Columbia University
In the City of New York

Advancing Sustainability Leadership at **Faculty House**

Integrative Capstone Workshop in Sustainability Management

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Prepared by Earth Institute Integrative Capstone Team, Columbia University

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Executive Summary

Columbia University recognizes the role it needs to play within its community in the face of climate change. Given its scale, the University has a responsibility to understand and work towards the reduction of its environmental impacts, including its carbon footprint. To fulfill its role and works towards these goals, Columbia University established its first campus-wide sustainability plan, *Sustainable Columbia*, in 2017. The plan establishes clear principles to guide the long-term sustainability vision of the University. Importantly, it sets measurable goals for reducing greenhouse gas (GHG) emissions associated with the University's operations.

The clients for this project included three key leaders that play major roles in advancing sustainability within Columbia University: the Office of Environmental Stewardship, University Events Management, and Faculty House. This report serves as a resource for Columbia University to utilize moving forward to make progress towards achieving the goals set forth in *Sustainable Columbia*. Specifically pertaining to the operations of Columbia University's Faculty House, this report provides the University with tools and recommendations to invest strategically in sustainable upgrades to the building, with aims at reducing GHG emissions associated with its operations.

This report consists of two main components, energy efficiency and sustainable operations. The energy efficiency portion of this report seeks to better understand the current lighting system in Faculty House. This includes a full-building lighting audit, as well as a building occupancy survey to gain insights into how the building currently meets the needs of its employees. The sustainable operations portion of this report focuses on quantifying environmental impacts of food and linen procurement for Faculty House. Both components of the project focus quantitative analyses on GHG emission calculations, to generate results and recommendations that align with the goals of *Sustainable Columbia*.

Based on an LED upgrade analysis, Faculty House could see a reduction of about 212,157 kilowatt hours (kWh) of energy consumption per year, representing a roughly 21% reduction in the building's total energy consumption. The decrease in energy consumption would result in approximately $15,000/year savings, pertaining solely to energy consumption charges. A discounted-cash flow analysis reveals that Columbia University could see this investment back in just 2.5 years.

Sustainable operations results include GHG emissions calculations for food and linen procurement. The food analysis quantified the associated GHG emissions from the 10 most popular menus by sales for Faculty House, as well as the newly developed Sustainable Living Menu. Through analyzing the menus by breaking them down into food categories, results reveal that the majority of GHG emissions in each menu come from animal-based products. As for linens, since implementing linen-less dining options for events in 2018, from 2017 to 2018 Faculty House has reduced linen procurement–based GHG emissions by approximately 30%, and water use by approximately 18%.

Energy efficiency results reveal that the GHG emissions reduction and associated cost–savings of a lighting upgrade justify an LED lighting retrofit. In terms of food procurement, it is recommended that Faculty House reduce animal-based ingredients across all menus served at the venue. To further reduce environmental impacts of linen procurement, it is recommended that Faculty House switch linen vendors to a Textile Rental Services Association (TRSA) clean-green certified linen vendor, which ensures a minimum standard of sustainability in operations, in turn further decreasing environmental impacts associated with their linen procurement.

Along with the results and recommendations, the report is accompanied with a series of tools that the clients can utilize to better track environmental performances pertaining to lighting, as well as food and linen procurement. This series of tools includes a lighting audit template, GHG inventory templates for calculating lighting-based, food-based, and linen-procurement based GHG emissions, as well as a building occupancy survey and scorecard.

By implementing the recommendations stated in this report, Faculty House can successfully reduce GHG emissions associated with its operations. Through doing so, it can continue to be a leader in sustainability on the Columbia University campus, helping the University achieve the goals set forth in *Sustainable Columbia*, as well as fulfill its role within its community in the face of climate change.

