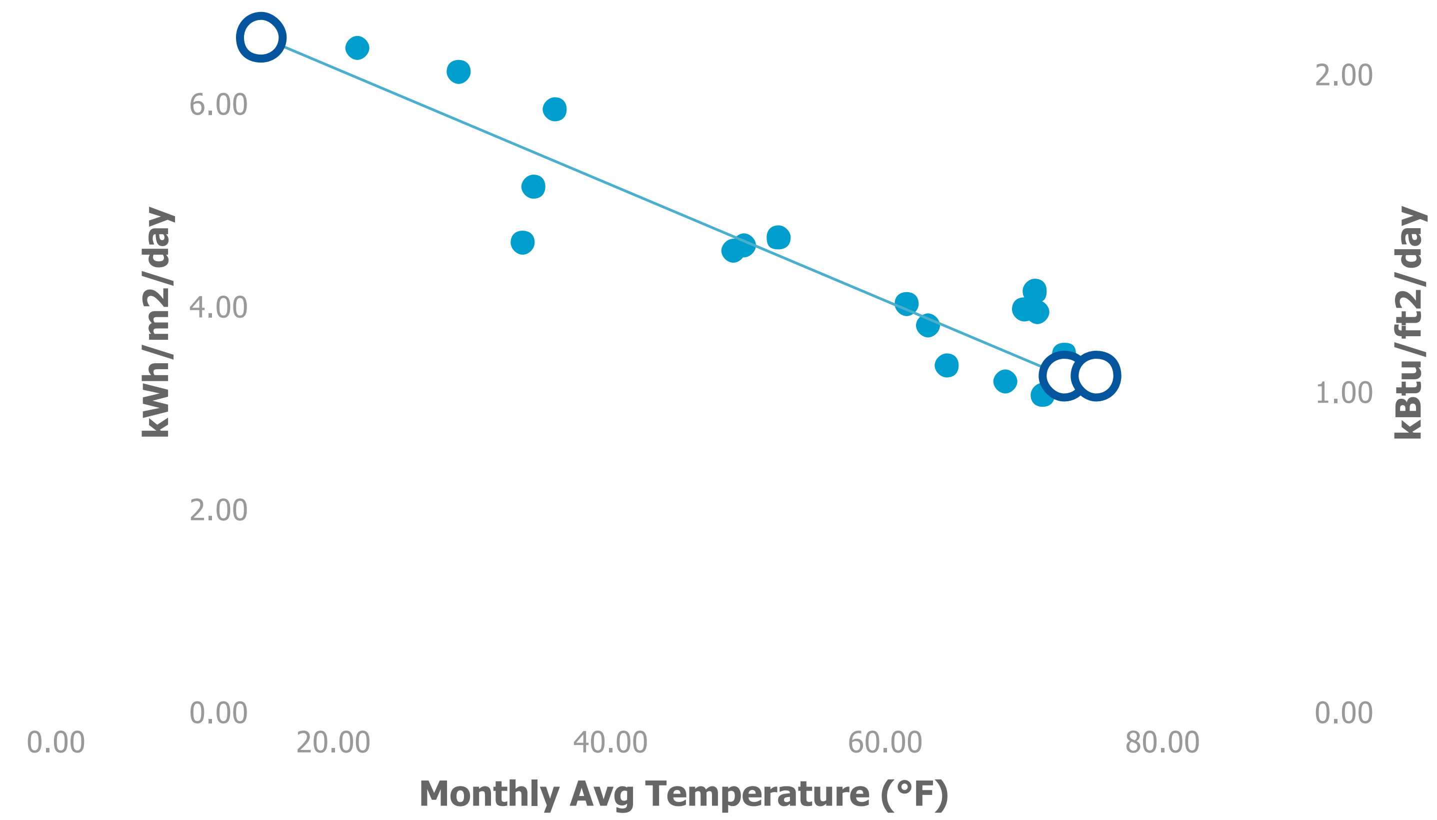
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$440,000

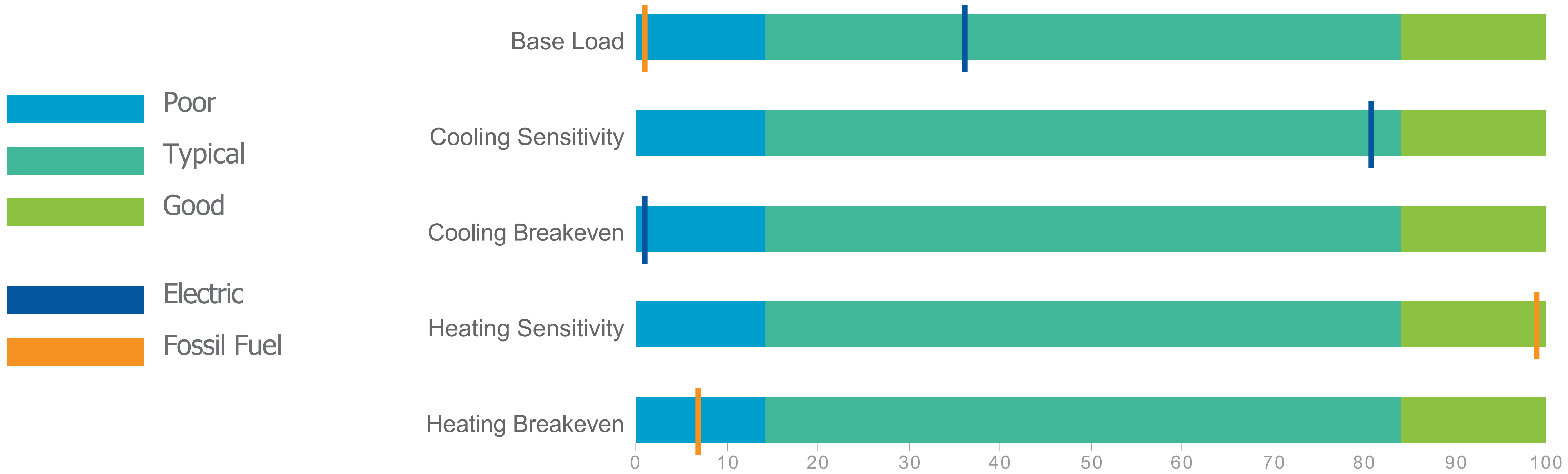
Total Potential Percentage Savings

22%

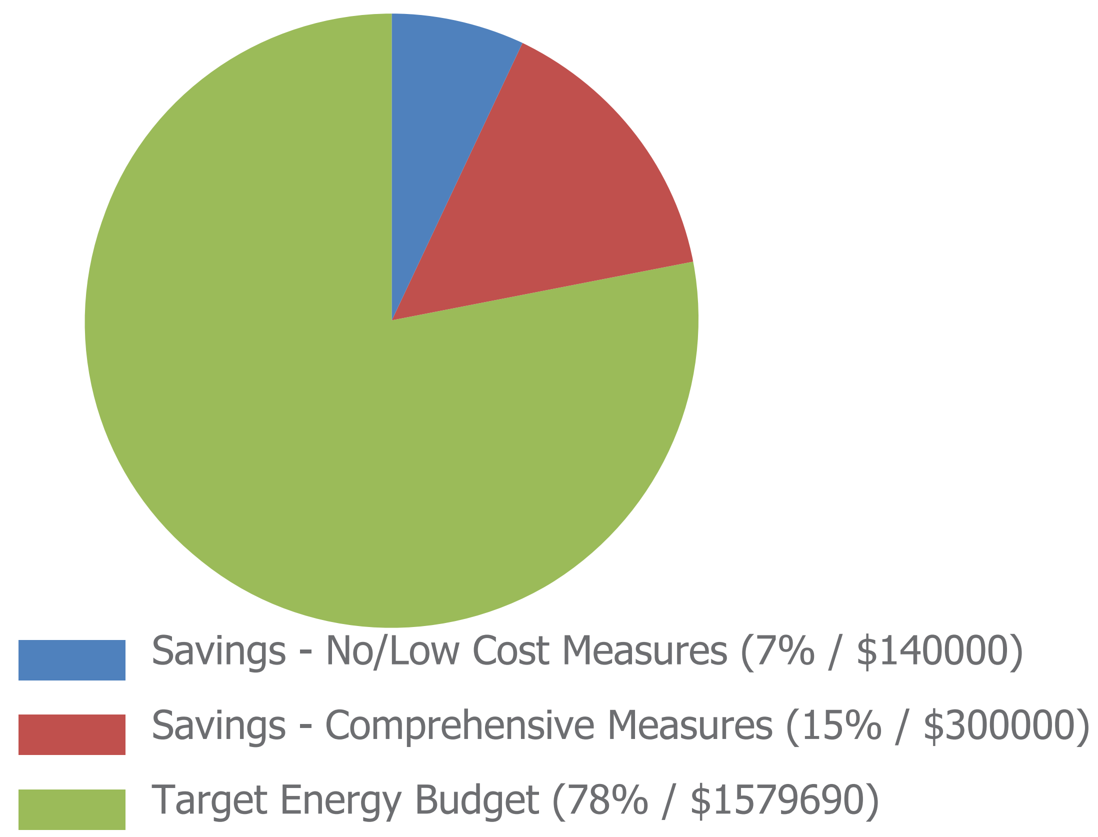
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Decrease heating setpoints
- Check fossil fuel base load

Benchmark Metrics

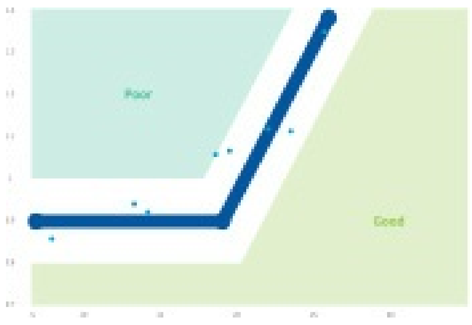


Savings Breakdown



Life Sciences Institute Building - Lab

Recommendations



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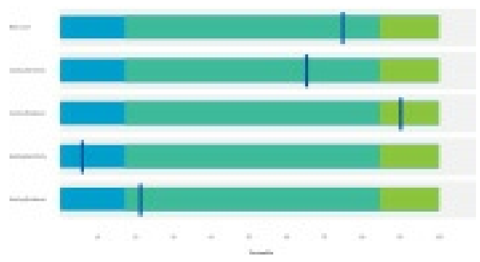

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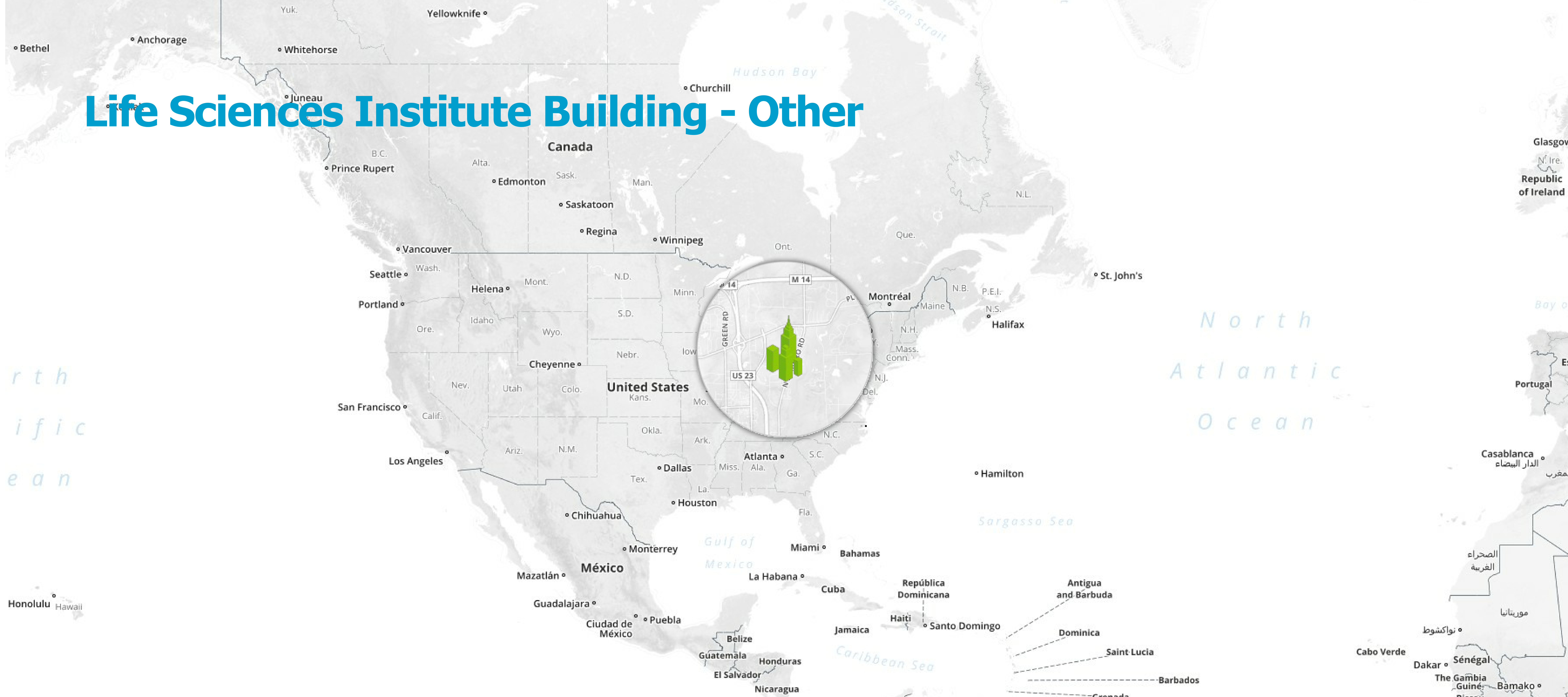
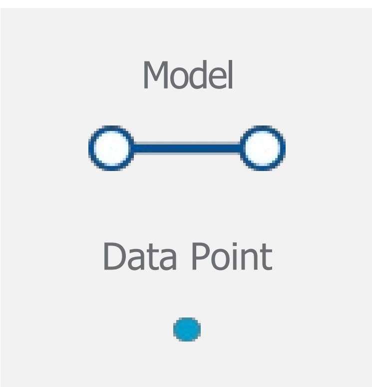
Life Sciences Institute Building - Other

