Link to the storymap: https://arcg.is/D059O

History of University of Rochester's Greenhouse Gas Emissions

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1. Big Picture

Sustainable energy is at the forefront of agendas across the world, where communities and local organizations are stepping up to address global climate change. Noticeably, the University of Rochester has taken effective measures to do its part in reducing greenhouse gas (GHG) emissions through targeted facility upgrades and intelligent planning. The University began tracking GHG emissions in 1990 with the data presented in Figure 1.1. It is evident that the school has taken many steps indicated by the reductions in CO_2 emissions and CO_2 intensity. In order to better understand and identify methods for improvement in emissions, the Utilities and Energy Management (UEM) team has been, and continues to, actively analyze data for determining the best means for improvement. For quick comparison, since 1990, the University's GHG emissions have declined 10%, while there has been an increase in ground square footage by 40%. Figure 1.2 shows this increase in square footage is largely due to growth in the Medical Center.

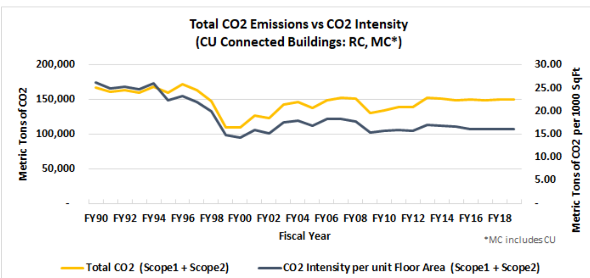

Figure 1.1: Total CO_2 emissions (gold) vs CO_2 intensity (blue). Scope 1 emissions refers to fossil fuel purchased for campus consumption. Scope 2 emissions refers to those associated with purchased electricity.

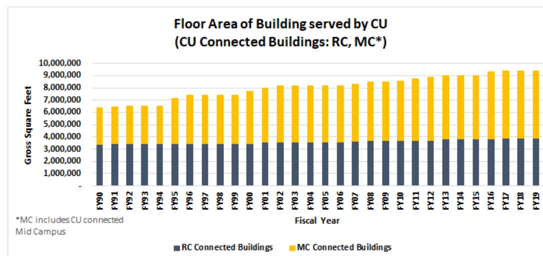

Figure 1.2: Floor area growth across River Campus (blue) and the Medical Center (gold) since 1990.

As this paper aims to encompass not only energy consumption at the University, but also energy generation as a whole, it would go amiss to neglect events prior to 1990. Beginning in 1903, a coal-fired power plant was constructed on the downtown campus to provide heating to the school, separate from River Campus.

From 1920 to 1924, the original Central Utility Plant was constructed with four boilers on what is known as River Campus today to provide heating in the form of steam. From 1967 to 1970, the plant was expanded by adding three more boilers. Additionally, from 1967 through 1972, a chiller plant was added, where four steam driven chillers were added allowing for chilled water to be used to cool buildings. As more buildings were installed, the energy

Figure 1.3: Steam tunnels being built for heating in the 1920s.

demand on campus has continued to grow to heat and cool the structures across campus[1].

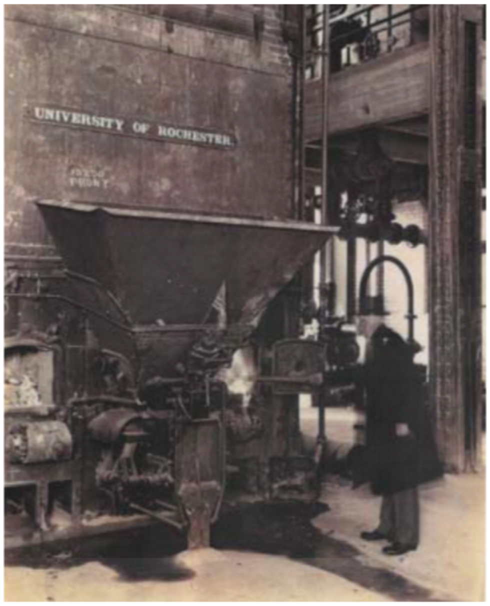

Figure 1.4: President Rush Rhees lighting the first fire in the new central utilities plant in 1924.

