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Pennsylvania Technical Assistance Program
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PennState
Donald P. Bellisario
College of Communications

Pennsylvania State University
Carnegie Building
Energy Savings Assessment

Prepared For:

Karen Mozley-Bryan & Juliet Pinto
The Penn State Donald P. Bellisario College of Communications
17 Carnegie Building
University Park, PA 16802

July 12, 2023

Prepared by:
Pennsylvania Technical Assistance Program
The Pennsylvania State University
University Park

JSM-22-041

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July 12, 2023

Karen Mozley-Bryan & Juliet Pinto
The Penn State Donald P. Bellisario College of Communications
Carnegie Building
University Park, PA 16802

Dear Karen and Juliet,

On behalf of the Pennsylvania Technical Assistance Program (PennTAP), we are pleased to present the results of the P2/E2 assessment conducted at The Pennsylvania State University's Carnegie Building on March 1 and 2, 2023. The intent of the assessment was to identify energy conservation opportunities to reduce greenhouse gas (GHG) emissions to offset the GHG emissions generated by faculty and staff business travel. A summary of the conservation opportunities and recommendations provided in the report is included below. These recommendations could reduce energy consumption by 26,488 kWh/yr and 153 MMBtu/yr, equivalent to $10,180 annually.

Project Summary

Conservation Opportunity	Electricity Savings (kWh/yr)	Steam Savings (MMBtu/yr)	Cost Savings ($/yr)	Project Cost ($)	Simple Payback (yr)
LED Upgrade	26,488	NA	2,183	5,477	2.5
Repair Window Seals	NA	11	4,164	TBD	TBD
Install Low-e Window Film	NA	127	3,100	TBD	TBD
Replace Weatherstripping on Main Entrance Doors	NA	15	733	TBD	TBD
Total	**26,488**	**153**	**10,180**	**5,477**	**2.5**

As previously mentioned, the intent of the assessment was to reduce the GHG emissions generated at the Carnegie Building to offset those generated from the College of Communications' faculty and staff's business travel. In total, the conservation opportunities identified in this report are expected to offset the GHG emissions resultant from:

- 822 round trips made by PSU Fleet cars to Harrisburg, Pennsylvania, from State College, Pennsylvania; ***or***
- 204 round-trip flights from the University Park Airport in State College to O'Hare International Airport in Chicago, Illinois[1].

[1]Travel to Harrisburg, Pennsylvania, is based on the use of a PSU Fleet 2019 Chevrolet Malibu hybrid sedan and a round-trip distance of 175 miles. Travel to O'Hare International Airport in Chicago, Illinois, is based on a round-trip flight traveling a total of 1,060 miles.

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Summary of Travel Offset by GHG Emissions

Conservation Opportunity	GHG Emissions Savings	Travel Offset due to GHG Reduction[1,2]	
		Roundtrip Travel to Harrisburg, PA	Roundtrip Travel to O'Hare Airport, Chicago, IL
	($MTCO_2e$/yr)	(# Car trips/yr)	(# Flights/yr)
LED Upgrade	17.70	521	129
Repair Window Seals	0.74	22	5
Install Low-e Window Film	8.47	249	62
Replace Weather stripping on Main Entrance Doors	1.01	30	7
Total	**27.92**	**822**	**204**

[1]*Depicts how many trips of* ***either*** *mode of transportation would be offset by the reduction in GHG emissions.*
[2]*Data is not cumulative.*

Please note that the attached report and analysis are provided to you at no cost due to grants received by PennTAP. Our funders require that we collect feedback from our clients in the form of periodic surveys to gauge the success of our program and its value to the small business community. Your assessment of the energy savings, our time, and the grant funds you may have been awarded should be considered economic benefits and recorded in the second survey you receive. We would appreciate your cooperation in completing these surveys. If you have any questions regarding the survey when it arrives, please do not hesitate to contact me.

Thank you, in advance, for your participation. I will follow up with you in a few weeks to ensure that you have received this report. In the meantime, please feel free to call me at (814) 865-4542 if you have any questions.

Warm Regards,

Jenn Jones, CSSGB, C.W.E.P., E.M.I.T.
PennTAP Technical Advisor
Phone: (814) 865-4542 | Email: jsm148@psu.edu

Assisted By:

Amanda Enns, PennTAP Student Intern
Penn State Engineering Leadership and Innovation Management Program

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List of Common Abbreviations & Acronyms

AFUE.........Annual Fuel Utilization Efficiency
BMP..........best management practice
Btu...........British thermal unit
CFL...........compact fluorescent
CO............carbon monoxide
CO_2 ....carbon dioxide
CO_2e ....carbon dioxide equivalent
CCF ....centum cubic feet
cfm ....cubic feet per minute
DTH..........dekatherm
EER ....energy efficiency ratio
°F ....degrees Fahrenheit
ft..............feet
ft^3.............cubic feet
gal............gallon
GHG.........greenhouse gas
hp ....horsepower
hr ....hour, hours
HSPF ....heating seasonal performance factor
HVAC ....heating, ventilation, and air-conditioning
HVLS ....high volume, low speed
ID ....identification
in..............inch
INC...........incandescent bulb
kW ....kilowatt
kWh ....kilowatt hours
klb............kilopounds
lb..............pound, pounds
LED ....light-emitting diode
MCF ....million cubic feet
MH...........metal halide bulb
MMBtu .....Million British thermal unit
mo ....month
$MTCO_2e$ ....metric tons carbon dioxide equivalent
MW..........megawatt
NO_x ....oxides of nitrogen
O_2.............oxygen
PA DEP......Pennsylvania Department of Environmental Protection
PennTAP ...Pennsylvania Technical Assistance Program
psi ....pounds per square inch
PUC..........Public Utility Commission
PVC ....polyvinyl chloride
REAP ....Rural Energy for America Program
SBAG ....Small Business Advantage Grant
SEER..........Seasonal Energy Efficiency Ratio
SO_2...........sulfur dioxide
sq ft ....square feet
USDA ....United States Department of Agriculture
W ....watts, wattage
Wh ....watt hours
yr ....year, years

1 Project Background

The Pennsylvania State University's Carnegie Building opened in 1904 and initially housed Penn State's first freestanding campus library (see Figure 1). From 1923 to 1925, the student fire department was also housed in the building. In 1941, it became the home of the music department. In 1972, the student newspaper began to use the building as its headquarters. Today, the Carnegie Building is currently home to the Donald P. Bellisario College of Communications (College of Communications). The building is comprised of three floors which house faculty and staff offices, a small theatre, and three classrooms.

Throughout the life of the building, many renovations have been completed. The largest renovation occurred in 1990, where the first and second floors were gutted, and the old library room was remodeled into a large cinema room. In 2002, the first and second floor landings and the ground floor were renovated. In 2019, the graduate lab space was created, and, in 2021, the Deans' suite and the advising area were remodeled.

Figure 1: Main Entrance of Carnegie Building

The representatives from the College of Communications that sit on Penn State University's Sustainability Council contacted PennTAP as they are interested in conserving energy to reduce GHG emissions to offset the emissions generated by faculty and staff business travel. PennTAP completed a P2/E2 assessment on March 1 and 2, 2023, where Karen Mozley-Bryan (Manager of Facilities, College of Communications) hosted:

- Jenn Jones – PennTAP Technical Advisor;
- Amy Jorden – PennTAP Technical Advisor;
- Amanda Enns – PennTAP Intern, Graduate Student, Penn State Engineering Leadership and Innovation Management;
- Aditya Krishnaswamy – PennTAP Intern, Graduate Student, Penn State Industrial Engineering, and;
- Ten EGEE 494 students.

While on-site, the lighting and building envelope were evaluated. The Carnegie Cinema was not evaluated as part of the assessment since the use of the space, and its contents, are not controlled by the College of Communications.

1.1 Hours of Operation

The facilities manager provided the Carnegie Building's hours of operation. Unless otherwise noted, these hours were used to complete the analysis provided in this report. While the Carnegie Building is open year-round; the occupancy of the building is dependent on the time of year and the use of the space. Classrooms and faculty/staff offices are occupied during the fall and spring semesters. Therefore, unless otherwise noted, the annual hours of operation for offices and classrooms are based on 30 weeks per year. On average, the faculty and staff offices are occupied four hours per day, five days per week, during these semesters. The spring 2023 semester schedule was used to determine the hours of operation for classrooms (see Table 1).