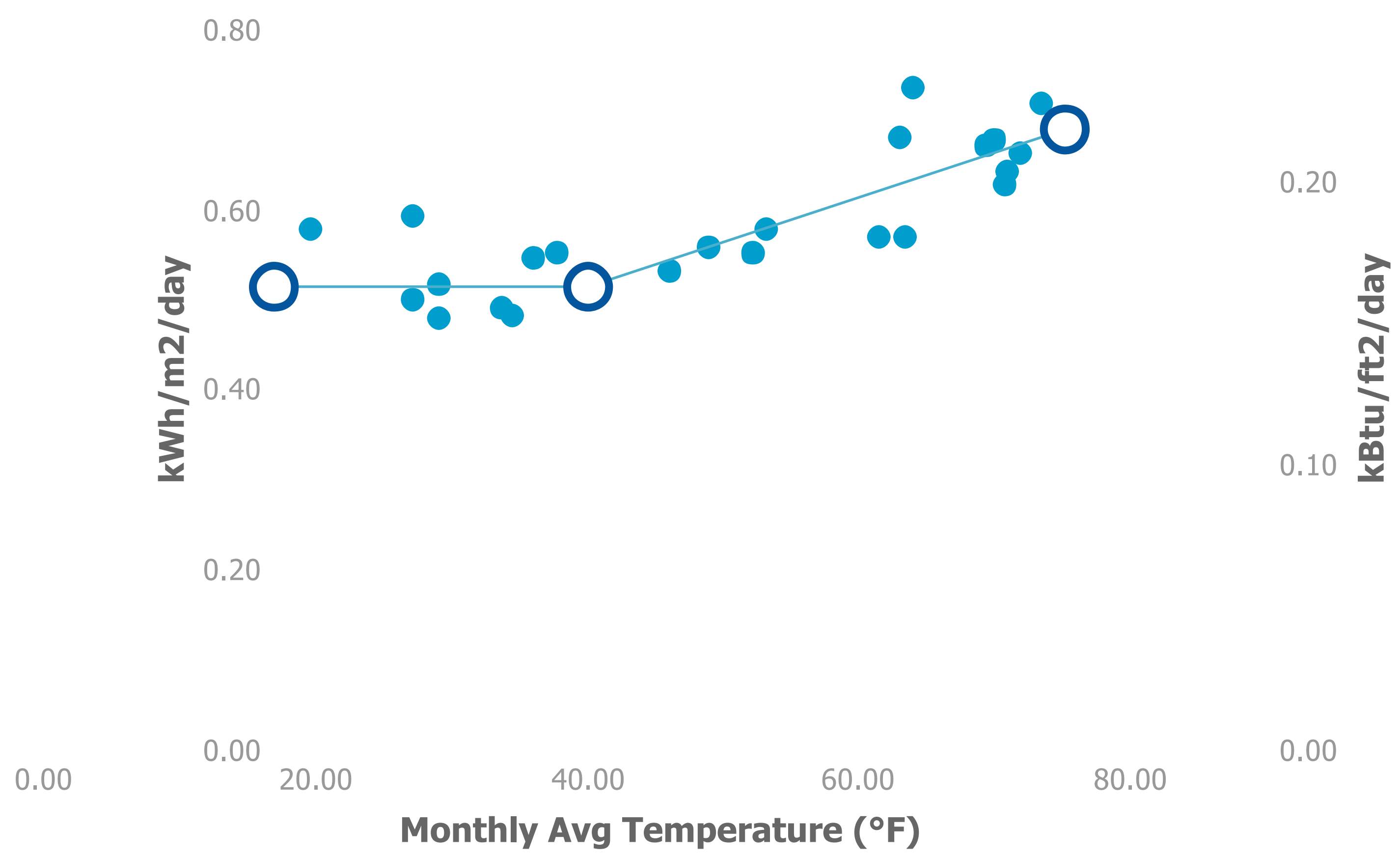


Life Sciences Institute Building - Other

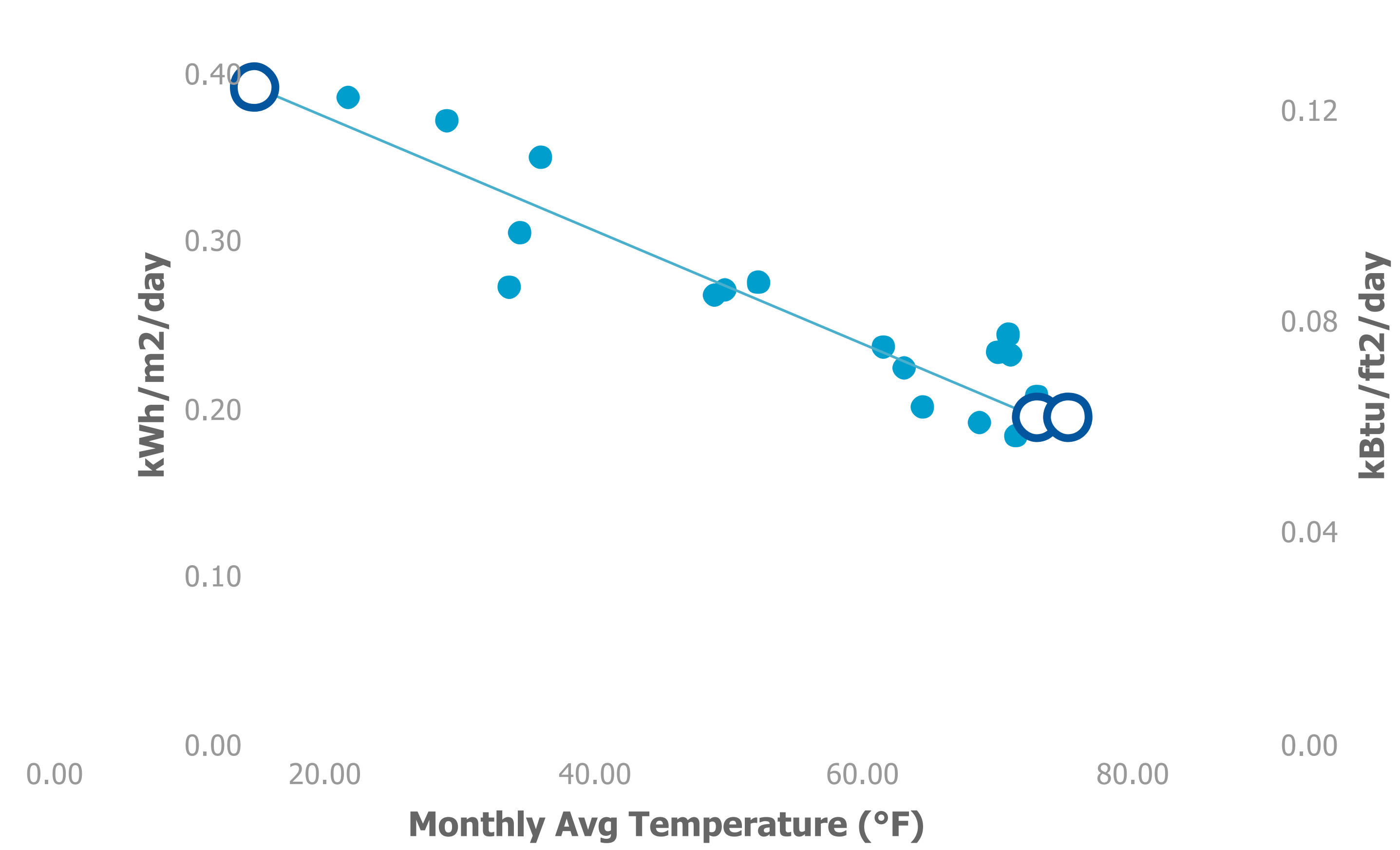
Weather Sensitivity

Electric





Fossil Fuel



Total Potential Location Savings

$100,000

Total Potential Percentage Savings

40%

Recommendations

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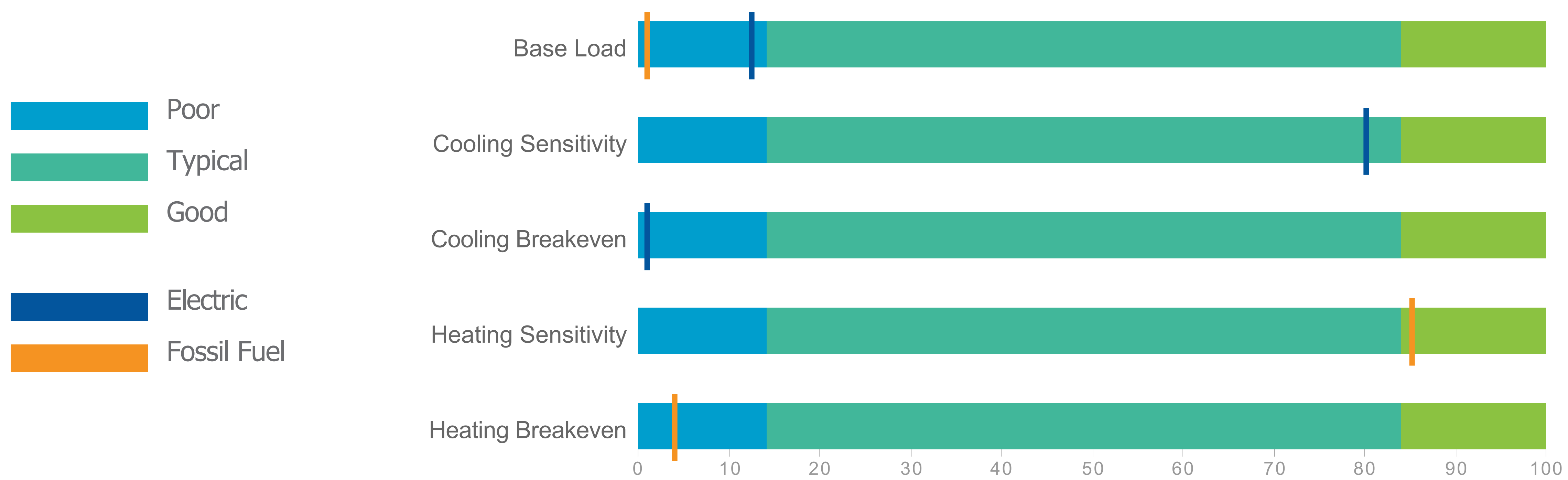
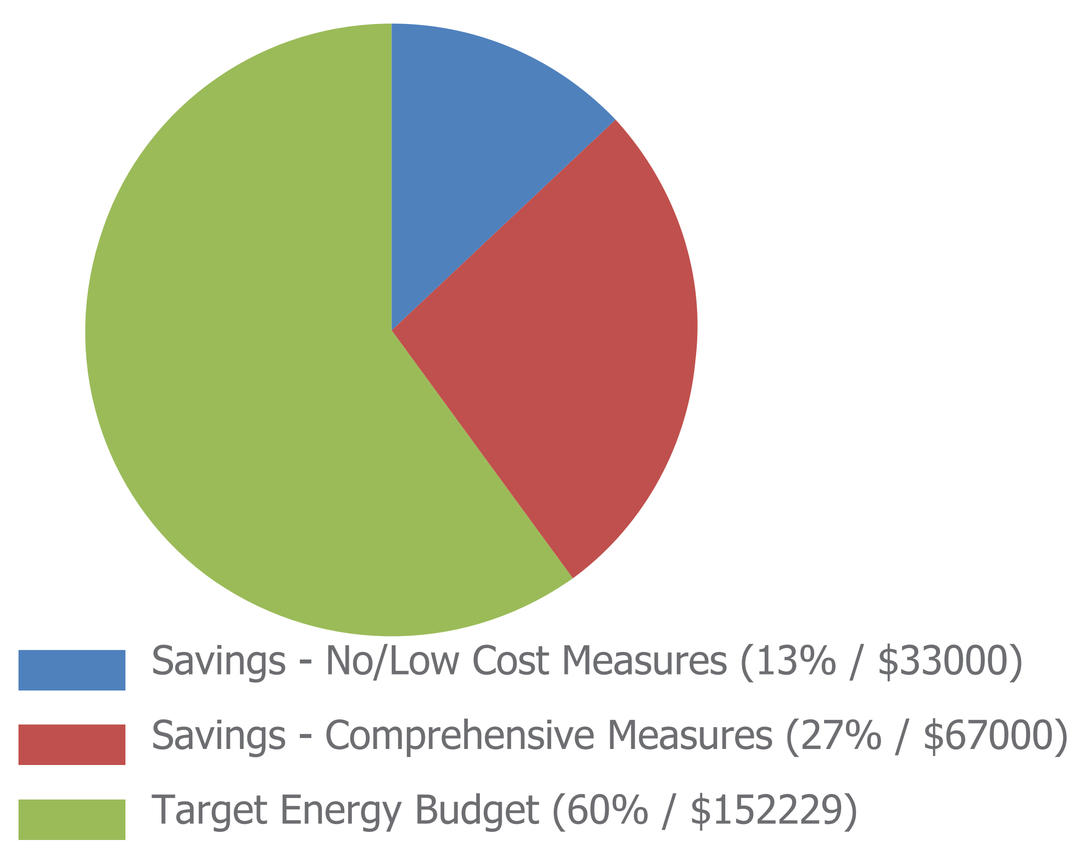
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Decrease heating setpoints
- Check fossil fuel base load

Benchmark Metrics

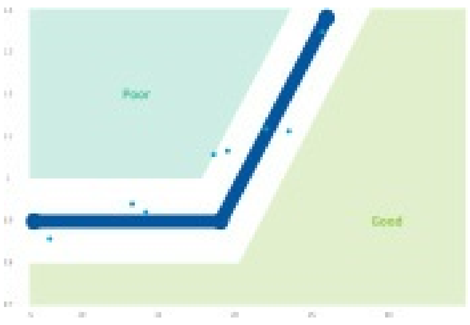


Savings Breakdown



Life Sciences Institute Building - Other

Recommendations



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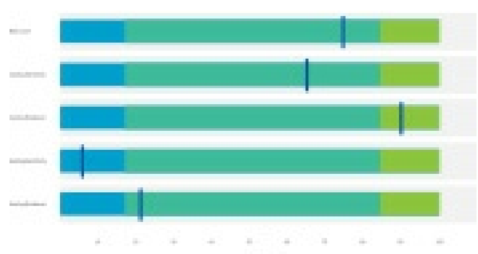