Glossary

Building management system (BMS)	A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.
Carbon dioxide equivalent (CO_2e)	Number of metric tons of CO2 emissions with the same global warming potential as one metric ton of another greenhouse gas.
Carbon impact/footprint	A carbon footprint is historically defined as the total emissions caused by an individual, event, organization, or product, expressed as carbon dioxide equivalent.
Cove light	A form of indirect lighting typically built into ledges like crown molding, valences, and cornices for windows, or any upper-wall recesses of a room.
Demand response	A change in the power consumption of an electric utility customer to better match the demand for power with the supply.
Emission factors (EF)	Representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.
EPA	Environmental Protection Agency.
Food loss	The edible amount of food available for human consumption but is rather not consumed for one or more various reasons.
Global Reporting Initiative (GRI)	Global Reporting Initiative: The Global Reporting Initiative is an independent international standards organization that helps businesses, governments and other organizations understand and communicate their impacts on issues such as climate change, human rights and corruption.
Global warming potential	Measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide.
Gut renovation	A renovation in which the space was stripped down to the girders. All materials replaced with new materials.
Greenhouse gas (GHG)	A greenhouse gas is a gas that absorbs and emits radiant energy within the thermal infrared range. Greenhouse gases cause the greenhouse effect. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
Hazardous air pollutants (HAPs)	Also known as toxic air pollutants or air toxics; pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects.

Illuminance	Illuminance specifies the luminous flux in the lux (lx) unit of measurement, of a light source that hits a certain area. It is 1 lux, when the luminous flux of 1 lumen evenly illuminates a 1-square meter surface. The illuminance is measured with a lightmeter on horizontal and vertical surfaces.
Lighting fixture	The frame that surrounds the actual light bulb, these fixtures are compatible only with certain light bulb types.
Lighting lamp	The physical light bulb that emits the light to the pre-designed area its intended for.
Lighting power Intensity	Referring to how much lighting power is used in each area (measured in watts of lighting per square foot).
New England Linen Service (NELS)	Current linen vendor
Pendant light	A lone light fixture that hangs from the ceiling usually suspended by a cord, chain, or metal rod.
Plug and process loads (PPLs)	Building electrical loads that are not related to lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants.
Potential to Emit (PTE)	A facility's maximum capacity to emit air pollutants if both physical design and operational limitations are taken into account. Limitations can include pollution control equipment, type of materials used in the process, and restricted hours of operation.
Recessed downlight	A lone light fixture that is installed above the ceiling line.
Scope 1 emissions	Direct emissions from owned or controlled sources.
Scope 2 emissions	Indirect emissions from the generation of purchased energy
Scope 3 emissions	All indirect emissions (not included in scope 2) that occur in the value chain, including both upstream and downstream emissions.
SCR Diesel DEF Catalytic Exhaust NOx reduction	Technology that uses a urea-based diesel exhaust fluid (DEF) and a catalytic converter to significantly reduce oxides of nitrogen (NOx) emissions. SCR is the leading technology being used to meet the Environmental Protection Agency's 2010 Heavy-Duty Highway Engines and Vehicle emissions reduction regulations.
Textile Rental Services Association (TRSA)	A third-party certifier for linen, uniform, and facility services companies.
Volatile organic compounds (VOCs)	Emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short–and long-term adverse health effects.

Introduction

Sustainability at Columbia University

In 2017 Columbia University launched its first campus-wide sustainability plan, *Sustainable Columbia*. However, the University's commitment to understanding the planet and preserving its resources dates back to 1949, with the establishment of the Lamont-Doherty Earth Observatory (LDEO), an institute dedicated to research in the Earth sciences. In 1996 the University established the Earth Institute (EI), with a mission of addressing complex global issues of sustainable development. Ten years later, the Office of Environmental Stewardship (OES) was created and tasked with driving sustainability initiatives and coordinating with stakeholders across campus. Over the years, the University has consistently demonstrated sustainability leadership – by developing a climate action plan and sustainability principles for its operations, setting bold goals to reduce greenhouse gas (GHG) emissions, and creating interdisciplinary education programs that train the next generation of sustainability practitioners. Overall, Columbia strives to improve its environmental performance, ensure a healthy community, and contribute to local, regional and global climate solutions.