Table 1: Spring 2023 Classroom Hours of Operation

Classroom	Hours of Operation (hr/week)
Room 001	6.25
Room 121	28.50
Room 024	21.75
Room 003	12.00

1.2 Labor and Miscellaneous Costs

The costs provided in this report are approximate and not guaranteed. They reflect the price of the recommended equipment only. PennTAP does not include labor, taxes, shipping, or other additional fees due to the variable nature of these charges.

2 Baseline Utility Consumption

Penn State owns and operates three chilled water plants, two steam boiler plants, a potable water system, and a wastewater treatment plant[2]. Electricity is primarily generated by West Penn Power, cogenerated by the steam boiler plants, and supplied from one of four West Penn Power substations. In addition, 1% of the electricity consumed at the University Park Campus is supplied by an on-campus 2 MW solar array[3]. Penn State's Office of the Physical Plant (OPP) provided utility bill data for January 2021 through December 2022. PennTAP used this data to complete a utility bill analysis to determine baseline utility consumption of the Carnegie Building (see Table 2). In 2021, it cost $95,315 to operate the Carnegie Building which increased to $102,766 in 2022. Due to the COVID-19 pandemic, most students and university employees primarily attended classes and worked remotely until the start of the fall 2021 semester which began in August of that year. Therefore, the increase in utility costs was most likely due to increased use of the building.

[2] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf
[3] https://sustainability.psu.edu/campus-efforts/operations/energy/solar-projects/

Table 2: Comparison of Annual Utility Cost for 2021 and 2022

Utility	2021 ($/yr)	2022 ($/yr)
Chilled Water	39,813	44,998
Electricity	22,884	24,440
Steam	30,945	30,676
Potable Water	858	1,432
Wastewater (Sewer)	815	1,220
Total	**95,315**	**102,766**

PennTAP averaged the cost of each utility over the two-year period to determine which utilities contributed the most to the Carnegie Building's operating costs (see Figure 2). Chilled water, steam, and electricity accounted for 98% of all operating costs, while water and wastewater accounted for 2%. This was expected since the water consumption, and subsequent wastewater generation, are the result of handwashing and restroom use. Steam (used for heating) and chilled water (used for cooling) accounted for over 50% of the average operating cost.

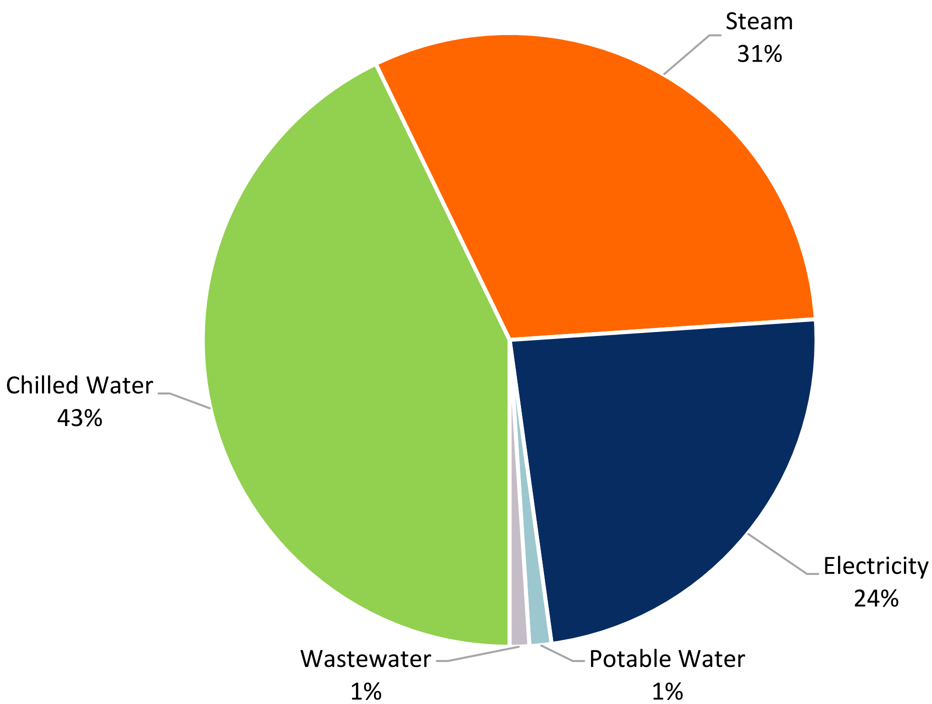

Figure 2: Average Annual Utility Cost Distribution

2.1 Chilled Water

The Carnegie Building is cooled by chilled water which is used for these purposes year-round. It is produced and supplied by Penn State's chilled water system, which is comprised of three production facilities connected through a distribution loop[4]. OPP provided chilled water consumption and cost data for January 2021 through December 2022. In 2021, the Carnegie Building consumed a total of 256,691 ton-hr of chilled water at a rate of $0.16/ton-hr. The same amount was consumed in 2022, however, the cost increased to $0.18/ton-hr. The chilled water costs and cost savings provided throughout this report were determined using the 2022 rate. The total cost of chilled water was $39,813 in 2021 and $44,998 in 2022. PennTAP graphed the monthly chilled water consumption from January 2021 to December 2022 (see Figure 3). As expected, consumption increases in the summer months due to comfort cooling and then decreases in the fall and winter months when it is used to regulate the building temperature. No change was observed in the 2021 monthly consumption when compared to that of 2022. This was not anticipated. PennTAP recommends investigating to determine why this occurred.

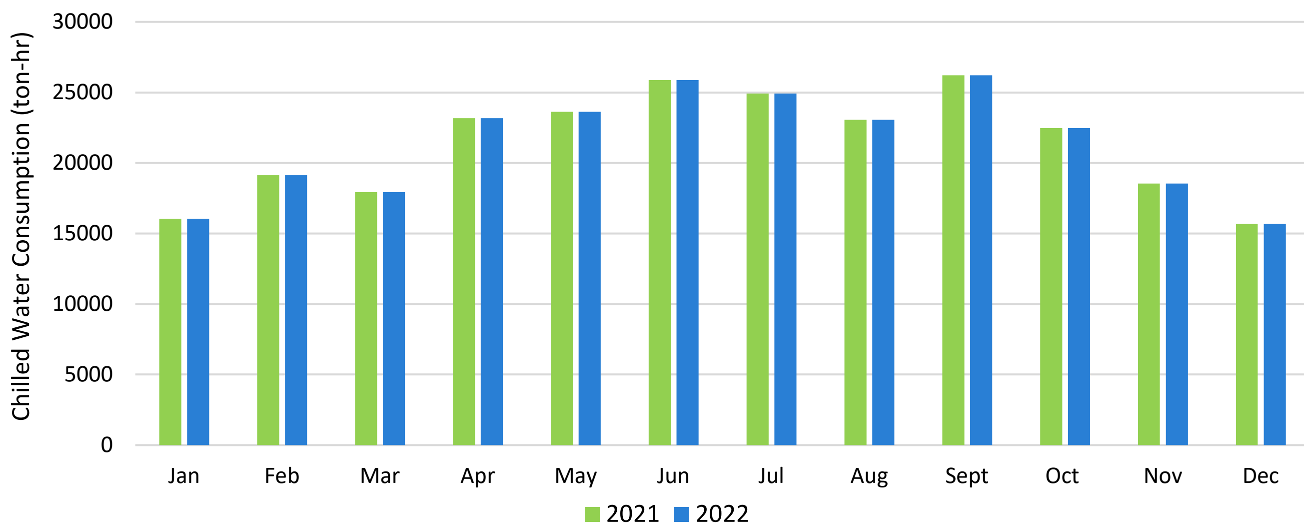

Figure 3: Comparison of Monthly Chilled Water Consumption – 2021 to 2022

2.2 Electricity Usage Analysis

As previously mentioned, electricity is primarily generated by West Penn Power, cogenerated by Penn State's steam plants, and supplied from one of four West Penn Power substations or an on-campus solar array[5;6]. OPP provided electricity consumption and cost data for January 2021 through December 2022. In 2021, the Carnegie Building consumed 255,398 kWh of electricity, at a rate of $0.09/kWh. In 2022, a total of 243,217 kWh was consumed at a rate of $0.10/kWh. The total cost of electricity was $22,884 in 2021 and $24,440 in 2022. The electricity costs and cost savings provided throughout this report were determined using the 2022 rate of $0.10/kWh.