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Check Fossil Fuel Base Load

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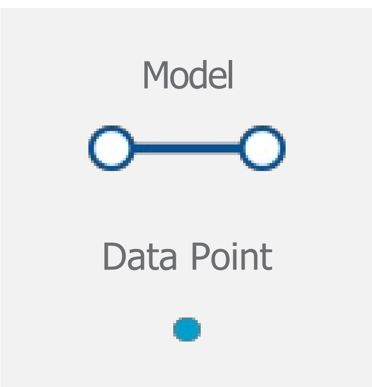
Medical Sciences Research Building III - Lab

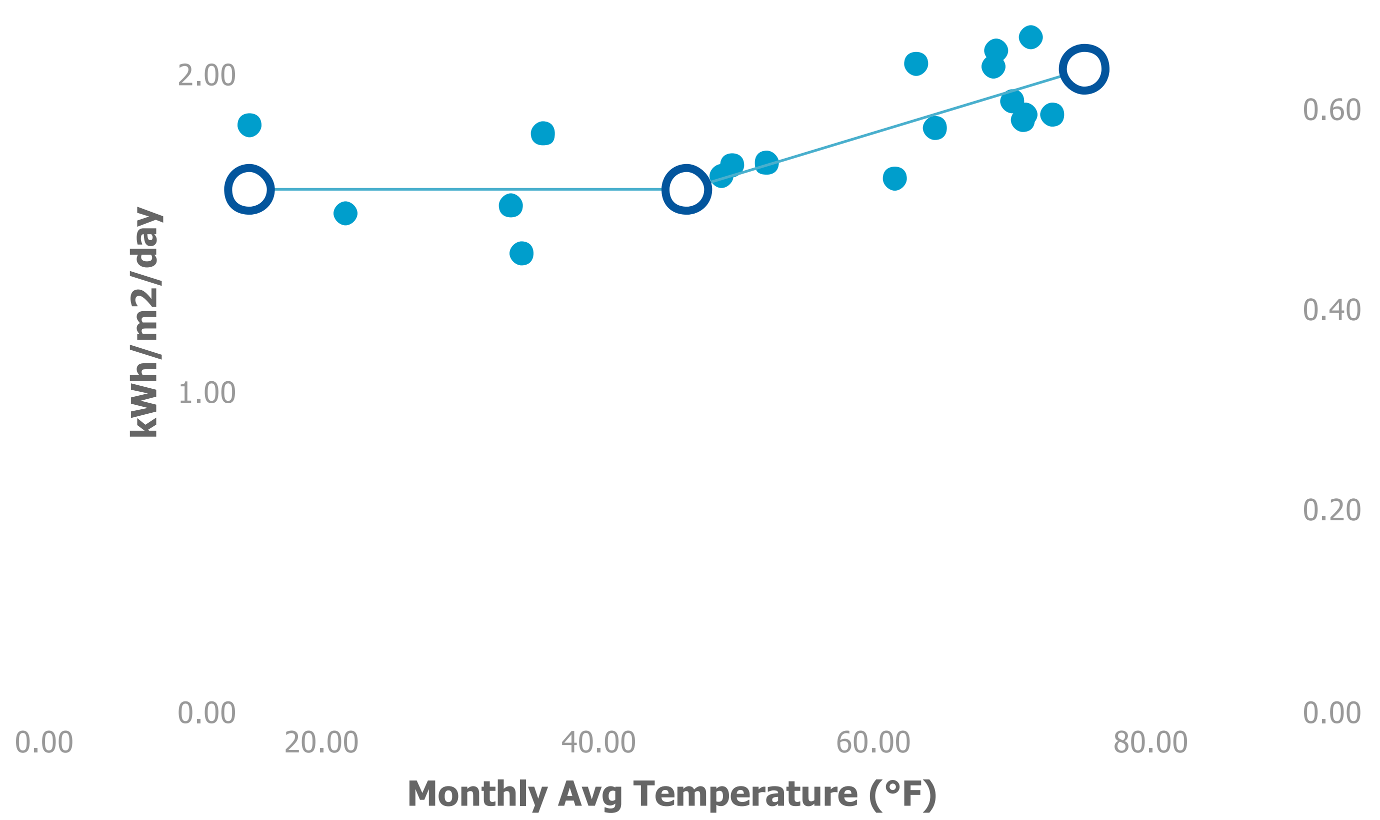
Medical Sciences Research Building III - Lab

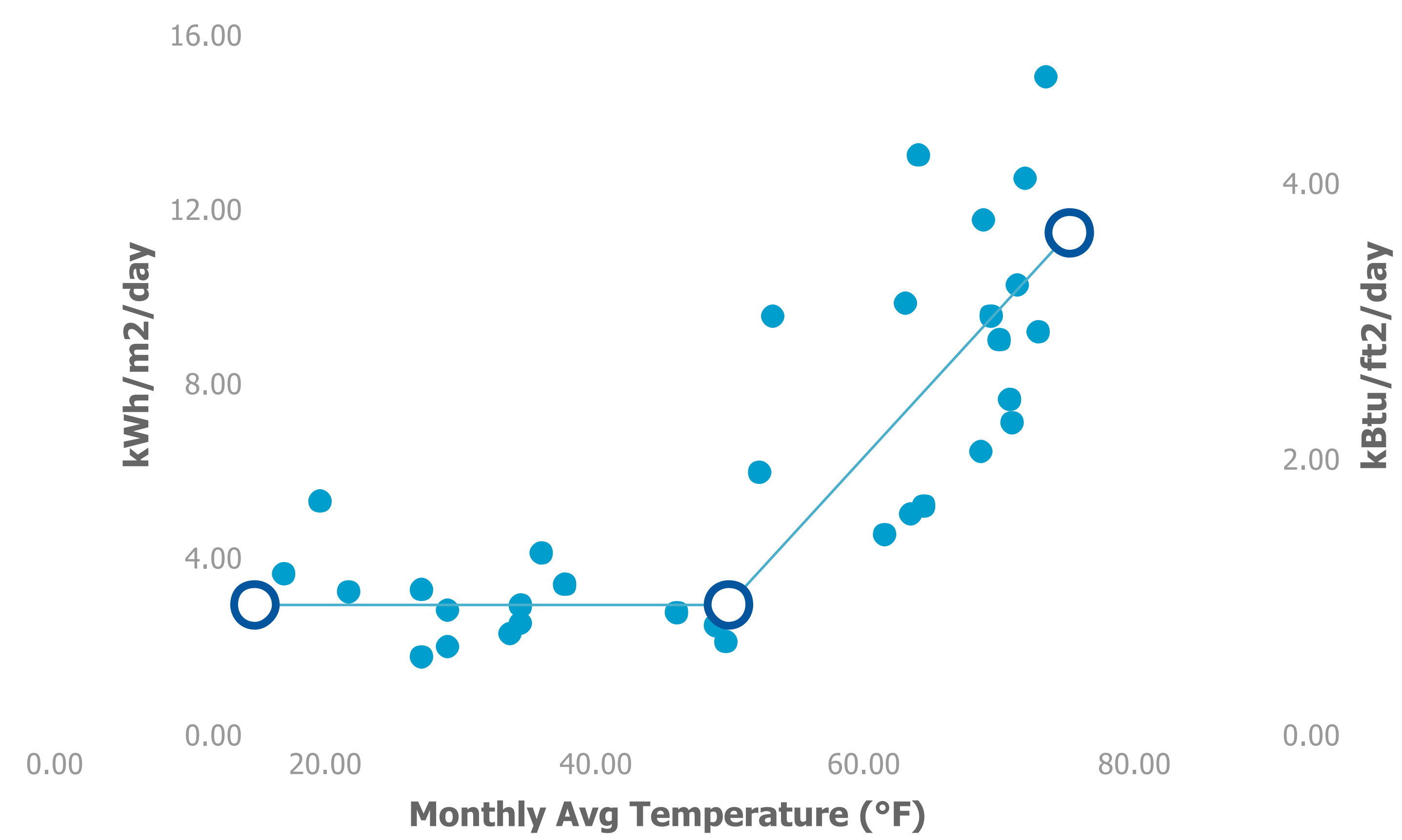
Weather Sensitivity

Electric

Fossil Fuel







Total Potential Location Savings

$290,000

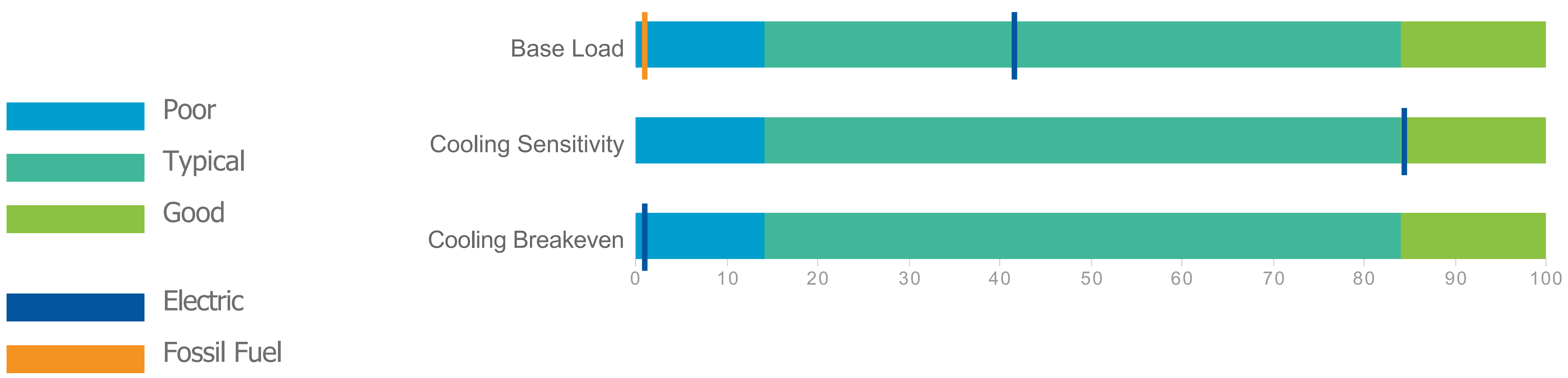
Total Potential Percentage Savings

14%

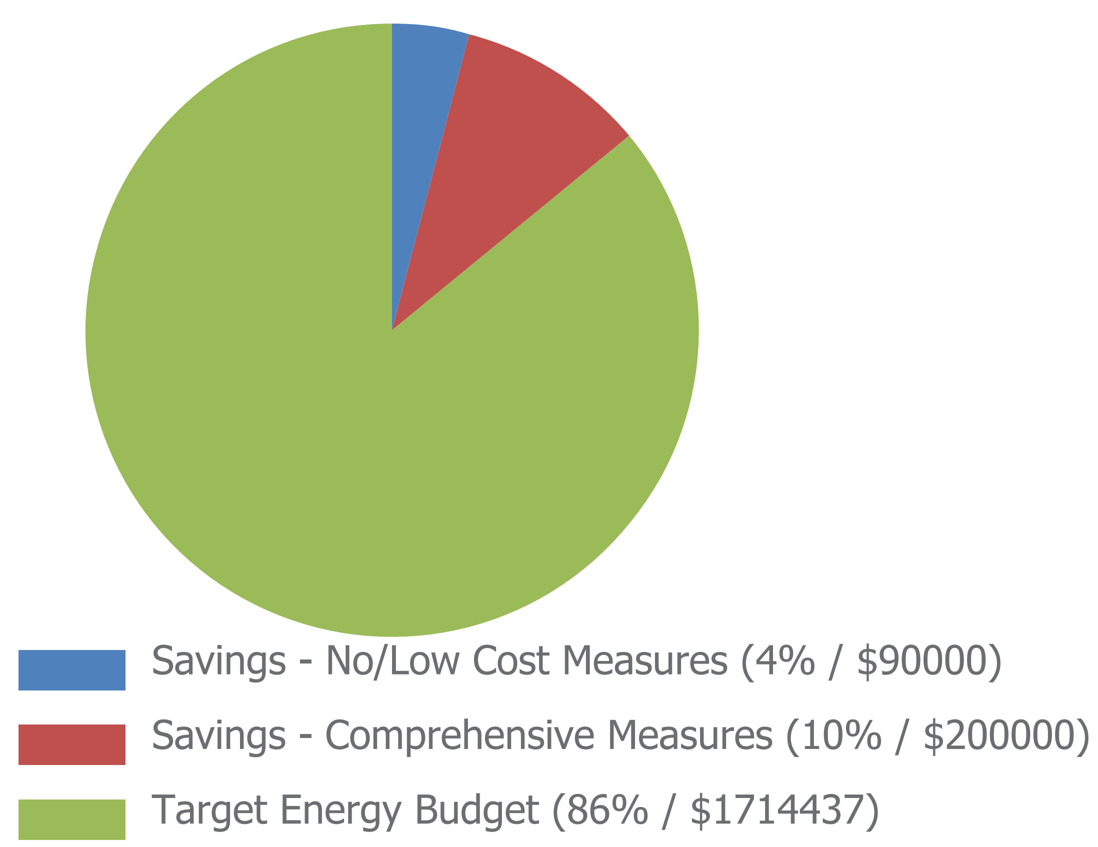
Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

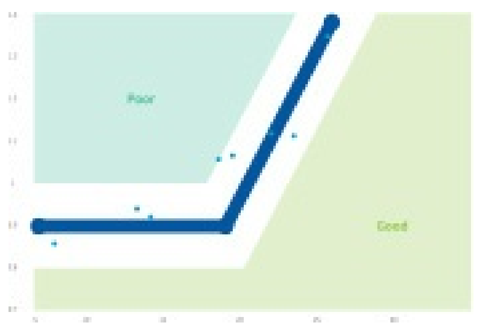


Savings Breakdown



Medical Sciences Research Building III - Lab

Recommendations



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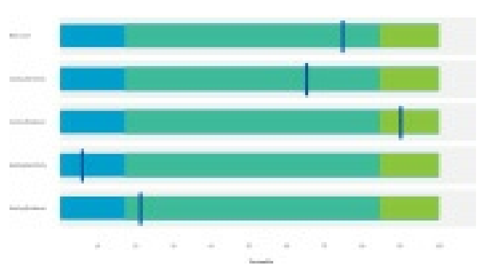