Columbia University spans over 36 acres and three campuses. With nearly 31,000 students and 16,000 employees, it is not only one of the largest private employers in New York City, but also a significant energy consumer and waste generator (Columbia University, 2017). Given its scale, the University has a responsibility to understand and work towards the reduction of its environmental impacts, including its carbon footprint. *Sustainable Columbia* is the result of collaboration across the University's three main campuses and a willingness to centralize sustainability initiatives.

The University is committed to advancing Columbia's core educational, research, and outreach missions to demonstrate its leadership; to plan, develop, implement, and measure strategic sustainability initiatives; and to foster a culture of sustainability. *Sustainable Columbia* establishes clear principles to guide the long-term sustainability vision of the University and sets measurable goals for reducing GHG emissions associated with the University's operations. The goals and strategies are focused around three key areas contributing to the University's carbon footprint: building energy supply and demand, transportation, and waste.

Sustainable Columbia commits the Morningside campus to specific goals over a targeted three-year period (2017–2020). At the time of this report, the University is in the planning phase for beyond 2020. In October 2019, students, faculty, and administrators met to discuss progress to date – including exceeding the GHG emissions reduction goal of 35% and offsetting 100% of the campuses' electricity.
The planning process for Plan 2030 began in November 2019, and the expectation is that the new plan will set ambitious goals to lead the University's action around climate change, including a roadmap for becoming operationally carbon neutral.

Sustainability at Faculty House

Faculty House, a premier event space on the Columbia University campus which hosts events for both the University and greater New York City community, has served as the center of intellectual and social interaction among Columbia University and the greater community for nearly a century.

Avoid, reduce, reuse and recycle is not a new adage for Faculty House. In fact, for years Faculty House has sought to reduce its environmental footprint.

The building underwent extensive renovations in 2008 and the 38,000 square feet of function and meeting space were retrofitted. Almost 75% of the materials of the 1923 original structure were refurbished, repurposed, recycled or donated during the renovation project. In 2010, Faculty House was awarded the distinguished Leadership in Energy and Environmental Design (LEED) Gold Certification by the United States Green Building Council. It was the first building on Morningside campus and the first McKim, Mead & White building in the country to be given this distinction, which was an environmental milestone both for Faculty House and Columbia University. LEED promotes a holistic building approach to sustainability by evaluating performance in five key areas of environmental and human health: sustainable site development, material selection, energy efficiency, water savings, and indoor environmental quality. Faculty House integrated energy-efficient and water-conserving utilities, appliances, fixtures and insulation, installed new HVAC systems to provide cleaner air quality, and selected local, recycled, low-emission furnishings, materials, and finishes.

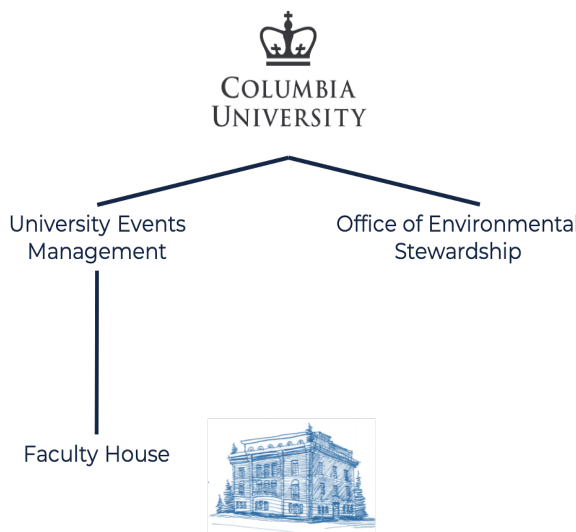
As a premier event venue on campus, Faculty House also put in place operational measures to decrease the impacts of its events and to foster environmental stewardship on premises within its operations. For nearly 10 years, Faculty House has introduced waste management efforts such as recycling and composting, switched to refillable water bottles for all events, managed food portions to avoid waste, and most recently, in 2018, introduced linen-free tables for events on the 1st, 2nd, and 4th floors.

Project Background

Clients

The clients for this project include several key stakeholders within the Columbia University community. These clients include the Office of Environmental Stewardship, University Event Management, and Faculty House. These three different yet critical entities all play a major role in leading sustainability within Columbia University.