[4] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf
[5] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf;
[6] https://sustainability.psu.edu/campus-efforts/operations/energy/solar-projects/

PennTAP graphed the monthly electricity consumption from January 2021 to December 2022 (see Figure 4). Over the course of both years, electricity consumption decreases during the summer months when the building is not heavily occupied. While the trends observed for both years are similar, the consumption observed from April 2021 to December 2021 was higher than that observed for the same period in 2022. Since in-person classes had not resumed until August 2021 due to the COVID-19 pandemic, monthly consumption was expected to be higher in 2022. PennTAP suspects the reduction in electricity consumption observed in 2022 is due to an LED lighting upgrade that was completed during a 2021-2022 renovation of the Dean's suite and advising area.

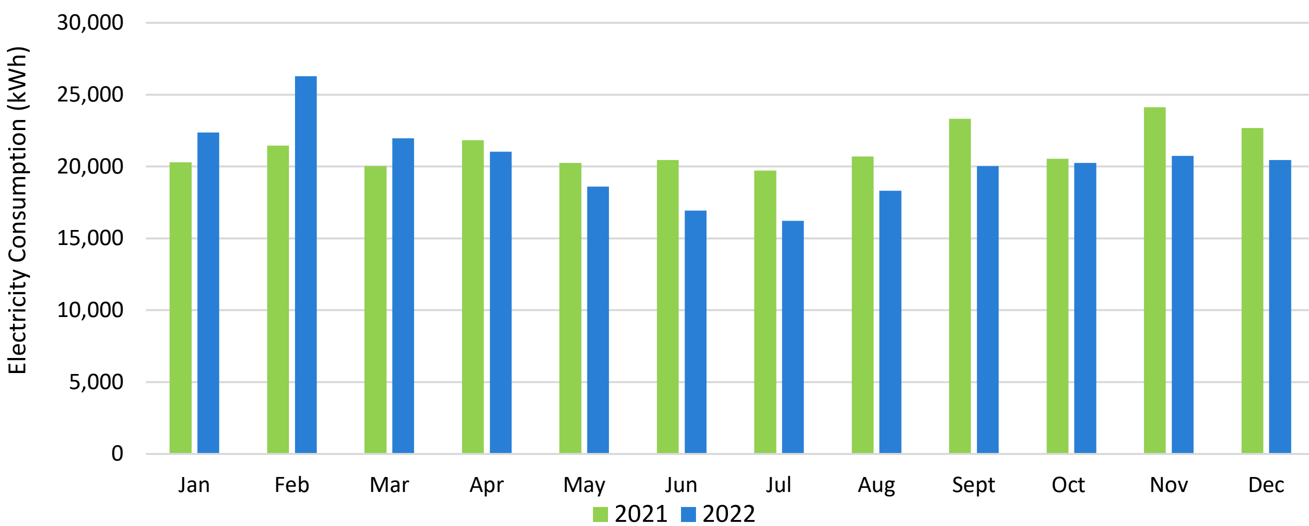

Figure 4: Comparison of Monthly Electricity Consumption – 2021 to 2022

2.3 Steam

Steam is generated and distributed to the Carnegie Building by one of the two on-campus steam boiler plants[7]. Steam is used for comfort and hot water heating. OPP provided steam consumption and cost data for January 2021 through December 2022[8]. In 2021, the Carnegie Building consumed 1,320 MMBtu of steam, at a rate of $23.45/MMBtu. In 2022, 1,280 MMBtu of steam was consumed at a rate of $23.96/MMBtu. The total cost of steam was $30,945 in 2021 and $30,676 in 2022. The steam costs and cost savings provided throughout this report were determined using the 2022 rate of $23.96/MMBtu.

PennTAP graphed the monthly steam consumption from January 2021 to December 2022 (see Figure 5). Overall, consumption increases in the winter months and decreases in the summer months. More steam was consumed from May 2021 through September 2021 when compared to the same period in 2022. This was not anticipated since steam is primarily used to heat hot water during these months and building occupancy would have been low due to the COVID-19 pandemic. Faculty and staff were primarily working remotely, and classes were held virtually until late August 2021. When comparing water consumption

[7] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf

[8] Steam is metered in klb, equal to 1,000 pound of steam mass flow. One klb is equal to 1,000,000 Btu or one MMBtu. PennTAP used this conversion factor to convert klb to MMBtu for the purposes of this report.

between years, less water was consumed during the same period in 2021 than in 2022 (see Section 2.4). Therefore, the trend observed is most likely not a result of increased hot water heating and may have been the result of failing to set back a thermostat that controls a given space. Steam consumption was higher in April 2022 and October 2022 when compared to the same months in 2021 due to a greater number of heating degree days (HDD). Heating degree days are a measure of how often the outside temperature falls below a given setpoint, in this case 65 °F, triggering the need for comfort heating.

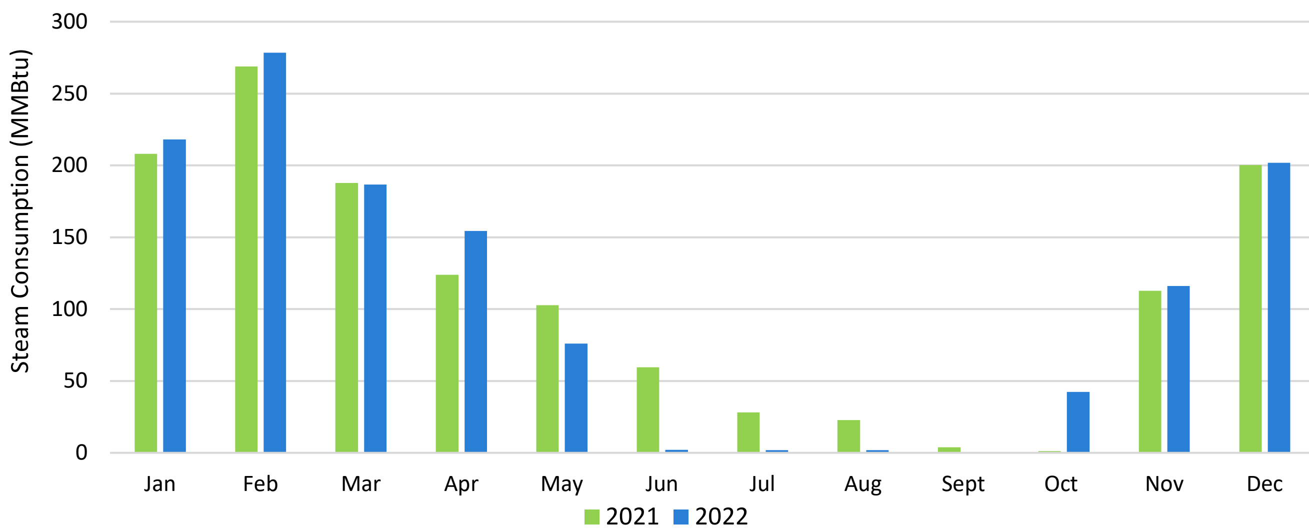

Figure 5: Comparison of Monthly Steam Consumption – 2021 to 2022

2.4 Potable Water

Penn State owns and operates the potable water and distribution system at the University Park Campus[9]. OPP provided potable water consumption and cost data for January 2021 through December 2022. In 2021, 70,900 gallons of water were used, at a rate of $0.012/gallon. Water consumption increased to 121,800 gallons in 2022, at a rate of $0.012/gallon. The total cost of potable water was $858 in 2021 and $1,432 in 2022.

PennTAP graphed the monthly potable water consumption for January 2021 to December 2022 (see Figure 6). Less water was consumed from January 2021 to August 2021 when compared to the same months in 2022. This was expected since faculty and staff were primarily working remotely, and classes were held virtually until late August 2021 when in-person classes resumed. From August 2021 through December 2022, the trends in consumption reflect trends in building occupancy during the fall and spring semesters. For example, in 2022, consumption decreased in December, January, and March due to the winter break and spring break. Likewise, consumption decreased during the summer months as a result of decreased building occupancy and use. Consumption was higher in November 2022 than in October 2022 which was not expected due to the Thanksgiving break in November. This may have been due to increased restroom use due to holiday events held at the Carnegie Cinema. Overall, consumption was also highest during the fall 2022 semester (August to December). While this may also be the result of increased building use, PennTAP

[9] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf

recommends monitoring water consumption to ensure that this trend does not continue. Increased water consumption can be the result of leaking faucets or pipes, running toilets, or failing water meters.