Figure 1.1 shows the decrease in CO_2 emissions and CO_2 intensity, which can be attributed to major advancements in energy sources and improved efficiencies. In 1998, there was a significant change made to the power plant, where the boilers were converted to burning natural gas instead of coal, quantified by a dip in the plot. This fall is directly correlated to the fact that natural gas has a much lower carbon footprint when compared to coal. It was found that this measure alone reduced emissions by 30%.

Citing past knowledge and operational studies, the idea of cogeneration in the US first came to light in the early 19th century. Also known as combined heat and power (CHP), this technology is a way to simultaneously produce electricity and heat, which then developed a foothold towards the end of the 19th century. The University of Rochester became a part of this movement by installing a cogeneration plant in 2005[1]. Other peer institutions have implemented similar plants, for example, NYU, Stanford, UNH, and Princeton.

Traditionally, power plants generate steam to spin a turbine, resulting in power and wasted heat. Cogeneration makes use of this waste allowing for two times the efficiency of traditional power plants, from about 30% to upwards of 80%, therefore reducing costs and carbon emissions. During the cogeneration process, a fuel source heats water to produce steam, which turns a turbine producing electricity and the steam or hot water is then supplied to buildings to heat them. Figure 1.5 details the individual processes for generating power and heat, whereas Figure 1.6 combines these two processes into one. Thus, having a cogeneration plant on campus, the University has been able to reduce overall GHG emissions by using one fuel source to both heat buildings and supply about ⅓ of the University's electricity demands.

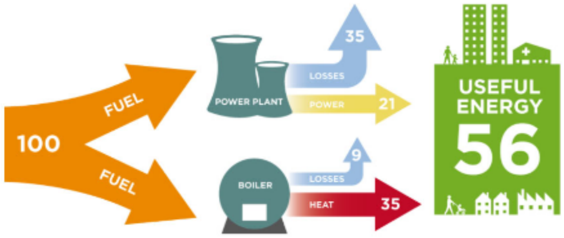

Figure 1.5: Figure showing the two different processes for generating power and heat

Figure 1.6: Figure showing improved efficiency of cogen operations with processes are combined.

2. Specific Buildings with Upgrades

This section aims to quantify savings both in electricity costs and GHG emissions reductions.

Central Utilities Plant:

Noted previously, the cogeneration system was added in 2005 for increased overall efficiency. As the plant provides heating and electricity to both the River Campus and Medical Center, it resides between the two locations. The plant houses five steam boilers with a capacity of 668,000 lbs/hr and four steam driven chillers with 22,000 refrigerant tons capacity. The plant supplies the University with ½ of the thermal heating and ⅓ of the electricity across the River and Medical Campuses. With this installation, it was found that GHG emissions decreased by 3%.

Figure 2.1: Central Utilities Plant site which utilizes cogeneration technology.

Middle Campus Chiller:

Figure 2.2: Exterior of the Middle Campus Chiller.

The Middle Campus Chiller Plant was constructed in 2008 as a satellite to the Central Utilities Plant to provide additional chilled water to the River Campus and the Medical Center. Because electric chillers are more efficient than its steam driven counterpart coupled with the clean energy grid in Upstate New York, this plant incorporated two electrical chillers with 4000 refrigerant tons of capacity. For reference, the coefficient of performance (COP), which is the ratio of cooling provided to the amount of energy required, for steam chillers averages 1.2, while the COP for electric chillers averages 7.6[2]. In other words, a higher COP is desired as it signifies higher efficiency. Then, in 2014, the plant was expanded by adding three more high efficient electric driven chillers allowing for an additional 8000 refrigerant tons of capacity. This installation of electric chillers has effectively reduced emissions by 4%.