Figure 1: Capstone Clients



The Office of Environmental Stewardship (OES) centralizes sustainability efforts across the University's campuses. The office establishes, organizes, and executes programs to reduce the environmental footprint of the University, as well as collaborates with students, staff, and neighbors to achieve the University's sustainability goals. OES led the University's efforts to create the first sustainability plan, Sustainable Columbia, which was developed collaboratively between Earth Institute faculty and Facilities and Operations, with input from students, faculty, and staff.

University Event Management (UEM) manages most events across the University's campuses. UEM assists faculty, staff, students, and outside guests in event planning processes such as finding available spaces on campus, providing catering options, and liaising between Facilities, Public Safety, and other campus support partners.

Faculty House is a premier event space on the Morningside Campus. It is a popular choice both within and outside of the Columbia University community for hosting a variety of events from seminars and meetings to conferences and weddings. University Events Management works extensively with Faculty House in facilitating events throughout the space.

Project Scope

The objective of this report is to provide recommendations for future courses of action to help advance sustainability within Faculty House and align its efforts with the Sustainable Columbia plan. Specific components of the project which are detailed in this report include:

1. Assessing the current lighting system and measuring baseline energy consumption and associated greenhouse gas (GHG) emissions for Faculty House.

2. Assessing the environmental impacts of food and linen procurement for Faculty House.

3. Researching and providing recommendations for energy efficiency upgrades and sustainable operations.

4. Outlining next steps for implementation of the recommendations.

This project is distinctive in that it is combining energy efficiency and operations approaches to addressing sustainability for a Columbia University entity. While the recommendations can be implemented separately, the holistic implementation of all of the recommendations will enable the stakeholders to catalyze sustainability leadership for Faculty House.

By implementing the recommendations, Faculty House can reduce the environmental footprint of its operations and events. Additionally, the tools which were developed and included in the appendices are scalable and can be applied to other buildings at Columbia University, thus further contributing to Sustainable Columbia's goals of GHG emissions reductions.

Methodology

Project Approach

In order to delve deeper into the categories of energy efficiency and sustainable operations, the two categories were further broken down into four sub-categories. Energy efficiency was broken down into Lighting and Best Practices teams, and Sustainable Operations was broken down in Food and Linens teams. Through doing so, specific strategies could be developed that could not only be brought together for a holistic approach to improving sustainability for Faculty House, but also be applied to other buildings across the University's campuses.

Figure 2: Project Approach Breakdown

Energy Efficiency

The Energy Efficiency team was tasked to assist Columbia University's Faculty House in finding ways to innovate their lighting system for energy and greenhouse gas emissions (GHGs) reductions, as well as cost savings. The team was also tasked with calculating the energy loss associated with the main entrance vestibule of Faculty House. While calculating the energy loss at the vestibule was determined to be out of scope for the project at hand, the team approached the objective in a way that could be accomplished given the duration of the project. The Energy Efficiency team conducted a lighting audit for Faculty House to establish a baseline of the current energy usage, GHGs, and systems in place, as well as installed Hobo Trackers, small battery-powered sensor devices, to collect data on temperature, relative humidity, and light intensity fluctuations in the main entrance vestibule. The team also focused on research to establish best practices and identify opportunities to implement new tools and resources that will help decrease electricity costs, lower GHG emissions, and reduce total energy consumption for Faculty House. The methodology to assess the current lighting system and propose recommendations can be divided into 6 steps:

1. Data collection and review
2. On-site audit
3. Energy, cost, and GHG analyses
4. Administer building occupancy survey
5. Survey responses data analysis
6. Results and recommendations

Data Collection and Review

To begin the data collection process, the team reviewed the architectural drawings and blueprints to locate and categorize each room in Faculty House according to specific space types before the physical lighting audit. The team then had to determine the lighting schedule for each room of the building by space-type in order to determine how much energy was consumed to operate the existing lighting system. For event spaces, the client provided monthly reservation lists for different events which included the total number of hours that each event space was booked during the calendar year. Notably, these reserved event hours also included the time needed to set up the event space as well as clean-up/disassembly times. For other room types, an estimated lighting schedule was created based on client feedback and best-practice assumptions. Below are two tables which outline the average lighting hours for each room type:

Table 1: Lighting Schedule by Room-type

Room Type	Daily Avg. Hrs.	Days per Week	Hours/Year
Kitchens	10	7	3640
Storage	0.25	5	65
Mechanical	0.5	7	182
Offices	8	5	2080
Corridors	12	7	4368
Lobby/Foyers	12	7	4368
Restrooms	4	7	1456
Stairwells	24	7	8736
Elevators	24	7	8736
Event Spaces	See Below	See Below	See Below

Table 2: Annual Reserved Event Hours by Event Space in 2018

Event Space	Annual Reserved Hours (2018)
1754 Board Room – 3rd Fl	1,364.76
Garden Room 1 – 1st Fl	1,629.08

Garden Room 2–1st Fl	1,821.95
Ivy Lounge–1st Fl	1,041.08
Presidential Ballroom (Pres123R)–3rd Fl	1,833.58
Presidential Room 1 & Reception–3rd Fl	527.28
Presidential Room 2–3rd Fl	287.42
Presidential Room 3–3rd Fl	567.67
Seminar 1 and Reception–2nd Fl	1,764.58
Seminar Room 2–2nd Fl	1,657.08
Seminar Room 3–2nd Fl	1,433.42
Seminar Room 4–2nd Fl	1,418.92
Skyline Dining Room–4th Fl	1,690.67
Total (2018)	17,037.50

The client also provided the team with utility data for Faculty House from ConEdison, including a monthly breakdown of its total annual energy consumption and costs from January 2017–April 2019 (Table 3). Since energy use data was unavailable for May 2019 onwards, the team approximated the projected consumption values for the remaining months by averaging the corresponding monthly totals from the two prior calendar years. Given the incomplete data set, 2018 was used as the base year for the energy, cost, and GHG emissions analysis since it was the most recent period that contained a full set of calendar year data without any gaps.

*Table 3: Monthly Energy Consumption at Faculty House in MWh (2017–2019) **

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2017	87.6	87.6	92	81.6	80	78.4	80	80.8	91.6	90.4	92	82.8	1024.8
2018	85.6	84.8	87.6	88	92	88.8	77.6	78.4	78.4	80	84.8	82.8	1008.8
2019	77.6	90.8	78.4	79.2	86	83.6	78.8	79.6	85	85.2	88.4	82.8	995.40

**Consumption data was unavailable for May 2019 onwards; values in light blue are projected averages.*

On-Site Audit

The on-site lighting audit included assessing the lighting quality and lighting components of Faculty House. The team also interviewed professionals from Faculty House and the Columbia University Facilities and Operations Team (CUFO) about lighting operational practice, as well as consulted experts in the relevant fields for insights and guidance. The team also interviewed these professionals regarding the Lutron control system. Lutron is a vendor contracted with the University that provides lighting-management hardware and software, so it was important to better understand how the interface works and how useful it is for the client.

Since calculating the actual energy loss at the main entrance vestibule was out of scope for this project, the team installed Hobo Tracker sensors to collect and analyze the vestibule's lighting intensity, temperature, and relative humidity to establish baseline data around potential fluctuations of the aforementioned factors. Hobo trackers are small, battery-operated devices, and the team installed three indoor Hobo Trackers in Faculty House for a period of six days, two at the main entrance vestibule (Lobby), which is frequently used by employees and guests alike, and one at the side entrance vestibule (right-side vestibule), which is mostly used by employees, and where packages of food, trash, and other resources are regularly transported in and out of Faculty House. The intentions of this data were to identify fluctuations in the temperature at the vestibules, which would warrant further investigations into quantifying the actual energy loss associated with them.