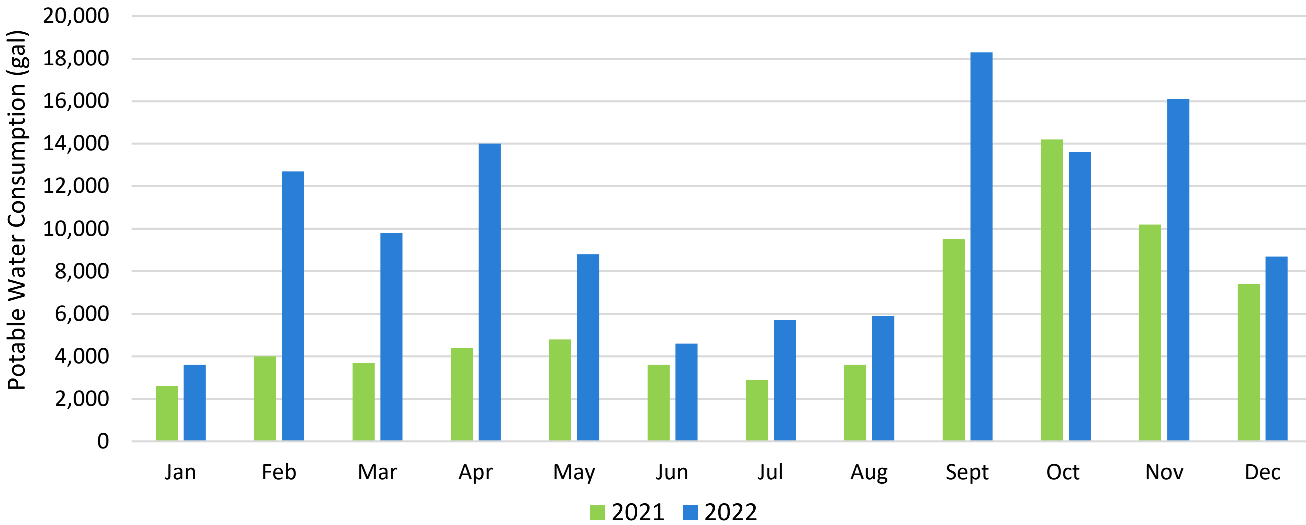

Figure 6: Comparison of Monthly Potable Water Consumption – 2021 to 2022

2.5 Wastewater

Wastewater is treated at an on-campus wastewater treatment facility that is owned and operated by Penn State[10]. OPP provided wastewater generation and cost data for January 2021 through December 2022. Wastewater is the result of restroom and breakroom use. In 2021, 70,900 gallons of wastewater were generated, at a rate of $0.010/gallon treated. In 2022, 121,800 gallons were generated, at a rate of $0.010/gallon treated. The total cost to treat the wastewater generated was $815 in 2021, and $1,220 in 2022.

PennTAP graphed the monthly wastewater generated from January 2021 to December 2022 (see Figure 7). In general, the volume of wastewater generated was equal to the volume of potable water consumed, and similar trends were observed (see Section 2.4). This was expected since the water consumed is not used for industrial processes. Less wastewater was generated in January 2021 to August 2021 when compared to the same months in 2022 due to decreased building occupancy as a result of the COVID-19 pandemic. As with potable water consumption, from August 2021 to December 2022, the wastewater generated reflects trends in building occupancy during the fall and spring semesters and summer break, with the same exceptions noted when looking at potable water consumption in Section 2.4.

[10] https://www.opp.psu.edu/sites/opp/files/utilityfactsheet_19-20.pdf

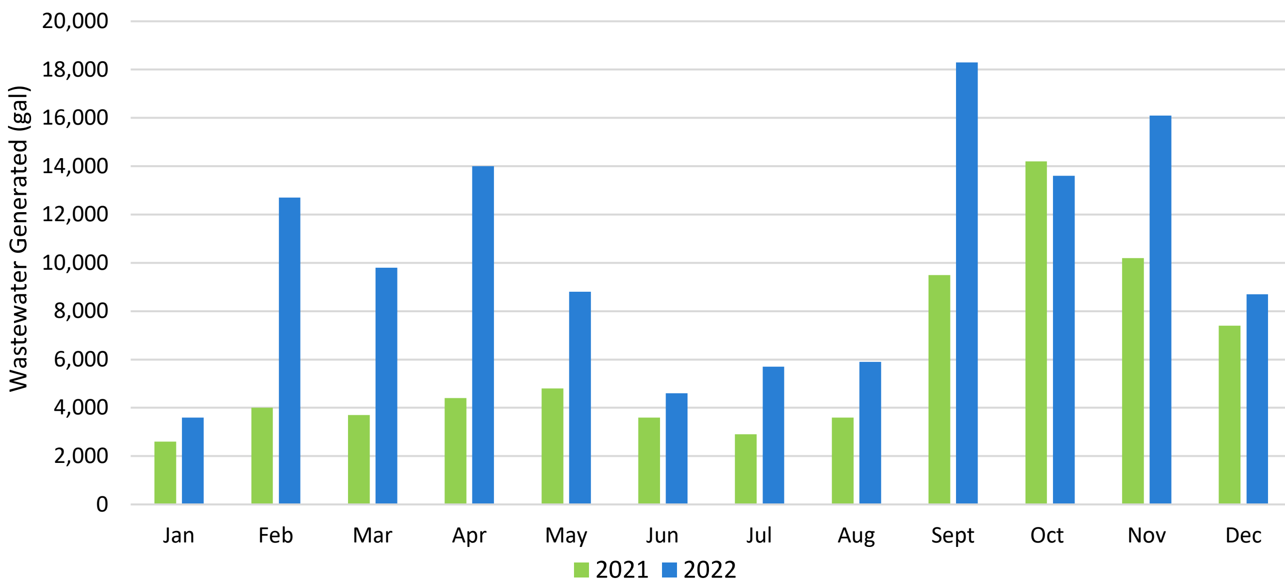

Figure 7: Comparison of Monthly Wastewater Generation – 2021 to 2022

3 P2/E2 Technical Analysis

During the P2/E2 assessment, the Carnegie Building's lighting and building envelope were evaluated. PennTAP conducted research and an analysis based on the observations made. The results of the analysis and subsequent recommendations are provided in the following sections.

3.1 Lighting

The Carnegie Building has been renovated several times since it was opened in 1904 (see Section 1). Lighting upgrades were often completed as part of these projects. The lighting found within an area of the building often reflects the technology for the time in which a renovation was completed. For instance, the first and second floor hallways, remodeled in 1990, are lit with compact and linear fluorescent bulbs, while the Dean's suite, advising areas, and graduate lab, remodeled in 2019 and 2021, contain LED bulbs.

During the assessment, PennTAP evaluated the existing lighting and completed an inventory of the non-LED bulbs (see Appendix A)[11]. Since several faculty and staff offices were not accessible, PennTAP worked with the facilities manager to determine the bulb type and number of bulbs/fixtures in the space. The facilities manager stated that office spaces tend to mirror each other based on where they are located. Therefore, the lighting observed in an open office was assumed to be in the neighboring ones. A mix of fluorescent lights, including T12s, T8s, T5s, CFLs, and circline fluorescents was observed when completing the inventory. PennTAP estimated the energy consumption and cost of these bulbs using their wattage and the hours of operation defined in Section 1.1 (see Table 3)[12]. The existing fluorescent bulbs consume approximately 50,057 kWh/yr of electricity, equivalent to an annual cost of $4,125.

[11] As mentioned in Section 1, the Carnegie Cinema was not included in the assessment.
[12] Stairwell lighting is used year-round for 24 hours per day, seven days per week. Hallway lighting is used year-round for 18 hours per day, seven days per week. All other lighting hours of operation align with those discussed in Section 1.1.