Building Upgrades:

The University of Rochester has explored a number of building upgrades to increase efficiency and in turn reduce GHG emissions. Beginning in 2015, the fraternity quad was upgraded as part of a solution to address a failing steam system and safety concerns. The solution used a conversion from steam heat to hot water utility and cogen heating, allowing for a reduction in energy usage in the building. This upgrade also included a packaged water to water heat exchanger with heat controls, pumps, and exchangers. Shown in Figure 2.3 are the energy savings, which in turn reduced costs by more than $47,000 per year. Further results found that there were simplified maintenance practices and an increase in electricity generator output, which nearly offset the total electrical energy required for the fraternity quad. With these energy savings, the school was able to offset more than 16 tons of CO_2 annually.

A similar building upgrade was completed this past year where Spurrier Hall was also upgraded to hot water utility from the inefficient steam. As will be noted in the future projects section, this form of upgrade will be completed for a number of other buildings, including half of Rush Rhees Library, Wilson Commons, and Eastman Dental School.

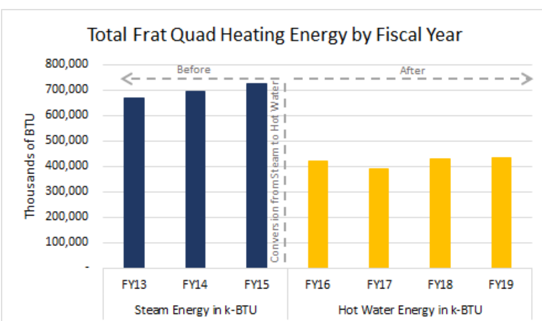

Figure 2.3: Plot quantifying the energy savings after upgrading the fraternity quad.

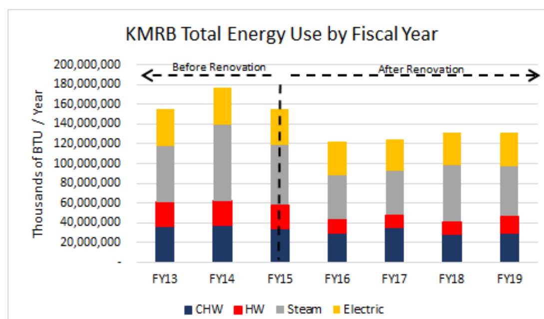

Figure 2.4: Plot of KMRB energy use before and after the renovation.

In 2015, the Kornberg Medical Research Building (KMRB) was upgraded with sights of reducing energy usage. The KMRB faced two main problems: the building's heating, ventilation, and air conditioning (HVAC) was using more energy per square foot than other research buildings on campus and the laboratories' airflow control was sub-optimal. In order to address these problems, the University reprogrammed the system to better control airflow within labs and to reduce overall air exchange rate. The University replaced older air valve controls with modern controls. This resulted in a successful reduction of building energy usage and costs, as shown in

Figure 2.4. There was a 23% reduction in overall KMRB energy use and an overall 2.8% reduction in overall medical center energy use.

Building upon the success of the Kornberg project, it was studied and then extended to upgrading another building of similar characteristics: Del Monte Medical Research Building. Del Monte is another energy intensive research building with high amounts of energy required per square footage. The study found that energy consumption rates in both buildings, prior to the Del Monte upgrades, proportionally matched one another and that the laboratory layout including the mechanical equipment were virtually identical. Del Monte was successfully upgraded in the summer of 2015, where it was found to yield a reduction in electricity and hot water consumption by 8% and 20% respectively.