The team's primary focus for the on-site lighting audit was the type and quantity of lamps, ballasts, and light fixtures currently in place, and the feasibility of replacing these with more cost-effective and energy-efficient alternatives. The team was also curious about the control system, the Lutron Quantum Vue, as to how the system works and integrates the lighting and services broader power requirements. The team walked around the premises with the blueprint of Faculty House, and documented various aspects of the lighting including but not limited to the location of light fixtures, type and quantity of fixtures and lamps, and physical conditions of the space. Light meters and laser tape measure devices were used to measure the illuminance of the rooms and fixture heights, respectively. The team then distributed a building occupancy survey to the staff of Faculty House. Lastly, the team inquired about the lighting system and practices adopted by the operations/maintenance staff to get a better understanding of what works well, and trying to locate areas of improvement for Faculty House.

Fixture Inventory

Due to the unavailability of the light fixture inventory of Faculty House and limitations of the lighting audit, the team was unable to establish a complete account of what type of lamps and ballasts are used for each fixture. Based on the findings of the lighting audits and expert interviews, reasonable assumptions were made for the lamp and ballast types used in each fixture, and an estimation the electricity consumed to power the interior light fixture was determined. Exterior lighting and interior cove lighting are excluded from this analysis due to data unavailability.

Most of the light fixtures in Faculty House are fitted with fluorescent lamps. A fluorescent light fixture consists of a lamp, ballast, and a starter. The ballast regulates the current through the lamp and provides starting voltage for the starter. Due to the lack of data, assumptions were made on the lamp and ballast types. More specifically, the lamp types were based on the samples provided by the Facilities team. Following the principle that the same type of lamp is used in comparable fixtures in rooms that serve a similar function, the team assigned the lamp type to the light fixtures. The samples are representative of the majority of fixtures based on the observed lighting levels and lighting quality on-site.

Based on the procurement history of the past three years provided by the client, it was assumed that there are two major types of ballasts used in Faculty House:

1. Lutron electronic dimming ballast with normal ballast factor for Lutron controlled fixtures in order to maintain capability with the control system

2. Fulham electronic ballast with high ballast factor for non-Lutron controlled fixtures.

To calculate the power consumed by a light fixture, the lamp-ballast combination needs to be considered as a whole because both lamps and ballasts consume electricity. This total amount of wattage required for a light fixture is known as input wattage. It is a function of the number of lamps and its arrangement, as well as the ballast type and ballast factor, which varies considerably between combinations. This rendered it difficult to determine a proxy for energy analysis without full disclosure of the ballast type. Based on the assumption on lamp and ballast types, the team referenced the input wattage of the fixtures using the XCEL Input Wattage Guide explicitly designed to provide estimate energy savings. The total power consumed by a fixture would be a multiple of the input wattage for a single lamp and the number of lamps in the fixture, assuming that every lamp has its own individual ballast regardless of the circuit arrangement.

The team then compiled all the information to create an inventory of light fixtures and lamps to identify the lamp type, quantity and input wattage of each of the interior light fixtures for the energy analysis, as shown in Appendix 1.

Energy, Cost, and Greenhouse Gas Emissions Analysis

Using the client utility data in conjunction with the lighting schedule and audit findings, the team was able to determine the proportion of Faculty House's total electricity consumption that is attributable to its existing lighting needs, relative to 2018 levels, using the following formula in Equation 1.

Equation 1: GHG Calculation Methodology for Lighting Energy Consumption

# of Lighting Fixtures per Room	x	# of Light Bulbs per Fixture	=	Total # of Light Bulbs
Total # of Light Bulbs	x	Input Wattage of Each Bulb	=	Total Wattage (KW)
Total Wattage (KW)	x	# of Annual Lighting Hours per Room	=	Total Annual Energy Use from Lighting (kWh)
Total Annual Energy Use from Lighting (kWh)	÷	Total Electricity Use at Faculty House (kWh)	=	% of Total Energy Use Attributable to Lighting

By multiplying the number of lighting hours in each room by the number of bulbs and their respective wattage, the team was able to calculate the total amount of energy consumption used for lighting. Then, the proportion of total consumption that is attributable to lighting at Faculty House was calculated by dividing that sum by the total amount of energy consumption that was reflected in the client's utility bills. Together, these key data points were combined into a spreadsheet and used as the foundation for the analysis to determine potential reductions for energy costs, GHG emissions, and energy consumption.