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Check Fossil Fuel Base Load

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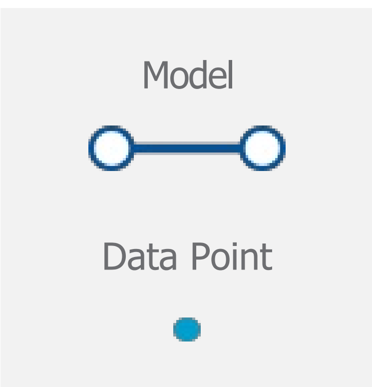
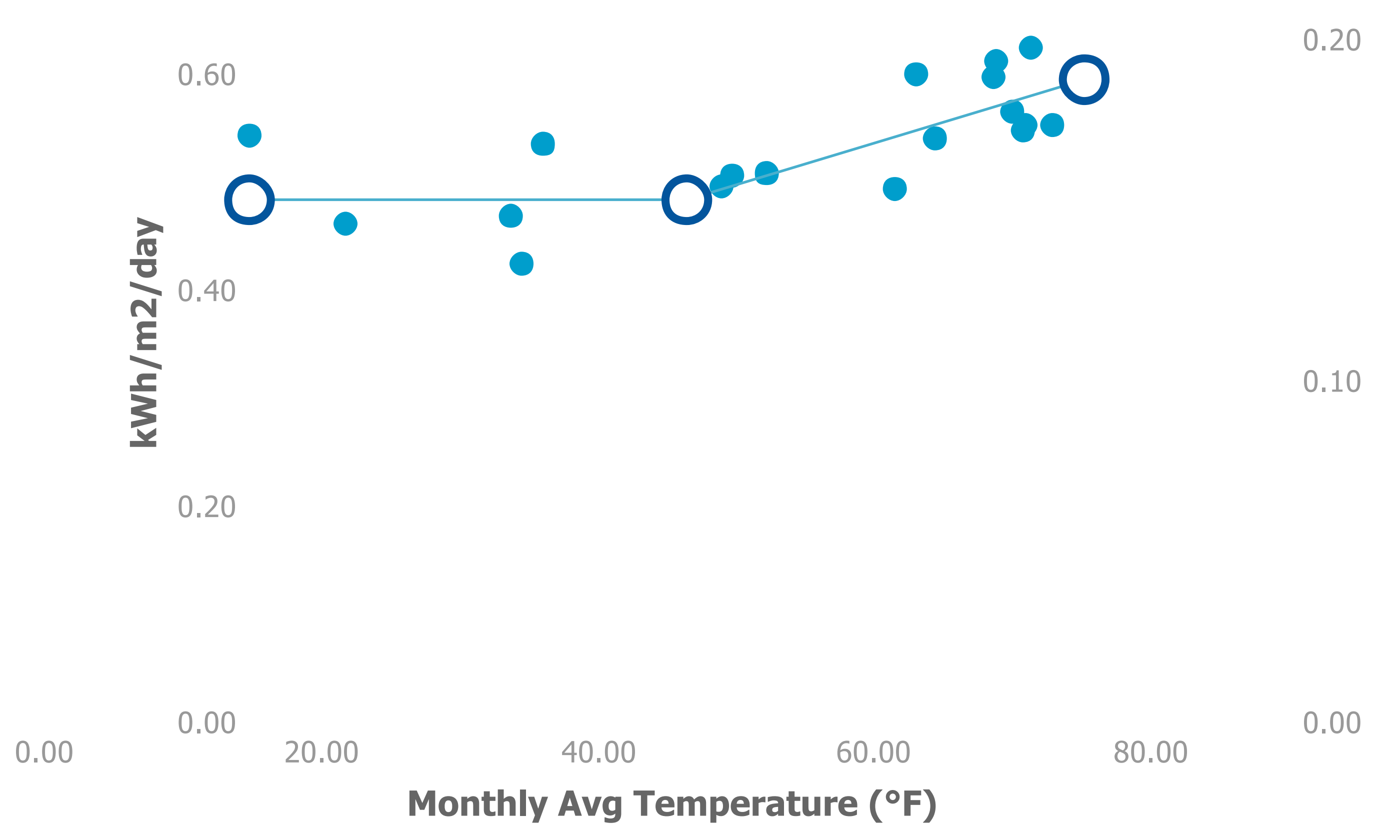
Medical Sciences Research Building III - Other

Medical Sciences Research Building III - Other

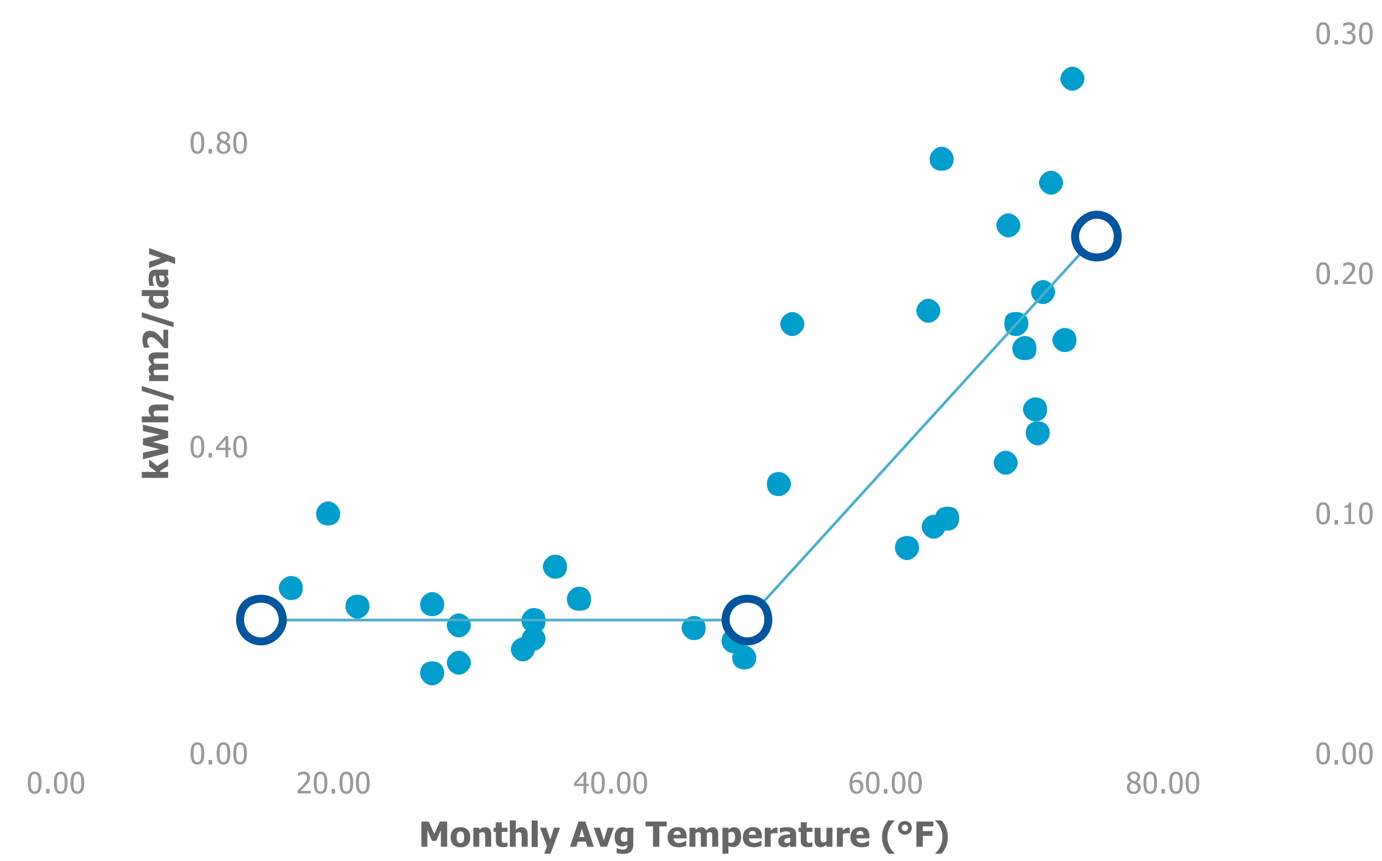
Weather Sensitivity



Electric



Fossil Fuel



Total Potential Location Savings

$43,000

Total Potential Percentage Savings

38%

Recommendations

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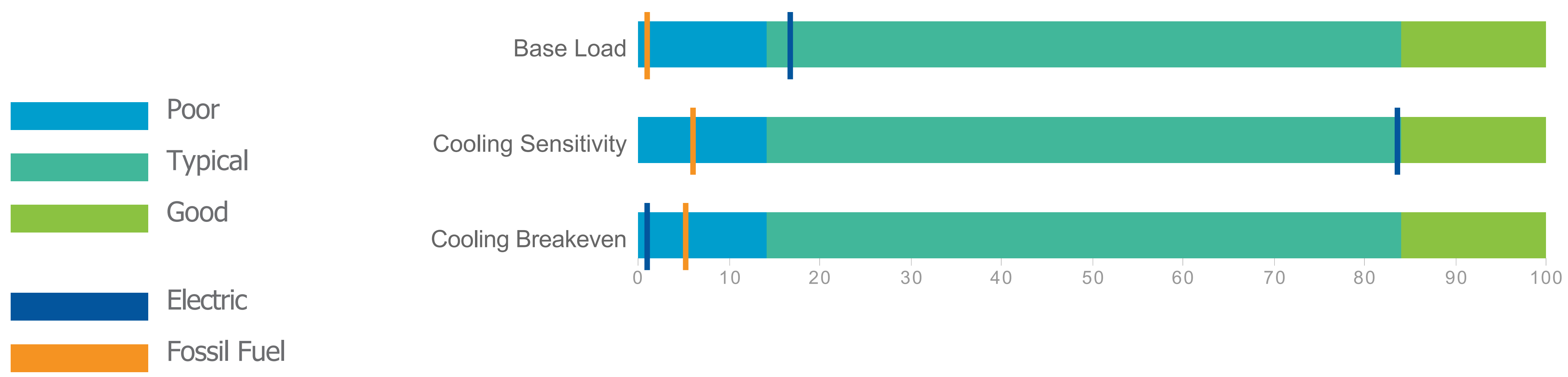
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Increase cooling system efficiency
- Check fossil fuel base load

Benchmark Metrics



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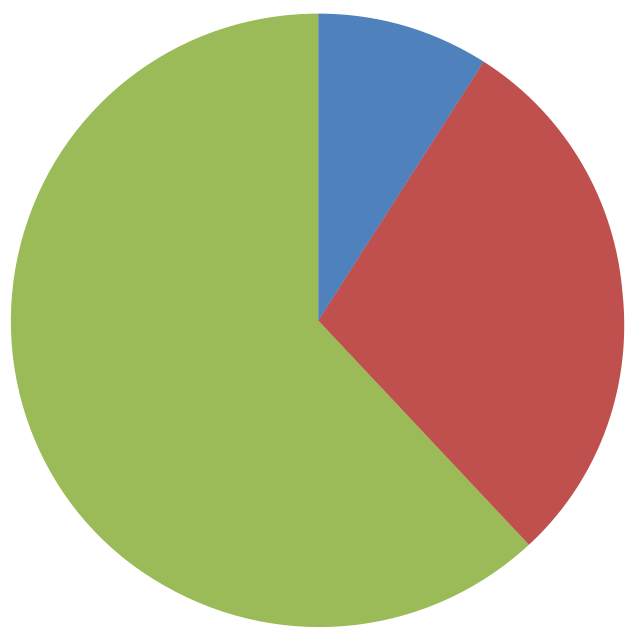
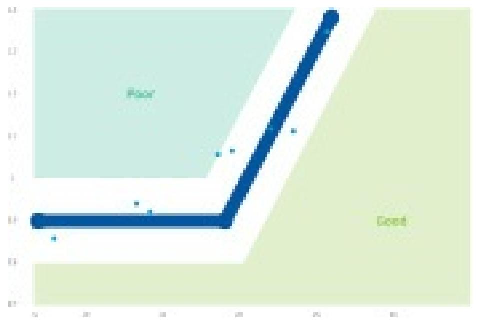


Savings - No/Low Cost Measures (9% / $10000)
Savings - Comprehensive Measures (29% / $33000)
Target Energy Budget (62% / $70981)

Medical Sciences Research Building III - Other

Recommendations



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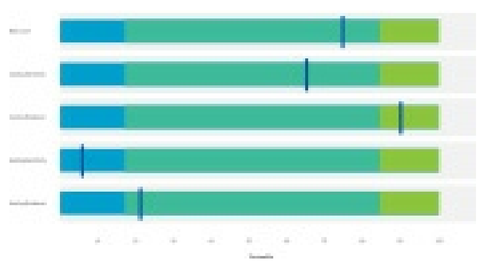

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Increase Cooling System Efficiency

The overall performance of the cooling equipment and systems in this building is below the typical performance found in similar buildings. Check all cooling related equipment and controls for efficient and fault-free operations. Consider upgrading equipment to newer, more-efficient models.