While the other upgrades have considered building logistics, another form of improvement considered lighting efficiency in 2015 and 2016. Incandescent bulbs produce light using electricity to heat a metal filament until it becomes hot resulting in 90% of the energy wasted as heat. On the other hand, light-emitting diodes (LEDs), are semiconductor devices that produce visible light when an electrical current passes through them with about 95% of the energy being converted to light. As a result LEDs use 75% less energy and last 25 times longer than incandescent bulbs. The light upgrades have occurred in Danforth Dining Center, Rush Rhees Library Room 354, Gale and Fairchild Residential Halls as well as parking areas of Trustee Lot, Riverside Lot, Bridge Lot, and the Medical Center Parking Garage. This has resulted in savings of over 1.1M kWh of electricity. Not only do these lighting upgrades reduce energy consumption seen in Figure 2.5, but they also increase visibility and public safety as shown in Figures 2.6 and 2.7[3].

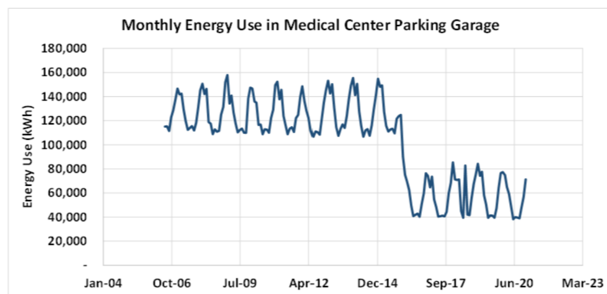

Figure 2.5: Graph of energy use reduction after implementation of LED lights in the Medical Center Parking Garage.

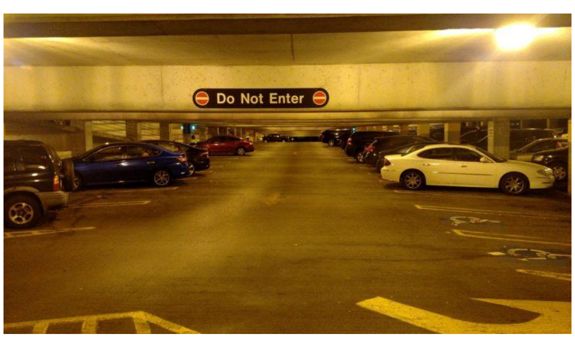

Figure 2.6: Medical Center Parking garage before LED upgrade

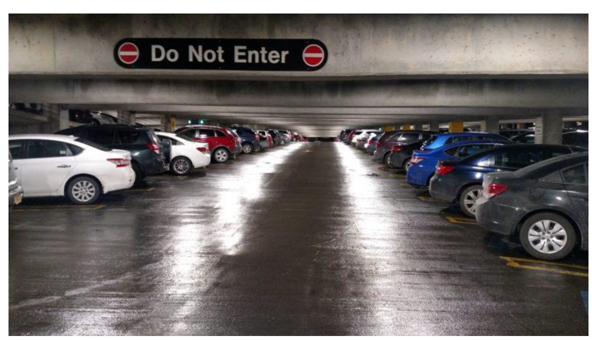

Figure 2.7: Medical Center Parking garage after LED upgrade

Solar Photo-Voltaic Generation and Grid Battery Storage:

Many people are interested in solar energy to aid in the transfer to renewables. In 2018, the University received $1 million from the New York State Energy Research and Development Authority to be used to "develop technology for improved energy systems and to advance fundamental science that promotes understanding of the impacts of energy technology on the environment and human health.[4]" In 2019, the grant was used to successfully install a 336 kW integrated solar and energy storage system on the roof of the Goergen Athletic Center.

Figure 2.8: Solar panels atop Goergen Athletic Center and Tesla Batteries for energy storage.

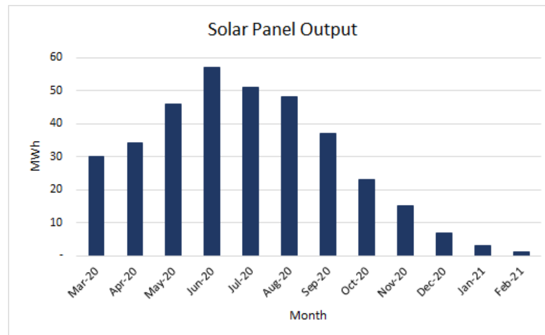

Figure 2.9: Electricity generation of the solar panels; highest during the summer.