The next step in the energy analysis was to identify what energy-efficient LED bulbs would be a compatible replacement to the existing lighting system and each fixture type. To identify appropriate wattage of LED lamps for replacement, we compared the initial lumens of the existing lamps with LED alternatives. The lumens' information was derived from the lamp specifications provided by the manufacturer. Maintaining the same lumens of the lamps before and after the retrofit assures that the current illuminance levels will not be compromised. Based on the required lumens, the team gathered wattage information for each LED replacement and inputted the values into the model. Once compiled, the team was able to calculate the energy reduction potential by switching out the existing lighting wattage figures with the new LED wattage values.

Cost Analysis

Using the utility bill data provided by the client, the team calculated the average unit cost of energy on a dollar-per-kilowatt hour ($/kWh) basis. To do this, the team summed the total annual energy costs of Faculty House that were directly related to consumption (re: exclusive of transmission, distribution and other fixed charges) and then divided that amount by the total number of kWh that Faculty House consumed during the 2018 calendar year, which came out to an average unit price of $0.71/kWh.

Similarly, in order to calculate the total projected cost savings, the average unit price was then multiplied by the projected kWh savings from switching to LEDs.

Next, the team identified the upfront capital expenditure requirements for procuring and installing the new LED bulbs by reaching out to vendors for quotes. Then, using the projected annual cost savings of switching to energy-efficient lighting over a 10-year period, a standard discounted cash flow analysis was performed in order to determine the payback period and return on investment using a net present value approach at a 9% discount rate. For the purposes of this analysis, operation and maintenance (O&M) savings were not included.

GHG Emission Analysis

Scope 2 emissions under the GHG Protocol are categorized as indirect emissions that arise from purchased electricity. These emissions are classified as indirect because they do not occur at the client's facility, but rather at the utility plant where the electricity is generated from various fuel sources. These emissions are a consequence of the activities of Faculty House because although the organization does not own or control the sources, its actions require the generation [and use] of electricity. Moreover, purchased electricity often represents one of the largest sources of GHG emissions and is the area where the most opportunities for reductions in GHG emissions exist.

GHG emissions from the generation of purchased electricity include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These emissions are calculated based on the amount of kWh purchased multiplied by the power plant emissions factor. Since there was not enough information about the specific plants or power pools that provide Faculty House with electricity, GHG emissions from electricity usage were calculated based on the region-specific emission factors for CO_2, CH_4, and N_2O–specifically, using the Environmental Protection Agency's (EPA) most recent eGRID emission factors for the Northeast Power Coordinating Council (NPCC) NYC/Westchester subregion (Equation 2), which were multiplied by the energy consumption totals from utility bills that Faculty House provided. Similarly, these EPA eGRID emission factors were used when calculating the GHG reduction potential of switching to LEDs.