Table 3: Estimated Cost of Current Non-LED Lighting

Bulb Quantity	Energy Consumption	Energy Cost
(#)	(kWh/yr)	($/yr)
618	50,057	4,125

PennTAP recommends replacing the remaining fluorescent bulbs with LEDs. PennTAP calculated the energy consumption of the existing and proposed lighting, expected implementation cost of an LED upgrade, estimated energy cost savings, and the simple payback period for the project (see Table 4). In the analysis, the installation of the new bulbs is assumed to be completed by OPP at no additional cost and does not include taxes or shipping charges that may apply.

Table 4: Lighting Upgrades Summarized by Bulb Type

Lamp Type	Bulb Quantity	Energy Usage (kWh/yr)			Implementation Cost*	Energy Cost Savings	Simple Payback Period
	(#)	Current	Proposed	Savings	($)	($/yr)	(yrs)
CFL triple - 42W	25	2,176	466	1,710	398	141	2.8
CFL - 23W	8	1,328	981	346	88	29	3.1
T12 4' - 40W	85	2,530	1,138	1,391	573	115	5.0
T8 4' - 32W	197	13,318	4,578	8,740	798	720	1.1
T8 2' - 17W	6	61	29	32	36	3	13.4
T5 4' - 54W	24	2,333	1,080	1,253	255	103	2.5
T5 4' - 28W	69	2,602	1,394	1,208	1,107	100	11.1
T8 3' - 25W	44	660	317	343	310	28	11.0
CFL 2' bi-ax - 40W	136	21,249	12,218	9,031	1,519	744	2.0
CFL twin - 26W	8	973	337	636	94	52	1.8
Circline Fluorescent - 40W**	16	2,827	777	2,050	300	169	1.8
Total	**618**	**50,057**	**23,316**	**26,741**	**5,477**	**2,203**	**2.5**

**The implementation cost provided is based on the cost of an equivalent LED bulb and does not include taxes, fees, or the cost of labor or equipment to install the LED bulbs. The actual project cost and savings may vary.*
*** The specifications for the circline fluorescent bulbs were assumed in the analysis since the bulbs were not accessible during the assessment. PennTAP recommends confirming the specifications when completing the upgrade. PennTAP is available to revise the analysis in the event the actual specifications differ.*

Many institutions replace the bulbs as they fail in order to spread the project cost of an LED upgrade over time. While this may seem more cost effective and allow one to utilize the existing lighting for the life of the bulb, it also leads to higher operational costs and reduced savings over time. Therefore, PennTAP recommends replacing all the lighting at the Carnegie Building at the same time. PennTAP determined the annual expected project cost and savings of an incremental upgrade when compared to a one-time upgrade over the course of a ten-year period (see Table 5). Over a ten-year period, the total savings achieved by a one-time upgrade exceeds the incremental upgrade by an estimated $9,620.

Table 5: Comparison of Incremental and One-Time Lighting Upgrade Costs and Savings

Year	Incremental Upgrades		One-Time Upgrade	
	Implementation Cost ($)	Annual Savings ($)	Implementation Cost ($)	Annual Savings ($)
1	702	317	5,477	2,203
2	631	610	0	2,203
3	607	892	0	2,203
4	586	1,163	0	2,203
5-10	1,278	9,432	0	13,221
Total	**3,804**	**12,414**	**5,477**	**22,035**

PennTAP also plotted the expected savings of a one-time upgrade and an incremental upgrade for comparison purposes (see Figure 8). A one-time upgrade is expected to result in significantly more savings over the ten-year period than an incremental upgrade.

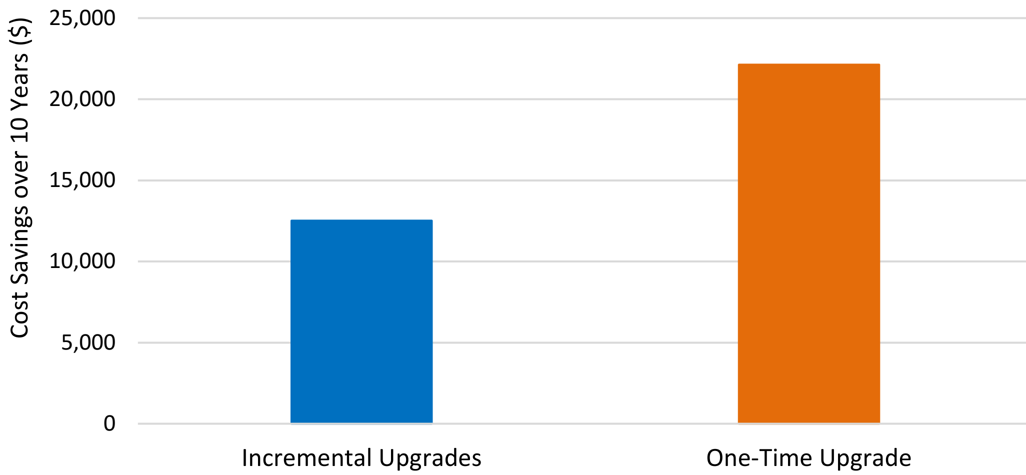

Figure 8: Comparison of Ten-Year Cost Savings from an Incremental vs. One-Time Lighting Upgrade

There are times where an incremental upgrade is unavoidable. Should this be the case, PennTAP recommends upgrading by space instead of when a bulb fails. Complete upgrades in the area that would lead to the greatest savings first. The savings generated from this upgrade can then be applied to the project costs of upgrading the remaining spaces. Following this logic, PennTAP recommends upgrading the ground floor first if the lighting is upgraded incrementally (see Figure 9).

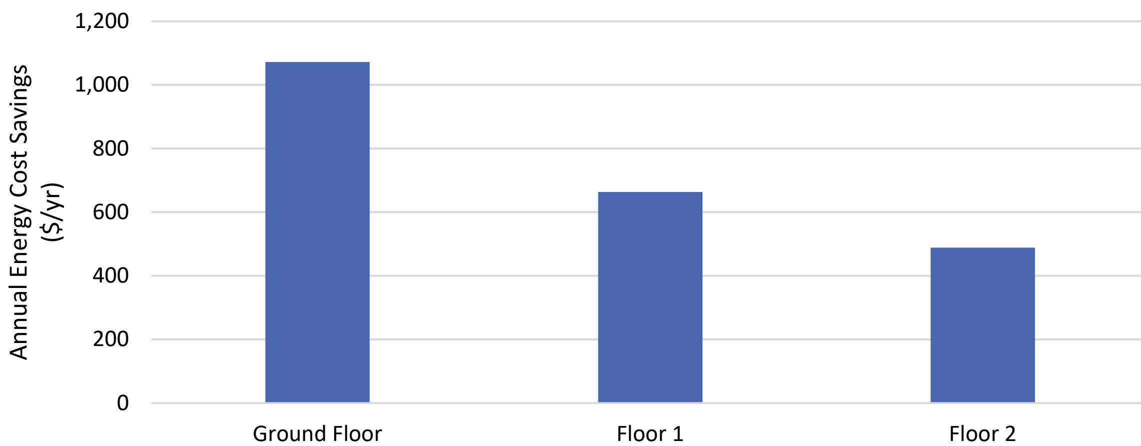

Figure 9: Comparison of Annual Savings from a Lighting Upgrade by Floor

In summary, the recommended lighting upgrade is expected to reduce energy consumption by 26,741 kWh/yr, equivalent to $2,203 and a GHG emissions reduction of 17.7 $MTCO_2e$ (see Table 6). The GHG emissions saved through the recommended updates were calculated using the EPA's P2 GHG Calculator[13].

Table 6: Expected Savings from Lighting Upgrades

Energy Savings	Cost Savings	GHG Emissions Savings	Implementation Cost	Simple Payback
(kWh/yr)	($/yr)	($MTCO_2e$/yr)	($)	(yr)
26,741	2,203	17.7	5,477	2.5

**The implementation cost provided is based on the cost of an equivalent LED bulb and does not include taxes, fees, or the cost of labor or equipment to install the LED bulbs. The actual project cost and savings may vary.*

Due to limited access to many of the offices and some additional areas during the assessment, PennTAP did not include occupancy sensors in our analysis. We recommend the inspection of all offices, classrooms, and study spaces for occupancy sensors and installing as needed. In addition, our analysis is based on a one-to-one lighting upgrade. PennTAP recommends consulting with a lighting contractor to complete a lighting design that will effectively light all spaces while conserving energy. In addition, a lighting contractor can determine if a replacement of the fixtures in addition to bulbs is necessary and which spaces are ideal for occupancy sensors and which type to install. Once a quote has been received, PennTAP is available to revise the analysis.