This project included 960 solar panels installed in 2019 followed by eight Tesla batteries in 2020, which translates to about 352 MWh per year using data from March 2020 to February 2021, shown in Figure 2.9. The batteries are used to store surplus energy and utilizes this energy during nighttime or when solar power is limited. These energy savings have yielded a reduction in \$25,000 in electricity costs and offset 78 tons of CO_2 annually.

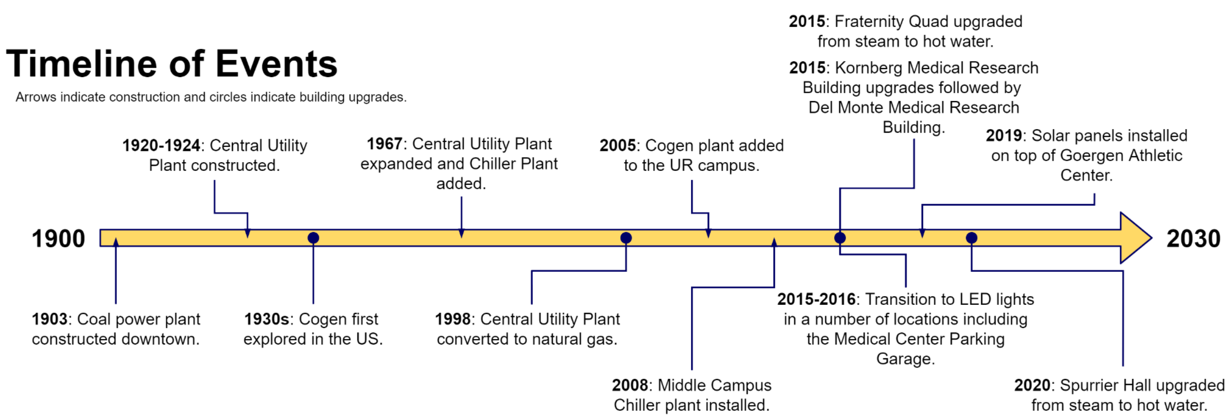

Figure 2.10: Comprehensive timeline of energy related construction and building upgrades for reducing GHG emissions.

3. Comparison Energy Usage per Square Foot in Old vs New Buildings

This section explores energy usage between buildings of similar characteristics from January 2019 to December 2020 to identify trends. For best comparison, chilled water was neglected for buildings without air conditioning like Susan B. Anthony Hall and Genesee Hall. Pay attention to the differing vertical axis scale and note that total energy refers to electricity, steam, and hot water. Older buildings are shown in blue and newer buildings are shown in gold.

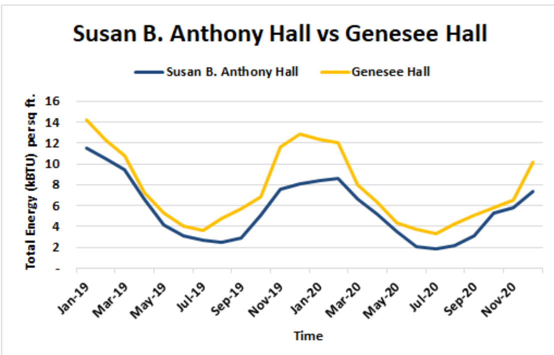

Figure 3.1: Comparison of residential buildings.

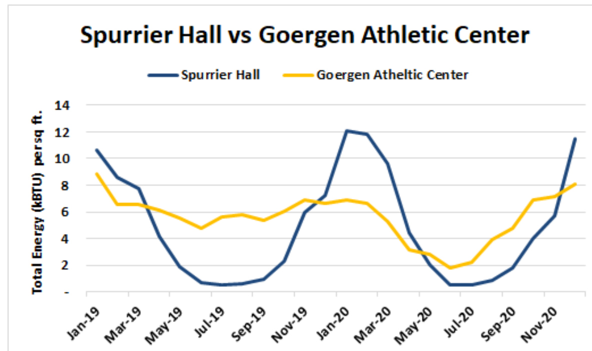

Figure 3.2: Comparison of athletic facilities.