Check Fossil Fuel Base Load

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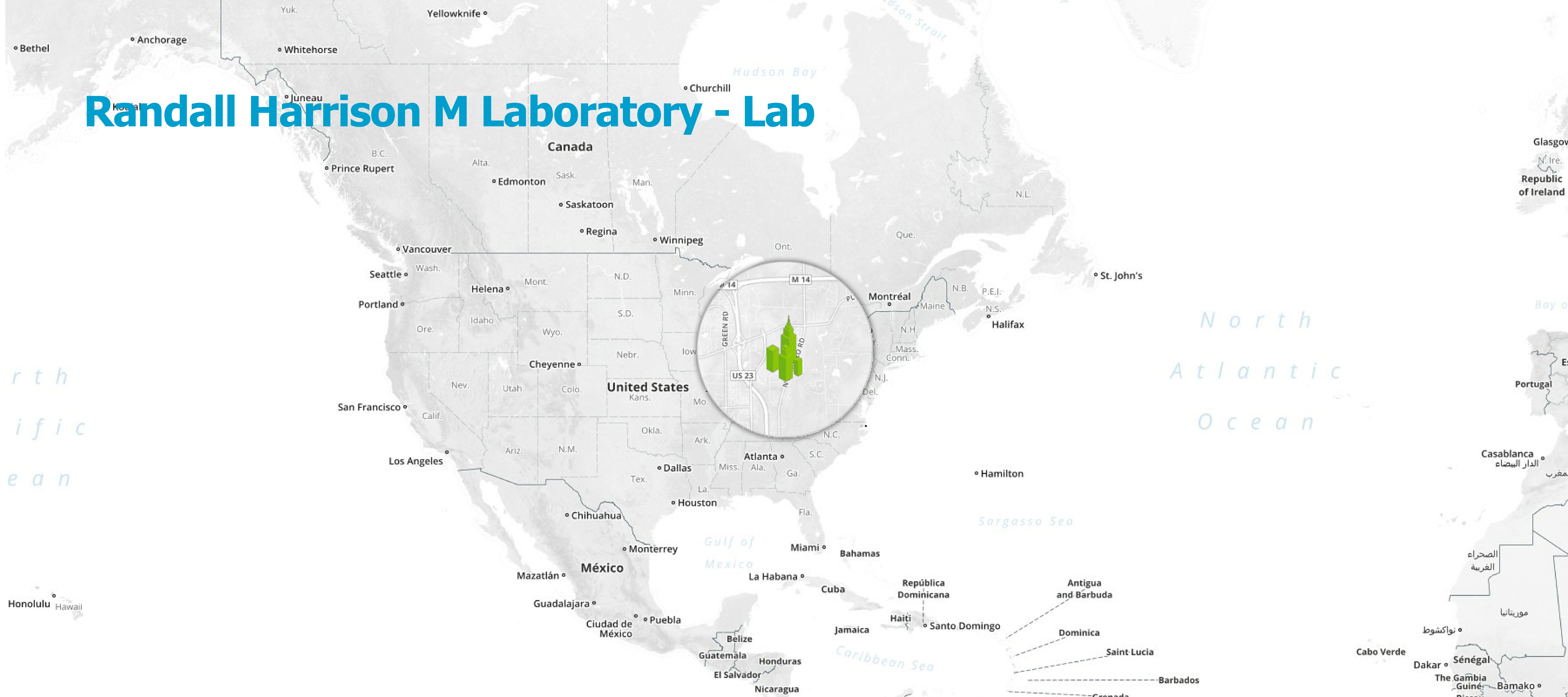
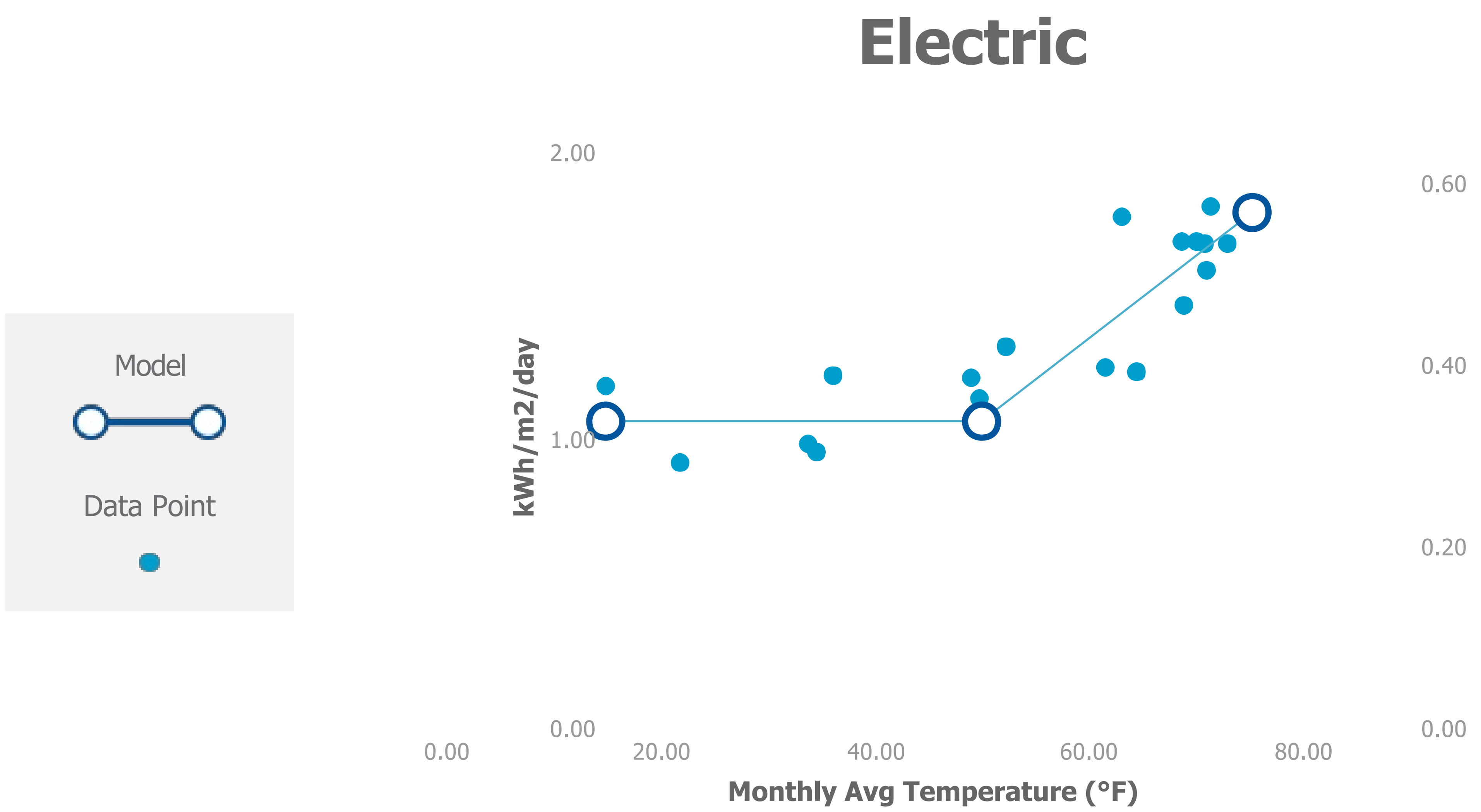
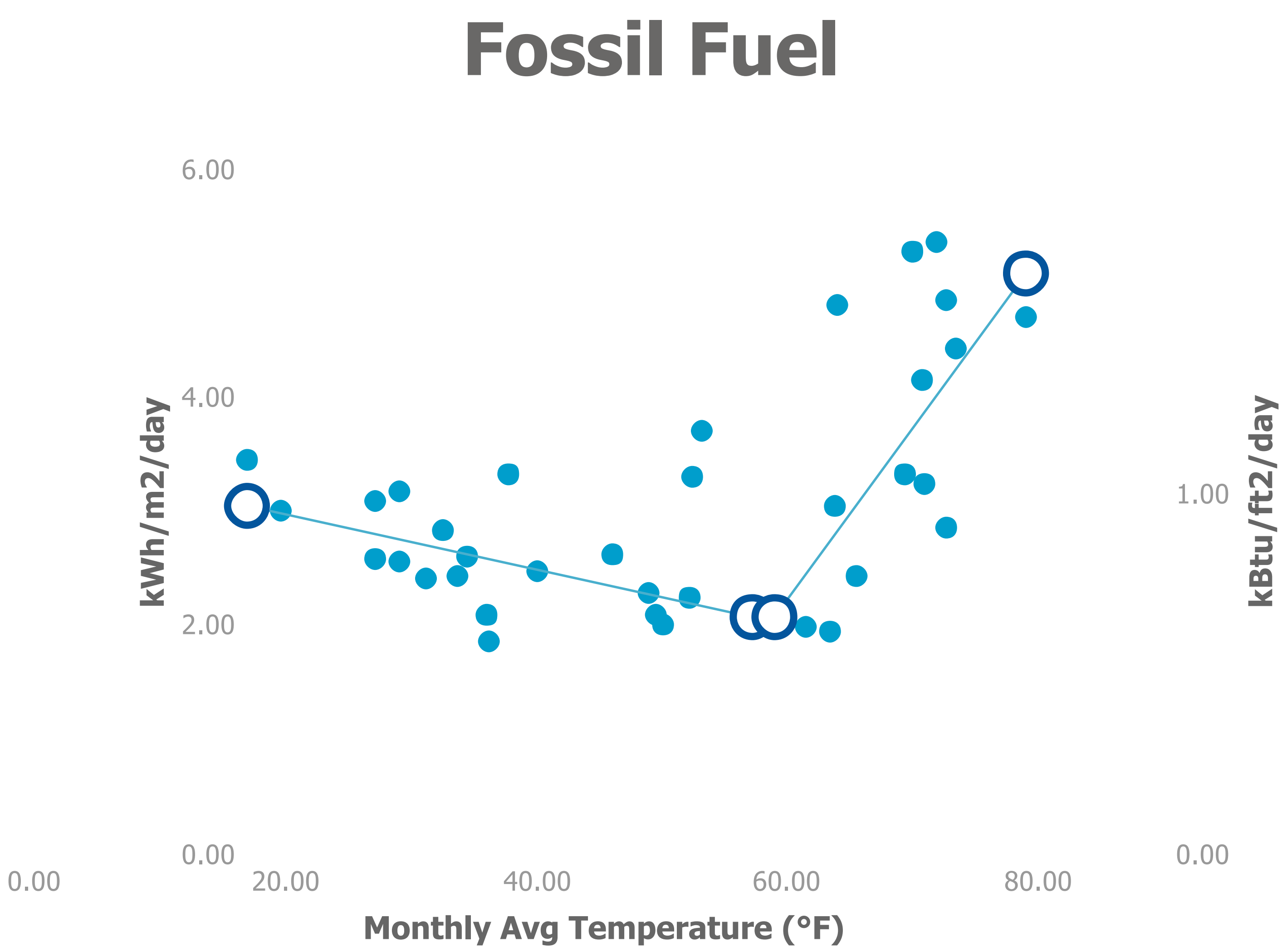
Randall Harrison M Laboratory - Lab



Randall Harrison M Laboratory - Lab

Weather Sensitivity





Total Potential Location Savings

$190,000

Total Potential Percentage Savings

19%

Recommendations

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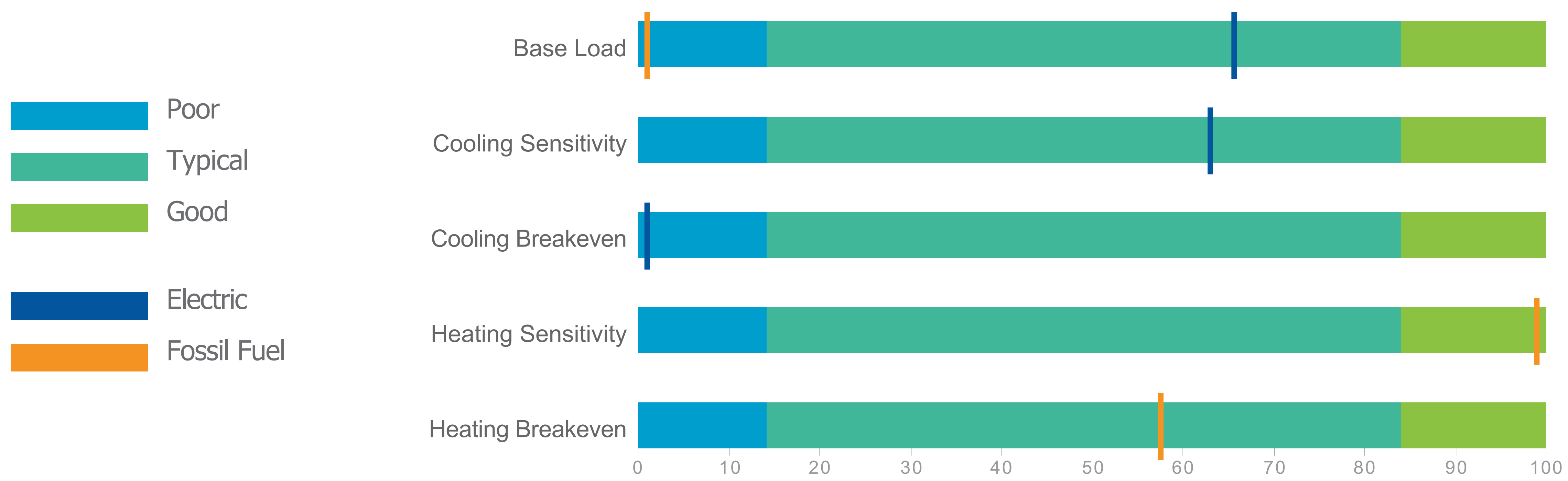
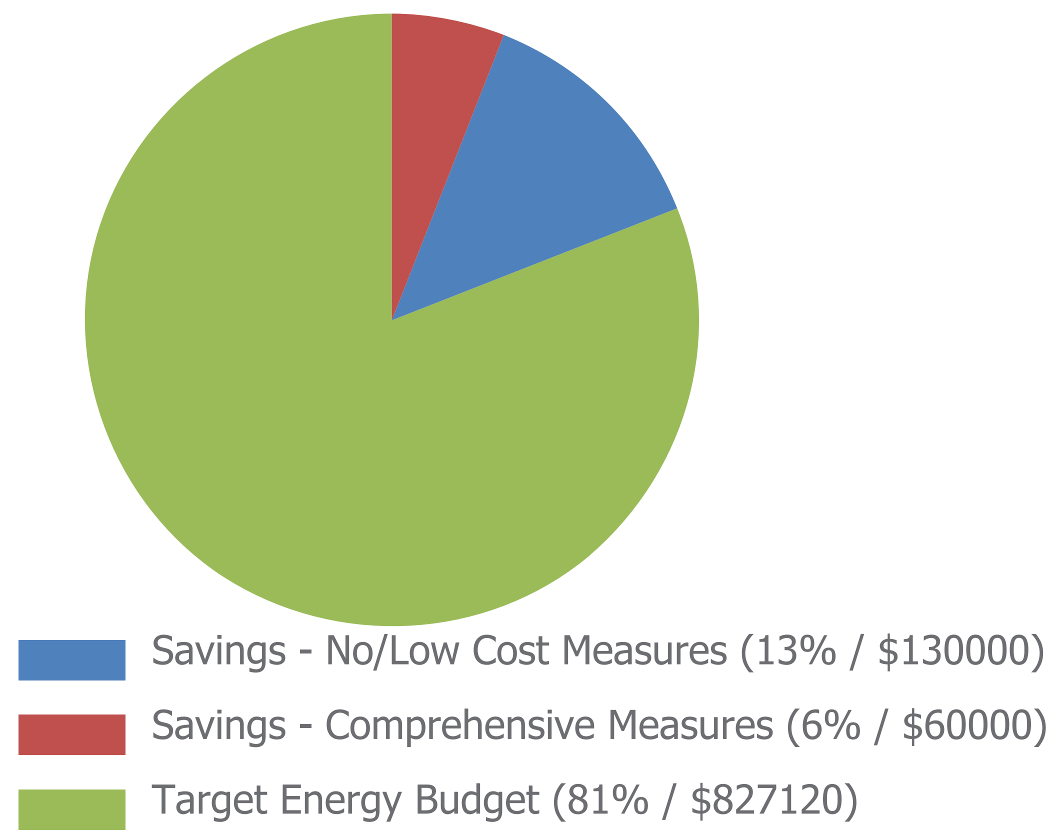
- Reduce equipment schedules
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics

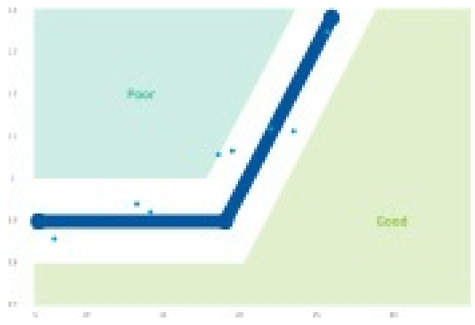


Savings Breakdown



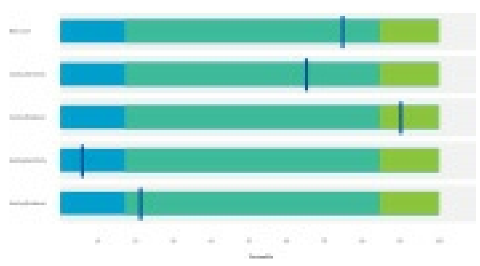
Randall Harrison M Laboratory - Lab

Recommendations



Weather Sensitivity

LEAN models are used to determine a building's sensitivity to weather. The regressed model parameters represent the weather independent energy use (or baseload), weather dependent energy use (or heating/cooling sensitivity), and the building balance-point temperatures (or temperatures where the building starts to use additional energy for cooling or heating).



Benchmark Metrics

Traditional approaches for energy benchmarking use gross performance factors such as the energy use intensity to compare buildings. The LEAN approach provides greater insight from its use of models and model coefficients. The model coefficients are benchmarked by comparing them to distributions of coefficients from a population of buildings with similar use. The coefficients are classified as good, typical or poor relative to similar buildings. Each building's coefficients and associated benchmark distributions are further used to identify the size and make-up of any energy efficiency opportunities.

Increase Cooling Setpoints

Both the occupied and unoccupied setpoints used during the cooling season or on zones that require cooling year round should be checked for opportunities to increase them. Increasing cooling setpoints will reduce the cooling loads of the building and the energy usage of cooling equipment and systems serving them.

Reduce Equipment Schedules

A building automation system should be used to schedule the equipment and systems that operate within a building. Look for opportunities to turn-off equipment during unoccupied times or during times of reduced occupancy and building use. Alarms should be setup and monitored to identify when over-ridden schedules are not returned to normal.

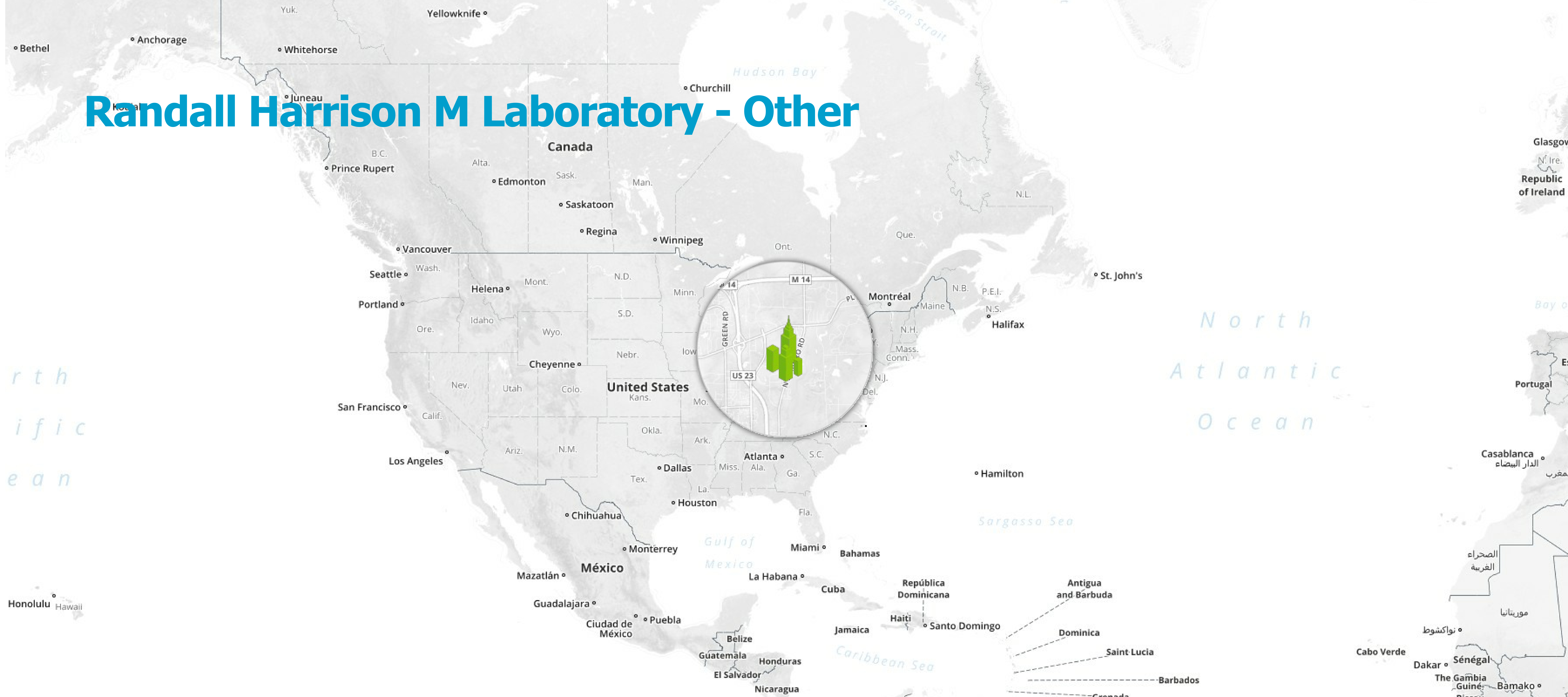
Add Fix Economizers

Fixing or installing air-side conomizers can significantly reduce the energy used to cool a building by bringing in outside air that is cooler and/or dryer than the inside air. This is often referred to as free cooling because there is little to no additional energy needed to use outside air to condition a building. Existing economizers should be checked for proper and efficient operations.

Check Fossil Fuel Base Load

The fossil fuel baseload, or year-round minimum usage, is higher than expected for this building. This can be caused by poor operating schedules, simultaneous heating and cooling, and faulty heating equipment. Identify and correct these conditions.

Randall Harrison M Laboratory - Other



Randall Harrison M Laboratory - Other

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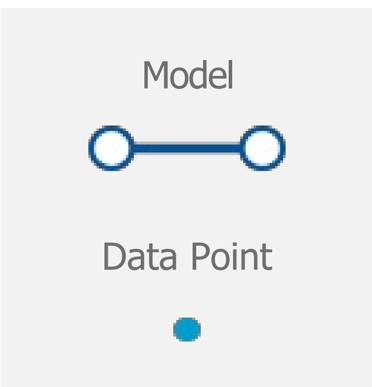
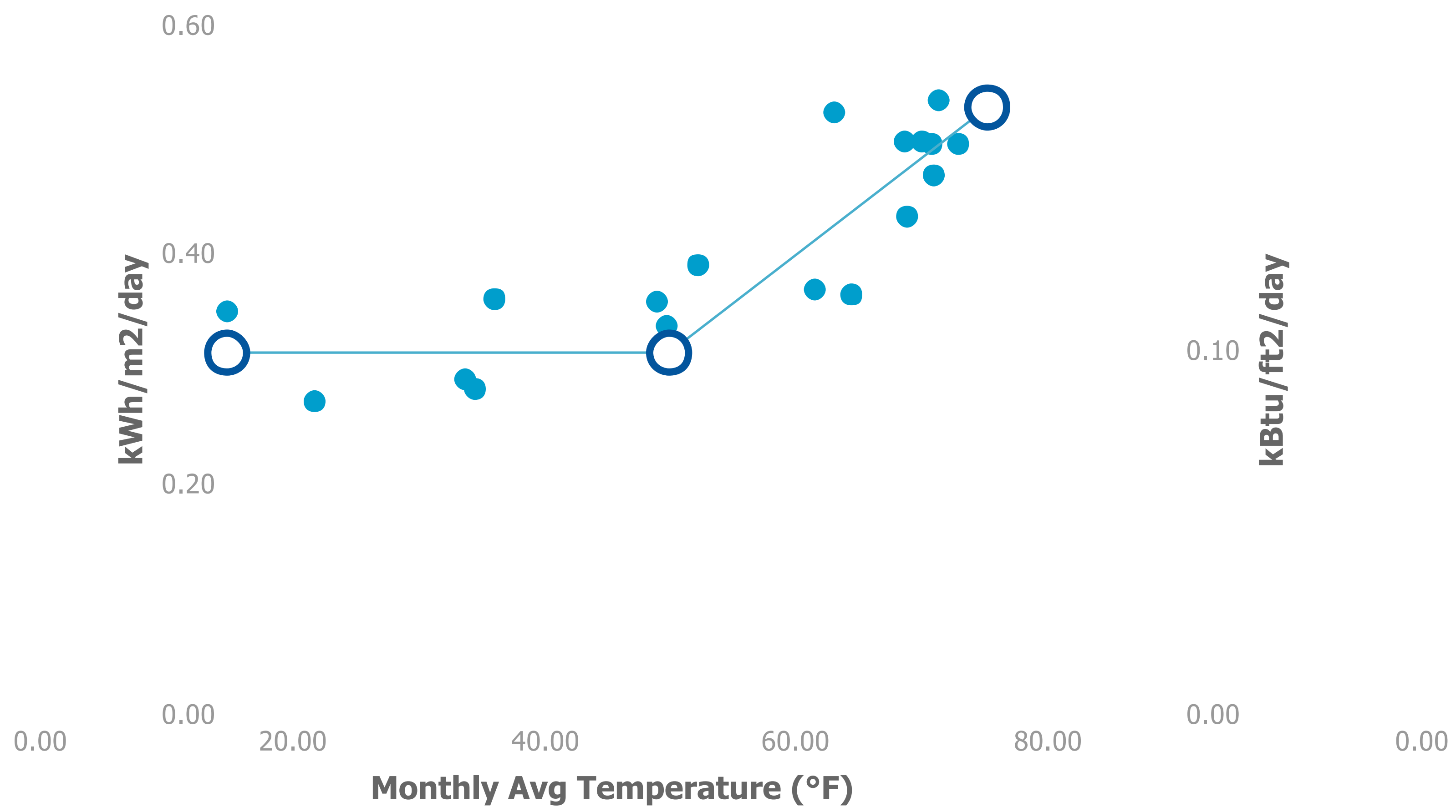
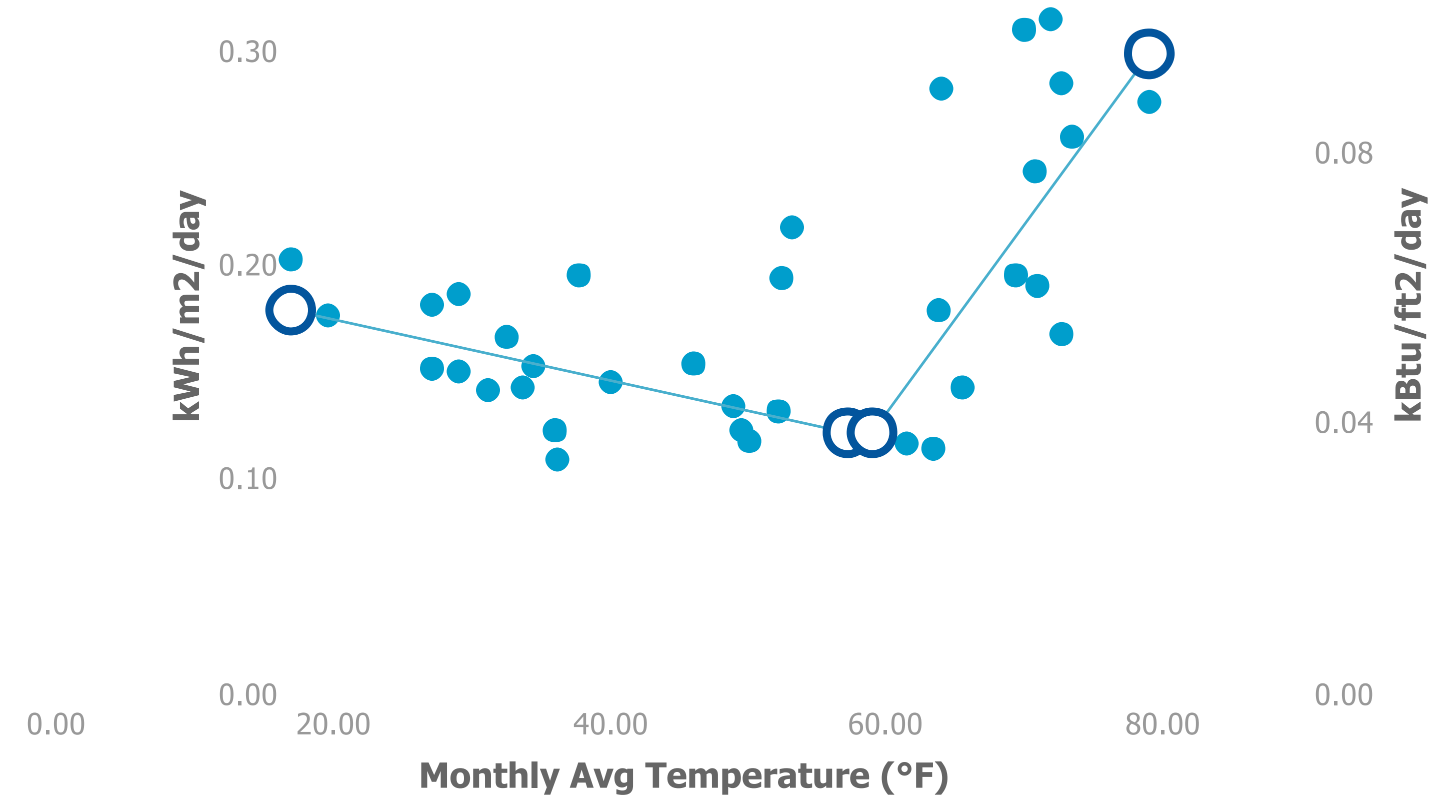