3.2 Building Envelope

In addition to the lighting, PennTAP evaluated the building envelope during the P2/E2 assessment. All windows and doors were evaluated to determine where heat loss may be occurring. PennTAP took several infrared (IR) images of the building envelope using a FLIR® E6 Thermal Imaging Camera to determine where heat loss may be occurring. The northwest side of the building was evaluated between 9:30 AM and 11:00 AM, on day 1, March 1, 2023. The outdoor temperature during this time was 37°F. On day 2, March 2, 2023, the southeast side of the building was evaluated between 9:30 AM and 10:30 AM. While the original forecast

[13] https://www.epa.gov/p2/pollution-prevention-tools-and-calculators

called for much cooler temperatures, the outdoor temperature was 49 °F and was too warm to effectively evaluate the southeast portion of the building for heat loss. Therefore, PennTAP assumed the heat loss observed on day 1 was indicative of that occurring throughout the entire building when completing the analysis.

Over 100 IR images were taken during the assessment. The images included in this report represent areas of concern or images that best represented the conditions observed when the building envelope was evaluated. The white and yellow areas in the IR images signify areas that are hot, while those that are purple or black represent cooler areas. Every IR image will exhibit contrast, however, that is not necessarily an indication of heat loss. IR images where there is a significant temperature difference tend to be areas requiring further investigation. Each image includes a reference scale for your convenience.

3.2.1 Windows

During the walkthrough, PennTAP observed open windows. According to the facilities manager, there are several windows that do not remain securely closed due to broken locks. PennTAP observed these conditions on several of the windows in the stairwell and lobby areas. In each case, cool air could be felt entering the building which causes the heating system to work harder to maintain temperature. We recommend evaluating the condition of the locks on all windows and repairing them when needed. In the image below, cool air can be observed entering the building through the open lower right window panel (see Figure 10). The window was not open because the space was overheated, but simply because the employee preferred a cooler work environment than those in the neighboring spaces. In addition, only one thermostat was observed for the offices in the suite. Due to the potential heat loss and subsequent increased energy consumption, we recommend using a personal fan instead of opening the window as a fan would consume significantly less energy.

Figure 10: Infrared Image of Open Window Observed During Assessment

PennTAP also recommends inspecting the window seals when checking each window for broken locks. PennTAP completed an analysis to determine the potential energy savings from repairing worn window seals and caulking on the first and second floors. The analysis was based on the heating degree days (HDD) for 2022 and a 1/8-inch gap in the seal[14]. Since the windows on the first floor have a perimeter of 30 feet and those on the second floor 32 feet, an average of two feet of worn seal per window was assumed. The

[14] HDD were obtained from https://www.degreedays.net/ and were based on weather station KUNV State College, University Park Airport, PA US (77.85W,40.85N). A set point of 65 °F was used.

reduction in GHG emissions was determined by calculating the natural gas saved by the steam plant due to steam consumption at the Carnegie Building and through use of the EPA's P2 GHG Calculator[15]. Based on the utility bill data provided by OPP, the operational costs are based on the steam provided, therefore the cost savings are based on the cost per MMBtu of steam saved (see Section 2). Based on the analysis completed, repairing worn window seals is expected to save 11 MMBtu/yr of steam, equivalent to $267 and 0.74 $MTCO_2e$/yr (see Table 7).

Table 7: Expected Savings from Window Seal Repair

Heat Loss Calculation							Recommended Savings		
Window Location	Number of Windows	Gap Width	Gap Perimeter	Specific Heat of Air	Density of Air	Average Wind Speed	Energy Savings	Cost Savings	GHG Emissions Savings*
	(#)	(in)	(ft)	(Btu/lb-°F)	(lb/ft)	(mph)	(MMBtu/yr)	($/yr)	($MTCO_2e$/yr)
1st Floor	23	1/32	2.0	0.24	0.077	3	5	120	0.33
2nd Floor	28	1/32	2.0	0.24	0.077	3	6	146	0.41
Total							**11**	**267**	**0.74**

While open windows and worn window seals are contributing to the heat lost in the winter, Figure 10 (above) and Figure 11 indicate that heat loss occurs primarily through the windowpanes and metal frame of each panel. Metal frames are poor insulators since metal rapidly conducts heat. Installing thermal breaks (an insulating plastic strip) between the inside and outside of the frame can serve to reduce heat loss[16].

Figure 11: Infrared Image of Window on Northwest Wall of Building

Thermal breaks may be labor intensive and costly to install. An easier solution would be to hang insulating curtains since heat loss is occurring at the windowpanes, too. Research has shown that having well-fitted layered curtains results in an insulation value equal to or greater than double-glazing, yet at a fraction of the cost. However, installing curtains will significantly reduce the amount of natural light available which may cause occupants not to use them or to use the overhead lighting more.

[15] https://www.epa.gov/p2/pollution-prevention-tools-and-calculators
[16] https://www.energy.gov/energysaver/window-types-and-technologies

While curtains are an option for the Carnegie Building, it may be better to apply a low-emissivity (low-e) window film. Low-e film can decrease heat loss in the winter and reduce energy consumption by at least 10%[17]. Low-e film is easier to install than replacing windows. It does not rely on human use, like curtains, to be effective and would serve to maintain the historical integrity of the Carnegie Building. In addition, low-e films can last as long as 15 years, and in some instances more[18]. PennTAP calculated the potential savings from installing low-e film on the windows of the Carnegie Building based on a 10% reduction in the steam consumed to heat the building in 2022. The same method was used to determine the reduction in GHG emissions as was used in the analysis provided in Table 7. And, as in Table 7, the cost savings are based on the cost to provide steam to the building. Installing low-e window film has the potential to reduce the steam consumed at the Carnegie Building by 127 MMBtu, equivalent to $3,053 and 8.47 $MTCO_2e$/yr (see Table 8).

Table 8: Expected Savings from Low-e Window Film Application

2022 Steam Consumption - Heating	Reduced Steam Consumption	Cost Savings	Emissions Savings
(MMBtu)	(MMBtu/yr)	($/yr)	($MTCO_2e$/yr)
1,274	127	3,053	8.47

3.2.2 Doors

The doors of a building can also represent a source of heat loss. Heat loss often occurs around the perimeter of the door as the weatherstripping wears out. PennTAP evaluated the doors of the Carnegie Building to determine areas where heat is being lost. Worn weatherstripping was observed at almost every entrance to the building. PennTAP recommends inspecting all doors and replacing the weatherstripping as needed.

During the P2/E2 assessment, the facilities manager stated that the main lobby on the first floor is one of the coldest areas in the building. PennTAP inspected and took IR images of the main entrance doors (see Figure 12). Heat loss is observed at the panels in the center of the door, indicating these panels are poorly insulated. PennTAP suspects these panels were once windows that were replaced with wood that matches the rest of the door. Heat loss is also observed in the window above the door. As with the other windows, repairing the seals and/or applying low-e film would serve to reduce heat loss (see Section 3.2.1).

Figure 12: Infrared Image of the Main Entrance Doors

[17] https://www.osti.gov/servlets/purl/1089147; https://www.buildings.com/exteriors/article/10186640/how-effective-is-low-e-window-film
[18] https://www.energy.gov/energysaver/window-types-and-technologies

In addition to the heat loss occurring from the center panels of the door, there is no weatherstripping between the main doors, resulting in a gap that is approximately 0.5-inch wide (see Figure 13). During the assessment, it was also noted that the wooden doors expand and contract depending on the season. A second gap was noted in the upper right corner of the right entrance door (not pictured). While ideally these doors should be replaced, there are limitations to what can be used since this is a historic building. Therefore, while PennTAP recommends replacing the door with a well-insulated one, this may not be feasible and, at the very least, the weatherstripping should be replaced.

Figure 13: Missing Weatherstrip – Main Entrance Door

PennTAP determined the energy savings once the weatherstripping has been replaced on the main entrance doors. The analysis was completed using the same method as that described in Table 7 in Section 3.2.1. Replacing the weatherstripping on the main entrance doors is expected to reduce the steam consumed at the Carnegie Building by 15 MMBtu, equivalent to $363 and 1.01 $MTCO_2e$/yr (see Table 9).