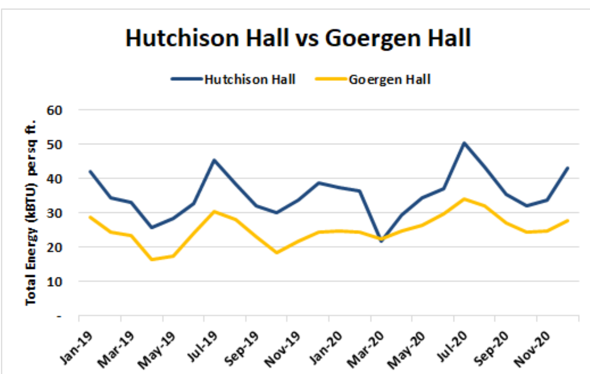

Figure 3.3: Comparison of research buildings.

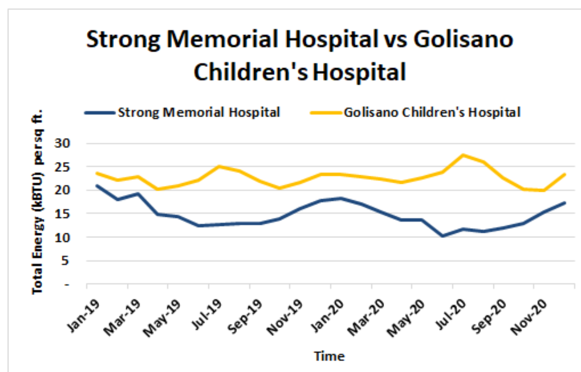

Figure 3.4: Comparison of hospitals.

While it is difficult to make strict comparisons between the buildings, generally spikes in energy usage occur in the winter months with the exception of Hutchison Hall and Goergen Hall. The older buildings were of similar performance to their newer counterparts. In research intensive buildings, like Hutchison Hall and Goergen Hall, and the hospitals, these are more energy intensive compared to residential buildings and athletic facilities. Validate data for Goergen Athletic Center and PV.

4. Future upgrades and improvements

There have been numerous advancements on campus for reducing GHG emissions and the school does not plan to stop their drive for improvement. Currently, there are a number of upgrades in the works, ranging from building conversions to energy management systems and long-term outlooks. A few of them are highlighted below.

- In the near-term and following an improved efficiency, Goergen Athletic Center (GAC), Wilson Commons, half of Rush Rhees Library, and Eastman Dental School are being studied to be converted from steam to hot water. The GAC will be completed by the end of this spring.
- Being implemented this summer, there will be an energy meter information system (EMIS) which will have a public interface to allow the user to track building energy intensity, building GHG intensity, and cost intensity. The system works by tracking, coordinating, and analyzing energy usage data. This information will allow the community, in addition to stakeholders, to interact and understand energy usage at the school. This project was paid for by an incentive through NYSERDA and RGE.
- The school is studying and reviewing paths for reaching various levels of reduction in GHG emissions on campus.
- The UEM team is starting a retro-commissioning program at the University. This process allows the team to reduce the energy usage and bills of each building by restoring the building's operations and maintenance (O&M) procedures.

5. *Conclusion*

The purpose of this work is to bring to light the sustainable measures taken by the UEM Team. Members of the school and community will easily be able to obtain an idea of the improvements in efficiency and sustainability, in the past, present, and future at the University. These improvements include upgrades to the Central Utilities Plant, like the addition of cogeneration, and upgrades to buildings, like the transition from steam to hot water. The UEM Team plans to continue their efforts by expanding the use from steam to hot water and implementing EMIS. As an addition to this report, linked is an interactive StoryMap showing similar information in addition to short video clips and a photo gallery of the campus construction and Central Utility Plant.