Electric



Fossil Fuel



Total Potential Location Savings

$19,000

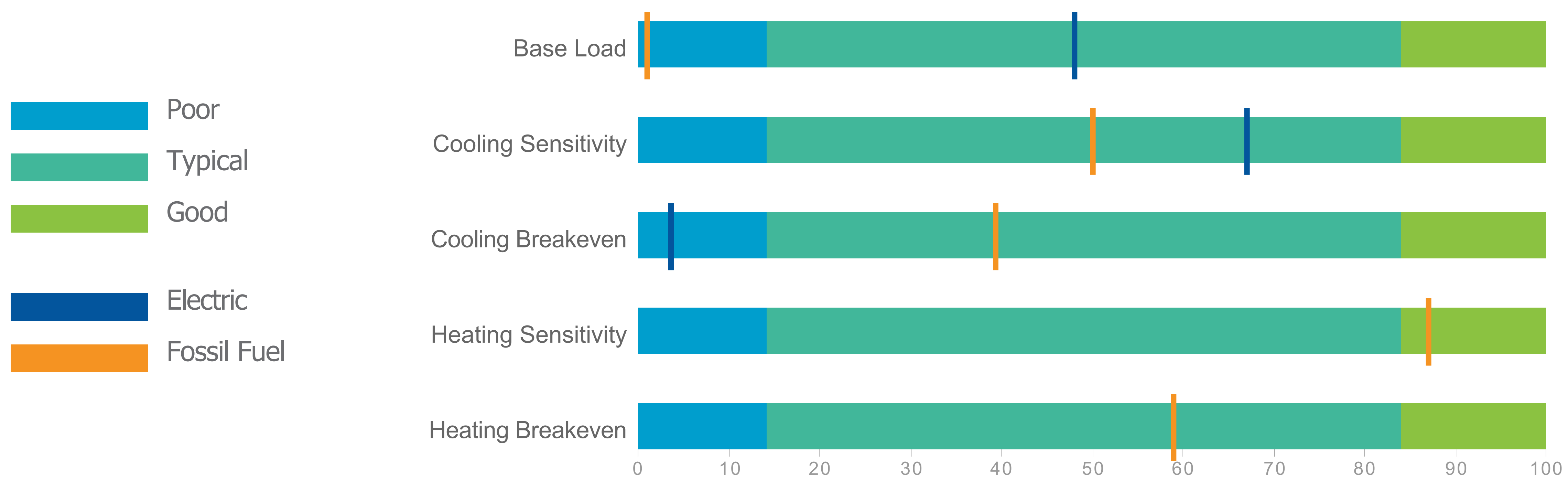
Total Potential Percentage Savings

17%

Recommendations

- Increase cooling setpoints
- Reduce equipment schedules
- Reduce lighting load
- Reduce plug loads
- Add fix economizers
- Check fossil fuel base load

Benchmark Metrics



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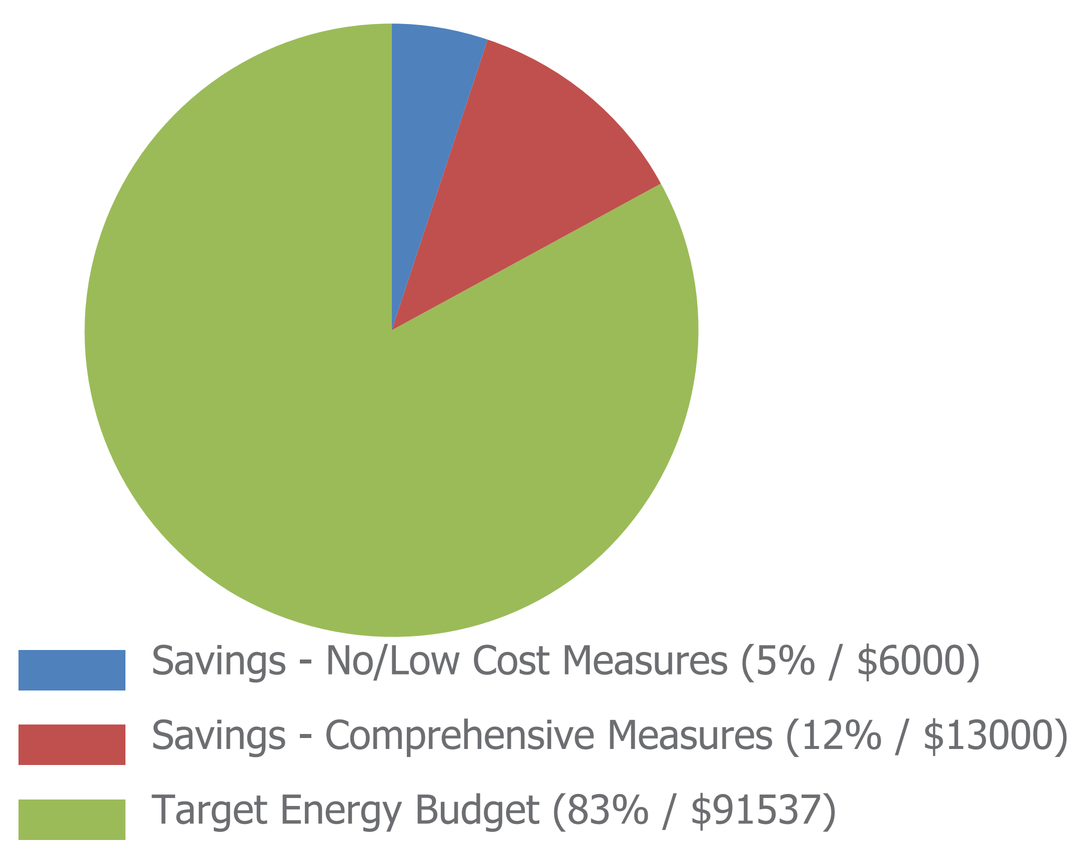
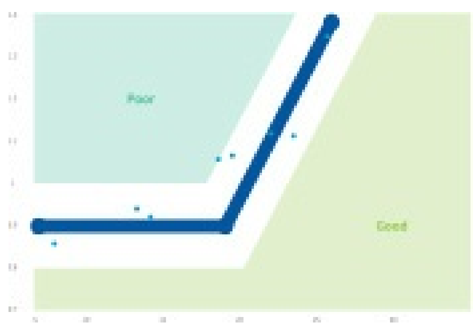


Randall Harrison M Laboratory - Other

Recommendations



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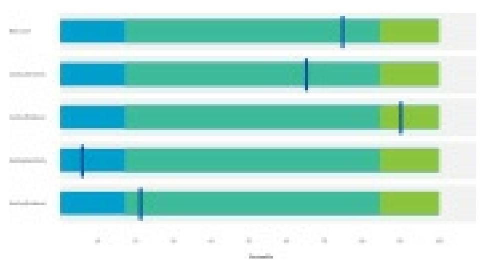

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Reduce Lighting Load

Lighting loads are reduced by improving both the control and efficiency of the lighting and by taking advantagve of natural daylighting whenever possilble. Existing or upgraded controls are used to dim and turn-off the lights appropriately; and lighting efficiency is improved by upgrading the bulbs and fixtures. Daylight utilitzation can be improved with better control of lights that are near existing windows and skylights, and with renovations to the building envelope and internal space configurations.

Reduce Plug Loads

Plug loads include anything that is plugged into standard electric recpetecals or outlets (e.g. personal computers, printers, coffee-makers, other office/lab/light-mfg equipment). Plug load reductions are accomplished by controlling/scheduling them where possible and upgrading the plugged in equipment to newer, more-efficient models.

Add Fix Economizers

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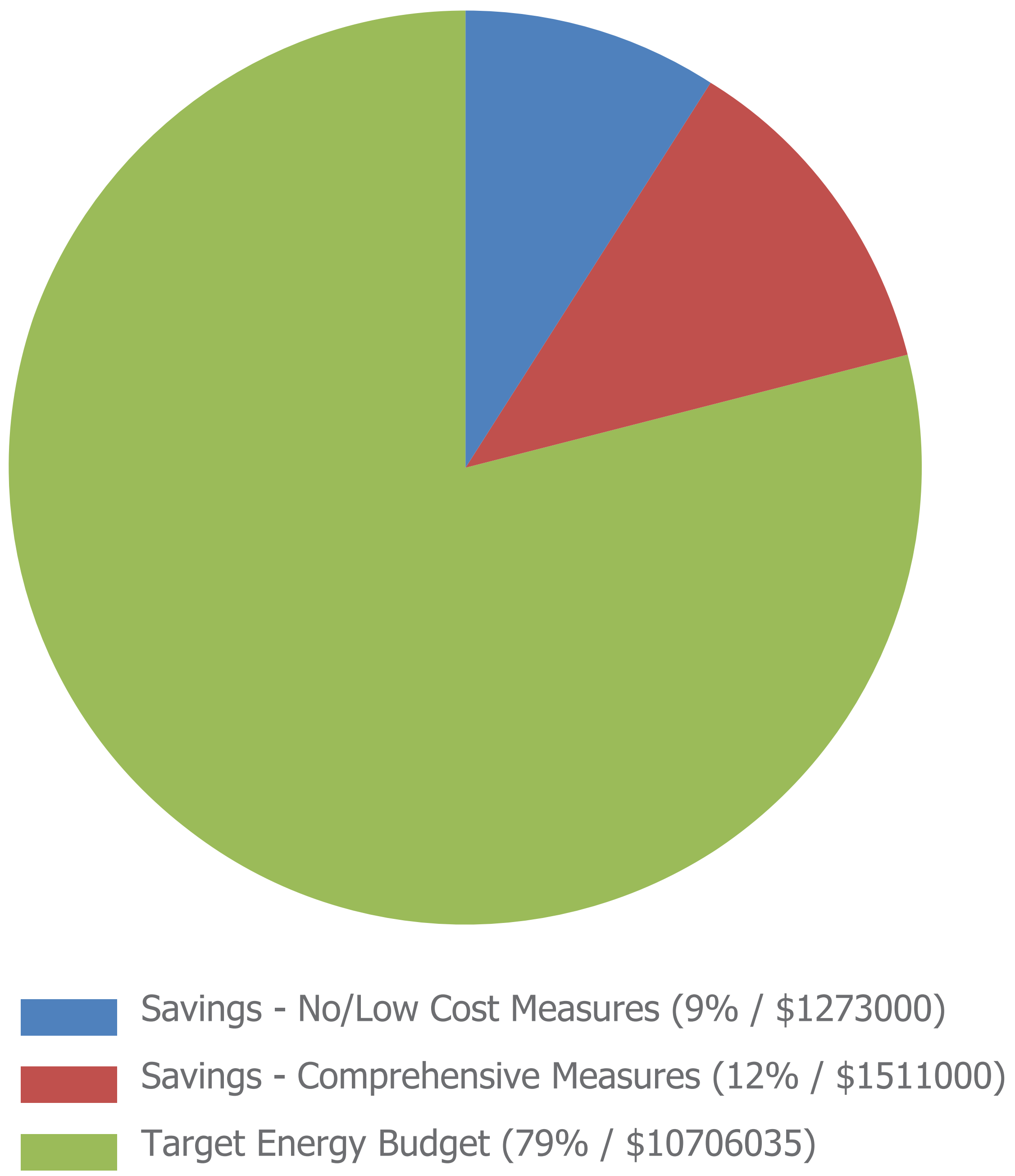
IV. Recommendations

Recommendations

Overall Cost/Low Cost Breakdown



Our LEAN Energy Analysis outlines recommended improvement measures. As the world's leading energy services company, Johnson Controls has the engineering expertise and operational excellence to retrofit your buildings with a customized approach. Where applicable, we identify grants, rebates or utility incentives and, if necessary, leverage financing vehicles to apply to your efficiency project. There is a wide spectrum of improvements reviewed with this analysis, ranging from low cost operational adjustment like decreasing setpoints, to improvements requiring construction-related activity like adding insulation and economizers. Additionally, while some recommendations are specific, others are more general, like reducing plug loads. Johnson Controls has the expertise to address any and all improvements. We want to help you engage and educate your building occupants because we know they can make a real difference in your energy efficiency success.

http://www.johnsoncontrols.com/content/us/en/products/building_efficiency/building/contact_us.html

Overall Potential Savings

$2,784,000

Overall Potential Percentage Savings

21%

Appendix H:
Johnson Controls Suggested Items Needed for an Audit

Appendix I:
Floor Plans for the Dana Building

Appendix J:
Johnson Controls Detailed Audit Form

Pages 222-228 have been removed for proprietary data protection.