Table 9: Expected Savings from Replacing Weatherstrip on Main Entrance Doors

Heat Loss Calculation						Recommended Savings		
Number of Doors	Width	Length	Specific Heat of Air	Density of Air	Average Wind Speed	Energy Savings	Cost Savings	GHG Emissions Savings
(#)	(in)	(ft)	(Btu/lb-°F)	(lb/ft)	(mph)	(MMBtu/yr)	($/yr)	($MTCO_2e$/yr)
1	0.5	8.67	0.240	0.077	3	15	363	1.01

3.3 Greenhouse Gas Emissions Reductions for Business Travel Offset

The representatives from the College of Communications that sit on Penn State University's Sustainability contacted PennTAP to identify energy conservation opportunities to reduce GHG emissions as an offset to those generated by faculty and staff business travel. PennTAP completed an analysis to determine the GHG emission that would be offset by the recommendations made in this report. PennTAP evaluated the emissions generated per mile from air travel and from using a Penn State Fleet car (see Table 10). Information regarding the number of trips or the average trip taken by the faculty and staff of the College of Communications was not available. Therefore, travel by Fleet car is based on round-trip travel to Harrisburg, Pennsylvania, from State College, Pennsylvania (175 miles). Most Penn State Fleet vehicles are

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hybrids. Therefore, the analysis is based on the emissions factor for a 2019 Chevrolet Malibu Hybrid [19]. Air travel was based on a 1,060-mile round-trip flight from the University Park Airport in State College, Pennsylvania to O'Hare International Airport in Chicago, Illinois. PennTAP used the EPA emissions per passenger mile for a medium haul flight data[20].

Table 10: Emissions Summary for Car and Air Travel

Travel Method	Trip	Distance (miles)	GHG Emissions ($MTCO_2e$/mile)
Car Travel	Round-trip Travel to Harrisburg, PA	175	0.03
Air Travel	Round-trip Travel to O'Hare Airport, Chicago, IL	1,060	0.14*

**Emissions factor was determined using the EPA's Simplified GHG Emissions Calculator. The emissions factor for air travel is based on an individual passenger and does not represent the total emissions resultant from the flight.*

Based on this analysis, PennTAP determined the GHG emissions to be offset by implementing the recommendations included in this report. In total, the conservation opportunities identified are expected to offset the GHG emissions resultant from 822 round trips made by car to Harrisburg, Pennsylvania, from State College, Pennsylvania, ***or*** 204 round trip flights from the University Park Airport to O'Hare International Airport, Chicago, Illinois (see Table 11).

Table 11: Summary of Travel Offset by GHG Emissions

Conservation Opportunity	GHG Emissions Savings ($MTCO_2e$/yr)	Travel Offset due to GHG Reduction*	
		Roundtrip Travel to Harrisburg, PA (# Car trips/yr)	Roundtrip Travel to O'Hare Airport, Chicago, IL (# Flights/yr)
LED Upgrade	17.70	521	129
Repair Window Seals	0.74	22	5
Install Low-e Window Film	8.47	249	62
Replace Weatherstripping on Main Entrance Doors	1.01	30	7
Total	**27.92**	**822**	**204**

Depicts how many trips of* ***either* *mode of transportation would be offset by savings– and is not cumulative.*

PennTAP created a reference table using the values in Table 10 to provide the Sustainability Council an easy way to determine the total GHG emissions that would be generated in a given year due to business travel within the College of Communications (see Table 12). To determine the total emissions per year, identify the total number of trips taken by car annually and locate the number closest to that value in the orange cells. Next, identify the total number of flights taken during the year and locate the number closest to that value in the purple cells. Follow the corresponding row (flight travel) and column (car travel) to the cell

[19] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=40842&#tab2
[20] https://www.epa.gov/climateleadership/simplified-ghg-emissions-calculator

where they intersect to determine the total emissions resultant from all travel during that year. For instance, 50 car trips and 25 flights would generate a total of 5.1 MTCO2e/yr (see the green cell in Table 12). In the event that the number of trips is between the values provided, it is up to the Sustainability Council to decide whether to round up or down when selecting the number of trips.

Table 12: GHG Emissions Reference Table for Business Travel

Average Annual Emissions ($MTCO_2e/yr$)		Fleet Car Trips (#/yr)								
		0	1	10	25	50	75	100	200	500
Air Travel (# flights/yr)*	0	0.0	0.0	0.3	0.8	1.7	2.5	3.4	6.8	17.0
	1	0.1	0.2	0.5	1.0	1.8	2.7	3.5	6.9	17.1
	10	1.4	1.4	1.7	2.2	3.1	3.9	4.8	8.2	18.3
	25	3.4	3.5	3.8	4.3	5.1	6.0	6.8	10.2	20.4
	50	6.8	6.9	7.2	7.7	8.5	9.4	10.2	13.6	23.8
	75	10.3	10.3	10.6	11.1	12.0	12.8	13.7	17.0	27.2
	100	13.7	13.7	14.0	14.5	15.4	16.2	17.1	20.5	30.6
	200	27.3	27.4	27.7	28.2	29.0	29.9	30.7	34.1	44.3
	500	68.4	68.4	68.7	69.2	70.1	70.9	71.8	75.2	85.3

**The emissions factor used in the analysis was determined using the EPA's Simplified GHG Emissions Calculator. It is based on an individual passenger and does not represent the total emissions resultant from the flight. If more than one passenger is on the same flight, PennTAP recommends treating each passenger as a unique flight.*

4 Summary

The representatives from the College of Communications that sit on Penn State University's Sustainability contacted PennTAP to identify energy conservation opportunities to reduce GHG emissions as an offset to those generated by faculty and staff business travel. PennTAP conducted a P2/E2 assessment at the Carnegie Building on March 1st and 2nd 2023, where several conservation opportunities were identified. The recommendations made in this report could save up to 26,488 kWh/yr of electricity and 153 MMBtu/yr of steam, equivalent to up to $10,180 annually and 27.9 $MTCO_2e/yr$ of GHG emissions. In addition, the recommendations included in this report are expected to offset the GHG emissions resultant from 822 round trips made by car to Harrisburg, Pennsylvania, from State College, Pennsylvania, or 204 round trip flights from the University Park Airport to O'Hare International Airport, Chicago, Illinois. A summary of the recommendations and savings is provided in Table 13.

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Table 13: Summary of PennTAP Recommendations and Savings

Conservation Opportunity	Electricity Savings	Steam Savings	GHG Emissions Savings	Travel Offset due to GHG Reduction[1,2]		Cost Savings	Project Cost	Simple Payback
				Roundtrip Travel to Harrisburg, PA	Roundtrip Travel to O'Hare Airport, Chicago, IL			
	(kWh/yr)	(MMBtu/yr)	($MTCO_2e$/yr)	(# Car trips/yr)	(# Flights/yr)	($/yr)	($)	(yr)
LED Upgrade	26,488	NA	17.70	521	129	2,183	5,477	2.5
Repair Window Seals	N/A	11	0.74	22	5	4,164	TBD	TBD
Install Low-e Window Film	N/A	127	8.47	249	62	3,100	TBD	TBD
Replace Weather stripping on Main Entrance Doors	N/A	15	1.01	30	7	733	TBD	TBD
Total	**26,488**	**153**	**27.9**	**822**	**204**	**10,180**	**5,477**	**2.5**

[1]*Depicts how many trips of* ***either*** *mode of transportation would be offset by the reduction in GHG emissions.*
[2]*Data is not cumulative.*

Please contact PennTAP with any questions or comments about the above items or with any questions or concerns in the future. Furthermore, the greatest measure of PennTAP's success is the accomplishments of our clients, as enabled by the solutions we provide them to grow their businesses. Please enjoy examples of PennTAP helping clients more effectively manage their energy and technical resources, creating real-world opportunities for student engagement, and benefiting Pennsylvania in several measurable ways.