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References:

[1] Su, Emily. "The History of University's Power Plant." *The Green Dandelion*, 22 Jan. 2020, blogs.rochester.edu/thegreendandelion/2020/01/the-history-of-universitys-power-plant/.

[2] PakBlogger. "HVAC Absorption Chillers vs Electric Chillers." *HVAC System , HVAC Water Chillers,Valves and Pumps*, 1 Jan. 1970, hvac-system-basics.blogspot.com/2012/07/hvac-absorption-chillers-vs-electric.html#.YGR540hKhQI.

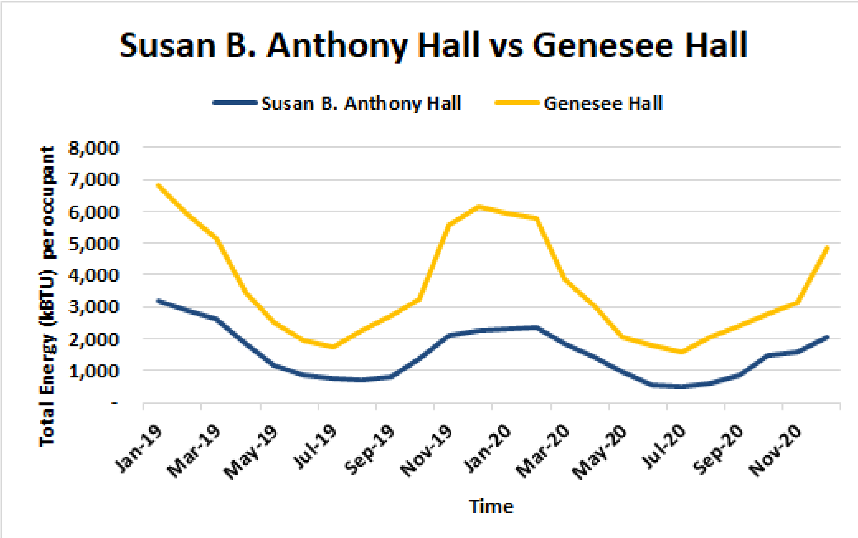
[3] Lemire, Alyssa. "LED Lighting Upgrades Illuminate the University." *The Green Dandelion*, University of Rochester, 27 June 2016, blogs.rochester.edu/thegreendandelion/2016/06/led-lighting-upgrades-illuminate-the-university/.

[4] Valich, Lindsey. "CEE Receives $1 Million Grant for Campus Solar Project." *NewsCenter*, University of Rochester, 23 Oct. 2018, www.rochester.edu/newscenter/cee-receives-1m-grant-for-campus-solar-project-344482/.

[5] *Central Utilities & Energy Management:Facilities and Services*, University of Rochester, www.facilities.rochester.edu/central_utilities/index.php.

Appendix:

The energy use per occupant comparison of Susan B. Anthony Hall and Genesee Hall



Other Future Projects

- The UEM team has also been working on developing different education and engagement systems. The first is a collaboration guide to be used for facilitating cooperation between UEM and academic programs at the University.
- The UEM team has also been exploring funding options for a district heat pump study. A heat pump would rely on electricity eliminating the need for combustible hydrocarbons and use rejected heat from chilled water to heat water. This inclusion of a large scale heat pump on campus would significantly reduce carbon emissions further contributing to the University's sustainability initiative.
- Undergoing a study of the chilled water in the hospitals, which should increase the efficiency of chilled water pumping. 2-1400
- Investigating feasibility of fault detection diagnostics (FDD) for HVAC on top of buildings for discrepancies in expected and actual readings.
- Future LED Light Upgrades: Robert B. Goergen Hall and Optics, the Memorial Art Gallery, and Hoyt Hall Auditorium.