References

[i] U.S. Department of Energy. (2016). Office of Energy Deliverability and Reliability. Retrieved from http://energy.gov/sites/prod/files/styles/hero_rotator/public/Second%20Installment%20Imagev2_1_0.png?itok=0j9kjF9I
[ii] Environmental Protection Agency. (April 2009). Buildings and their Impact on the Environment: A Statistical Summary. Environmental Protection Agency Green Building Workshop. www.epa.gov/greenbuilding/pubs.
[iii] U.S. Energy Information Administration (EIA). (March 2016). Monthly Energy Review March 2016. U.S. Department of Energy. Washington, DC. http://www.eia.gov/totalenergy/data/monthly/
[iv] Keoleian, G.. (2015). Energy Systems Lecture. SNRE 574
[v] Alliance to Save Energy. (2016). Energy 2030. Washington, DC. www.ase.org/policy/energy2030
[vi] Planet Blue & Office of Campus Sustainability. (2014). Metrics & Reporting: 2014 Raw Data. University of Michigan. Ann Arbor, MI.
[vii] U.S. EIA. (2009). Household Energy Use in Michigan: A closer look at residential energy consumption. Residential Energy Consumption Survey Program. Washington, DC.
[viii] University of Michigan. (October 2014). Revenues, Expenditures & State Appropriations: All Campus Data. http://obp.umich.edu/wp-content/uploads/pubdata/factsfigures/finance_umsystem_14-15.pdf
[ix] University of Michigan. (June 2014). 2014 Annual Report. Regents of the University of Michigan. Finops.umich.edu/reporting/annualreports.
[x] University of Michigan. (June 2014). 2014 Annual Report. Regents of the University of Michigan. Finops.umich.edu/reporting/annualreports.
[xi] DTE Energy. (2016). Fuel Mix. DTE Energy Company.
[xii] International Institute for Sustainable Laboratories. About I²SL: Advancing sustainable laboratories globally. Arlington, VA. http://www.i2sl.org/about/index.html
[xiii] Liang, Chi-Yuan. (2005). A New Approach to Measuring Energy Productivity of an Economy. International Association for Energy Economics. http://www.iaee.org/documents/denver/liang.pdf
[xiv] IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.* Geneva, Switzerland: IPCC.
[xv] IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.* Geneva, Switzerland: IPCC.
[xvi] IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.* Geneva, Switzerland: IPCC.
[xvii]European Commission. (2016). Paris Agreement*.* Climate Action. Brussels, Belgium: European Commission. Retrieved from http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm
[xviii]European Commission. (2016). Paris Agreement*.* Climate Action. Brussels, Belgium: European Commission. Retrieved from http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm
[xix] The United States of America. (2015). Intended Nationally Determined Contributions*.* Paris, France: United Nations Framework Convention on Climate Change.
[xx] Environment & Energy Publishing, LLC. (2016). Legal Overview. Retrieved from http://www.eenews.net/interactive/clean_power_plan/fact_sheets/legal.
[xxi] Office of Management and Budget. (2013). Federal Climate Change Expenditures Report to Congress. Executive Office of the President of the United States, Washington, DC.
[xxii] Alliance to Save Energy. (2016). Buildings*.* Washington, DC: Alliance to Save Energy. Retrieved from http://www.ase.org/buildings
[xxiii] Building Technologies Office. (2015) "Chapter 5: Increasing Efficiency of Building Systems and Technologies." *Quadrennial Technology Review.* U.S. Department of Energy. Washington, D.C.
[xxiv] Building Technologies Office. (2015). "Chapter 5: Increasing Efficiency of Building Systems and Technologies." *Quadrennial Technology Review.* U.S. Department of Energy. Washington, D.C.
[xxv]Better Buildings. (2015). Progress Report 2015. U.S. Department of Energy. Washington, D.C.
[xxvi] Johnson Controls. (2016). About Us. http://www.johnsoncontrols.com/about-us/our-company
[xxvii] A GLOBAL LEADER. (n.d.). www.johnsoncontrols.com
[xxviii] Johnson Controls. (2008). Case study Louisiana State University. Retrieved from http://www.johnsoncontrols.com.sa/content/dam/WWW/jci/be/case_studies/Louisiana_State_Univ_REBRANDED.pdf
[xxix] Johnson Controls. (December 2013) University of Hawai'i. 80 million in energy savings. Retrieved from http://www.johnsoncontrols-hawaiienergy.com/uhcc.PDF
[xxx] Johnson Controls. (2014). Ann Arbor Public Schools Project Profile. Retrieved from http://latinamerica.johnsoncontrols.com/content/dam/WWW/jci/be/case_studies/Ann%20Arbor%20CS.pdf
[xxxi] Land, Building and Real Estate. (April 2016). Stanford University. Retrieved from https://lbre.stanford.edu/
[xxxii] Flynn, E. Et al. (August 2013). Stanford University. The Building Energy Retrofit Programs. Retrieved from http://files.eric.ed.gov/fulltext/ED540313.pdf

[xxxiii] Singh, S. Et al. (October 2014). Sustainable Stanford. Create an ERP. Retrieved from https://sustainable.stanford.edu/sites/default/files/HowTo_ERPCustomProject.pdf
[xxxiv] Utilities Department. (September 2013) Stanford University. Energy Retrofit Program Guidelines. Retrieved from http://lbre.stanford.edu/sem/sites/all/lbre-shared/files/docs_public/ERPGUIDE%202004%20final.pdf
[xxxv] Sustainable Stanford. (2016) Stanford University. Retrieved from https://sustainable.stanford.edu/sesi/innovation
[xxxvi] Johnson Controls, Inc. (2016). Energy Recovery Ventilators. Retrieved from http://www.johnsoncontrols.com/buildings/air-systems/energy-recovery-ventilators
[xxxvii] Building Automation System.org. (2016) Benefits of Building Automation Systems. Retrieved from http://www.buildingautomationsystem.org/Benefits-Of-Building-Automation-Systems.html
[xxxviii] Johnson Controls, Inc. (2016). Building Automation Systems. Retrieved from http://www.johnsoncontrols.com/buildings/building-management/building-automation-systems-bas
[xxxix] Johnson Controls, Inc. Building Automation Systems. http://www.johnsoncontrols.com/buildings/building-management/building-automation-systems-bas
[xl] Johnson Controls, Inc. (2016). Variable Speed Drives. Retrieved from http://www.johnsoncontrols.com/buildings/building-management/building-automation-systems-bas
[xli] Donnelly, M., Kummer, J., & Drees, K. (2013). *LEAN Energy Analysis : Using Regression Analysis to Assess Building Energy Performance.* Institute for Building Efficiency. Washington, DC: Johnson Controls.
[xlii] (Donnelly, Kummer, & Drees, 2013)
[xliii] Donnelly, M., Kummer, J., & Drees, K. (2013). *LEAN Energy Analysis : Using Regression Analysis to Assess Building Energy Performance.* Institute for Building Efficiency. Washington, DC: Johnson Controls.
[xliv] Sever, F., Kissock, K., Brown, D., and S. Mulqueen. (2011). “Estimating Industrial Building Energy Savings using Inverse Simulation.” ASHRAE Transactions, Volume 117, Part 1.
[xlv] Regents of the University of Michigan. (2016) Office of Undergraduate Admissions http://admissions.umich.edu/about-u-m/rankings-facts-figures
[xlvi] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[xlvii]Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[xlviii] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[xlix] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[l] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[li] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[lii] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[liii] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[liv] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[lv] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[lvi] Regents of the University of Michigan. (2013) Plant Operations. Retrieved from http://energymanagement.umich.edu/about-us/opsteam-history/
[lvii] Regents of the University of Michigan. (2016). Planet Blue Campus Sustainability Goals. Retrieved from http://sustainability.umich.edu/about/goals
[lviii] Regents of the University of Michigan. (2016). Planet Blue Campus Sustainability Goals. Retrieved from http://sustainability.umich.edu/about/goals
[lix] Murphy, C. (2014). Planet Blue. Retrieved from https://www.michigan.gov/documents/deq/Murphy-EnergyConservation-UMHHC_434225_7.pdf
[lx] Murphy, C. (2014). Planet Blue. Retrieved from https://www.michigan.gov/documents/deq/Murphy-EnergyConservation-UMHHC_434225_7.pdf
[lxi] Our Employees, Top Story Announcements. (May 2015). University of Michigan Health System Headlines. Retrieved from https://www.umhsheadlines.org/2015/05/u-m-hospitals-and-health-centers-awarded-for-environmental-sustainability-for-12th-straight-year/
[lxii] Herman, B. (September 2013). 50 of the Greenest Hospitals in America. Retrieved from http://www.beckershospitalreview.com/lists/50-of-the-greenest-hospitals-in-america.html

[lxiii] University of Michigan. (October 2014). University Financial Profile. Retrieved from http://obp.umich.edu/wp-content/uploads/pubdata/factsfigures/finance_umaa_14-15.pdf
[lxiv] University of Michigan Office of the Provost. (April 2013). Capital Project Guidelines. Retrieved from http://www.provost.umich.edu/space/capital/CP_Guidelines.pdf
[lxv] Board of Regents University of Michigan (June 2014). FY 2015 General Fund Budget. Retrieved from https://publicaffairs.vpcomm.umich.edu/wp-content/uploads/sites/19/2015/01/FY15-BUDGET-PRESENTATION.pdf
[lxvi] Regents of the University of Michigan. (2016). University Budget – Understanding the Budget. Retrieved from http://www.vpcomm.umich.edu/budget/understanding.html#g
[lxvii] University of Michigan. (June 2014). 2014 Annual Report. Regents of the University of Michigan. Finops.umich.edu/reporting/annualreports.
[lxviii] University of Michigan. (June 2014). 2014 Annual Report. Regents of the University of Michigan. Finops.umich.edu/reporting/annualreports.
[lxix] Committee Members. (2015). July 2015 Report from the President's Greenhouse Gas Reduction Committee. Retrieved from Report.http://sustainability.umich.edu/media/files/Greenhouse-Gas-Reduction-Committee-Report-2015.pdf
[lxx] DTE Energy. (2016). Fuel Mix. DTE Energy Company. Retrieved from https://www2.dteenergy.com/wps/portal/dte/aboutus/environment/details/Generation%20and%20Emissions/
[lxxi] University of Michigan Plant Operations. (2014). Annual Report. Retrieved from http://www.plantops.umich.edu/director/PDF/Plant_Operations_2014_Annual_Report.pdf
[lxxii] Energy Star. (March 2016). U.S. Energy Use Intensity by Property Type. Retrieved from https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf
[lxxiii] Planet Blue. (2015). University of Michigan Sustainability Report. Retrieved from http://sustainability.umich.edu/media/files/Greenhouse-Gas-Reduction-Committee-Report-2015.pdf
[lxxiv] President's Committee on Greenhouse Gas Reduction. (2015). Report from President Schlissel's Greenhouse Gas Reduction Committee. University of Michigan. Retrieved from http://sustainability.umich.edu/media/files/Greenhouse%20Gas%20Reduction%20Committee%20Report%202015%20(1).pdf
[lxxv] Donnelly, M., Kummer, J., & Drees, K. (2013). *LEAN Energy Analysis: Using Regression Analysis to Assess Building Energy Performance.* Washington, DC: Johnson Controls.
[lxxvi] Lawrence Berkeley National Laboratory. (August 2011). Labs21 Benchmarking Tool. U.S. Department of Energy Federal Energy Management Program.
[lxxvii] Johnson Controls. (2015). *LEAN Energy Analysis: University of Michigan, Ann Arbor.* Milwaukee, WI: Johnson Controls Inc.
[lxxviii] Degree Days.net. (2016). Custom Degree Day Data. Retrieved from www.degreedays.net (using temperature data from www.wunderground.com Ann Arbor, MI)
[lxxix] Johnson Controls. (2015). *LEAN Energy Analysis: University of Michigan, Ann Arbor.* Milwaukee, WI: Johnson Controls Inc.
[lxxx] Anonymous. (Nov 2010). The Difference Between ASHRAE Level 1, 2 & 3 Energy Audits. Retrieved from http://microgrid-solar.com/the-difference-between-ashrae-level-1-2-3-energy-audits/#sthash.kqKOxPUk.dpuf
[lxxxi] Anonymous. (Nov 2010). The Difference Between ASHRAE Level 1, 2 & 3 Energy Audits. Retrieved from http://microgrid-solar.com/the-difference-between-ashrae-level-1-2-3-energy-audits/#sthash.kqKOxPUk.dpuf
[lxxxii] Sand, James. (March 2004). "Demand Controlled Ventilation Using CO_2 Sensors." Oak Ridge National Laboratory, for U.S. Department of Energy, Energy Efficiency, and Renewable Energy. Washington, DC.
[lxxxiii] Anonymous. (Nov 2010). The Difference Between ASHRAE Level 1, 2 & 3 Energy Audits. Retrieved from http://microgrid-solar.com/the-difference-between-ashrae-level-1-2-3-energy-audits/#sthash.kqKOxPUk.dpuf
[lxxxiv] Anonymous. (Nov 2010). The Difference Between ASHRAE Level 1, 2 & 3 Energy Audits. Retrieved from http://microgrid-solar.com/the-difference-between-ashrae-level-1-2-3-energy-audits/#sthash.kqKOxPUk.dpuf
[lxxxv] Office of the Registrar. (September 2015). University of Michigan Total Enrollment Overview. Retrieved from http://www.ro.umich.edu/report/15enrollmentsummary.pdf
[lxxxvi] Amon, D. Et al. Labs for the 21st Century (2010). Labs21 Environmental Performance Criteria 3.0. Retrieved from http://www.i2sl.org/documents/toolkit/epc_3-0_508.pdf
[lxxxvii] Amon, D. Et al. Labs for the 21st Century (2010). Labs21 Environmental Performance Criteria 3.0. Retrieved from http://www.i2sl.org/documents/toolkit/epc_3-0_508.pdf
[lxxxviii] Elger, Dana. (October 2015). University of Michigan: Michigan News. "U-Michigan Invests in Major Campus Sustainability Efforts." Retrieved from http://ns.umich.edu/new/releases/23239-u-michigan-invests-in-major-campus-sustainability-efforts
[lxxxix] Mudali, Anuja. (November 2015). The University Record. "University Managing Energy Consumption as Campus Grows." Retrieved from https://record.umich.edu/articles/university-managing-energy-consumption-campus-grows