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Appendix

Appendix A: Lighting

Table 14: Formulas for Calculating Cost Savings and Implementation Cost for Lighting

Description	Value	Calculation
Energy Consumption	(kWh/yr)	Lamp Wattage (in kWh) x Ballast Factor x Operating Hours
Energy Savings	(kWh/yr)	(Current – Proposed) Energy Consumption
Capital Cost	($)	Sum of ($/Lamp * Number of Lamps of Each Type)
Simple Payback	(yr)	Implementation Cost / Total Cost Savings

Table 15: Existing and Proposed LED Lighting Upgrade Details

Location	Current			LED Replacement		Savings		Implementation Cost*	Simple Payback
	Bulb Type	Wattage	Bulb Quantity	Wattage	Energy Cost	Energy Consumption	Cost Savings		
		(W)	(#)	(W)	($)	(kWh/yr)	($/yr)	($)	(yr)
Floor G - Room 008	T5 4' - 28W	28	36	15	56	590	49	577	11.9
Floor G - Room 008	CFL 2' bi-ax - 40W	40	12	23	29	257	21	134	6.3
Floor G - Room 020	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 023	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 022	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Classroom 001	CFL triple - 42W	42	9	9	6	278	23	143	6.2
Floor G - Classroom 001	CFL 2' bi-ax - 40W	40	6	23	11	96	8	67	8.5
Floor G - Room 004	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 005	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 007	T5 4' - 28W	28	2	15	1	16	1	32	25.0

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Location	Current			LED Replacement		Savings		Implementation Cost*	Simple Payback
	Bulb Type	Wattage	Bulb Quantity	Wattage	Energy Cost	Energy Consumption	Cost Savings		
		(W)	(#)	(W)	($)	(kWh/yr)	($/yr)	($)	(yr)
Floor G - Room 009	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 010	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Room 018	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - Classroom 024	T5 4' - 28W	28	8	15	32	339	28	128	4.6
Floor G - Classroom 024	CFL triple - 42W	42	8	9	19	861	71	127	1.8
Floor G - Q001-Q006, F001, F003	CFL 2' bi-ax - 40W	40	88	23	781	7,001	577	983	1.7
Floor G - Entrance 003	T5 4' - 28W	28	1	15	6	61	5	16	3.2
Floor G - Room 002	T5 4' - 28W	28	2	15	1	16	1	32	25.0
Floor G - F002	CFL triple - 42W	42	1	9	3	154	13	16	1.3
Floor G - Room R011	T5 4' - 28W	28	4	15	6	62	5	64	12.5
Floor G - Room R015	CFL 2' bi-ax - 40W	40	8	23	18	163	13	89	6.6
Floor G - Room R015	CFL 2' bi-ax - 40W	40	4	23	9	82	7	45	6.6
Floor G - Z001	T8 4' - 32W	32	4	11	32	734	60	16	0.3
Floor G - Z002	Circline Fluorescent - 40W**	40	2	11	16	507	42	38	0.9
Floor G - Classroom 003	T5 4' - 54W	54	24	25	89	1,253	103	255	2.5
Floor G - Classroom 003	CFL triple - 42W	42	7	9	9	416	34	111	3.3
Floor 1 - Room 129	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 128	T8 4' - 32W	32	6	11	3	76	6	24	3.9
Floor 1 - Room 127	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 125	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 124	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 123	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 122	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 114	T12 4' - 40W	40	6	18	5	79	7	40	6.2

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Location	Current			LED Replacement		Savings		Implementation Cost*	Simple Payback
	Bulb Type	Wattage	Bulb Quantity	Wattage	Energy Cost	Energy Consumption	Cost Savings		
		(W)	(#)	(W)	($)	(kWh/yr)	($/yr)	($)	(yr)
Floor 1 - Room 115	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 116	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 117	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 118	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 119	T12 4' - 40W	40	6	18	5	79	7	40	6.2
Floor 1 - Room 107	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 1 - Room 106	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 1 - Room 105C	T8 4' - 32W	32	6	11	3	76	6	24	3.9
Floor 1 - Room 105B	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 105A	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 105	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 104	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 103	T12 4' - 40W	40	4	18	4	53	4	27	6.2
Floor 1 - Room 102	T8 4' - 32W	32	6	11	3	76	6	24	3.9
Floor 1 - Room 110	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 1 - Room 111	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 1 - F001 Lobby	CFL twin - 26W	26	4	9	14	318	26	47	1.8
Floor 1 - F001 Lobby	Circline Fluorescent - 40W**	40	2	11	8	271	22	38	1.7
Floor 1 - Z102	Circline Fluorescent - 40W**	40	1	11	8	253	21	19	0.9
Floor 1 - Q101-Q105	T8 4' - 32W	32	40	11	170	3,931	324	162	0.5
Floor 1 - Q101	T8 4' - 32W	32	3	11	13	295	24	12	0.5
Floor 1 - Q101	T12 4' - 40W	40	3	18	21	309	25	20	0.8
Floor 1 - Q101	CFL 2' bi-ax - 40W	40	6	23	53	477	39	67	1.7

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Location	Current			LED Replacement		Savings		Implementation Cost*	Simple Payback
	Bulb Type	Wattage	Bulb Quantity	Wattage	Energy Cost	Energy Consumption	Cost Savings		
		(W)	(#)	(W)	($)	(kWh/yr)	($/yr)	($)	(yr)
Floor 1 - Area Between Q101&104	CFL - 23W (100W Inc. replacement)	23	3	17	20	84	7	33	4.8
Floor 1 - Room 126	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 1 - Room R130	T8 4' - 32W	32	4	11	4	101	8	16	2.0
Floor 1 - Room 101	Circline Fluorescent - 40W**	40	4	11	2	70	6	75	13.1
Floor 1 - Room 101	T8 4' - 32W	32	18	11	10	227	19	73	3.9
Floor 1 - Room R120	T8 4' - 32W	32	6	11	7	151	12	24	2.0
Floor 2 - Room 215	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 213	T8 4' - 32W	32	6	11	3	76	6	24	3.9
Floor 2 - Room 212	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 211	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 210	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 209	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 208A	T8 2' - 17W	17	6	8	2	32	3	36	13.4
Floor 2 - Room 217	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 218	T8 4' - 32W	32	6	11	3	76	6	24	3.9
Floor 2 - Room 219	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 220	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 221	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 222	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 223	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - Room 224	T8 4' - 32W	32	4	11	2	50	4	16	3.9
Floor 2 - F201	Circline Fluorescent - 40W**	40	3	11	13	407	34	56	1.7
Floor 2 - F201	CFL twin - 26W	26	2	9	7	159	13	23	1.8

Location	Current			LED Replacement		Savings		Implementation Cost*	Simple Payback
	Bulb Type	Wattage	Bulb Quantity	Wattage	Energy Cost	Energy Consumption	Cost Savings		
		(W)	(#)	(W)	($)	(kWh/yr)	($/yr)	($)	(yr)
Floor 2 - Room 206	Circline Fluorescent - 40W**	40	1	11	1	17	1	19	13.1
Floor 2 - Room 206A	Circline Fluorescent - 40W**	40	1	11	1	17	1	19	13.1
Floor 2 - Q201	CFL 2' bi-ax - 40W	40	12	23	106	955	79	134	1.7
Floor 2 - Q201	CFL twin - 26W	26	2	9	7	159	13	23	1.8
Floor 2 - Room 208A	T8 3' - 25W	25	32	12	19	250	21	226	11.0
Floor 2 - Room 208B	T8 3' - 25W	25	12	12	7	94	8	85	11.0
Floor 2 - Q202, Q203, Q204, Q205	T8 4' - 32W	32	20	11	85	1,966	162	81	0.5
Floor 2 - F202	Circline Fluorescent - 40W**	40	1	11	8	253	21	19	0.9
Floor 2 - F202	CFL - 23W (100W Inc. replacement)	23	5	17	61	262	22	55	2.5
Floor 2 - Room R216	T8 4' - 32W	32	4	11	4	101	8	16	2.0
Floor 2 - Z201	Circline Fluorescent - 40W**	40	1	11	8	253	21	19	0.9

**The implementation cost provided is based on the cost of an equivalent LED bulb and does not include taxes, fees, or the cost of labor or equipment to install the LED bulbs*
***The specifications for the circline fluorescent bulbs were assumed in the analysis since the bulbs were not accessible during the assessment. PennTAP recommends confirming the specifications when completing the upgrade. PennTAP is available to revise the analysis in the event the actual specifications differ.*