Equation 2: GHG Calculation Methodology for Purchased Electricity Consumption

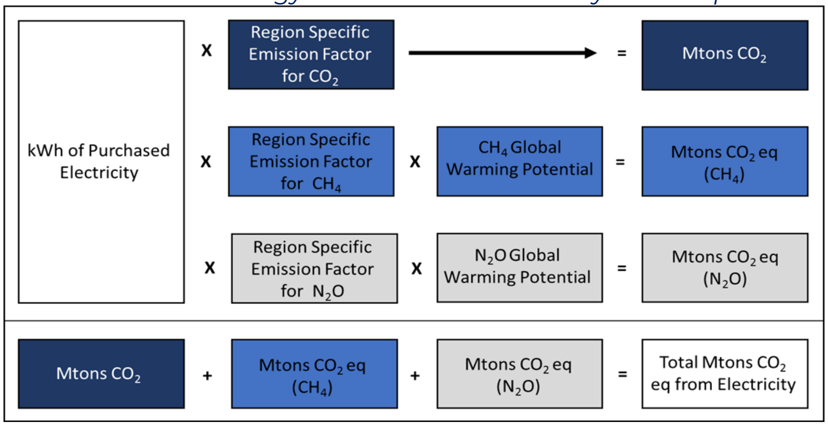


Table 4: EPA's eGRID GHG Emission Factors for Purchased Electricity in NYC

GHG Emission Factors (lb. /MWh)			
CO_2	CH_4	N_2O	CO_2e
635.8	0.022	0.003	637.1

Baselining Energy Costs, Consumption and GHG Emissions

Once the aforementioned cost, consumption, and emissions data were collected, a baseline was established in order to compare projected changes, namely savings and reductions, over time. For the purposes of this report, a 2018 base year was used for this analysis because it was the most recent period that contained a full set of calendar year data without any gaps, as noted earlier.

Best Practices

Building Satisfaction Survey and Identifying Lighting Quality Occupant Comfort

According to the U.S. Green Building Council (USGBC), the term sustainable building is evolving towards designs with healthier conditions in the workplace. For the last few years, wellness accreditation, which focuses on building occupant's health and well-being, has gained considerable attention in the U.S. real estate market (Bell, 2018). Improvements in the workplace, including benefits such as better lighting systems and better designs, bring considerable advantages and cost savings considering that employee management and turnover represent the highest share of costs for companies (Powell, 2017). On the other hand, the Environmental Protection Agency established that on average Americans spend approximately 90% of their time indoors, and that indoor air is generally two to five times more toxic than outside air due to poor ventilation (Clark Howard, 2017). As such, Faculty House should consider this when establishing future sustainability strategies.

Research on health and wellness in the workplace keeps finding new property features that need to be measured. For this reason, the different standards available include diverse categories such as access to nature, acoustics, active design & ergonomics, air quality, light, nourishment, safety and security, thermal comfort, and water (Playbook for Sustainably Healthy Workplaces, 2018). With 3,858 projects, 238 of which are certified across 58 countries, WELL Building Standard is the first and leading tool for improving health and well-being in buildings worldwide. WELL is a performance-based rate system that evaluates the different elements of the space that influence the health and well-being of the occupants.

Following the WELL standard, as a first approach to assess occupant comfort at Faculty House, the team developed and administered a building occupancy survey with the purpose of measuring Faculty House staff satisfaction associated with four features of the building: lighting, air quality, thermal comfort, and acoustics. The framework used was the Indoor Environmental Quality (IEQ) Survey developed by UC Berkeley Center for the Built Environment (CBE), which is a simple, intuitive, and anonymous questionnaire that takes less than 10 minutes to respond to, and which allows for identifying building services and design features of properties that are less functional. The results help to inform a prioritization of actions to improve satisfaction and productivity (Center for the Built Environment, 2017). The survey was administered at Faculty House during a daily morning staff meeting. The survey was then collected, and the team used a scorecard created to quantify the results in terms of satisfaction rates in the four categories.

Sustainable Operations

Food

The Food team was tasked with assisting Columbia University's Faculty House in better understanding the environmental impact of food served at Faculty House, as well as the best practices that would allow the clients to reduce and ameliorate these impacts. The Food team established that the environmental impact should be calculated as a carbon footprint of greenhouse gas emissions associated with the food served at Faculty House. As a result, a baseline of their current carbon impact was calculated for the 2019 financial year using Faculty House's 9 most popular menus and a newly designed Sustainable Living Menu. The methodology to assess the GHG emissions of food served can be divided into 6 steps:

1. Literary review & background research
2. Data collection
3. Greenhouse Gas accounting framework
4. Greenhouse Gas computations
5. Data analysis
6. Results and recommendations

Literary Review and Background Research

A preliminary analysis of various literature was conducted to better understand the environmental impacts of food. The team also researched the emerging sustainability practices in catering, including zero waste and procurement. A thorough review of literature on greenhouse gas accounting through lifecycle analysis concerning food was carried out to better inform the design of the team's methodology. In particular, the research allowed the team to gain an understanding of food impact calculations through proxies and rapid calculations.

Data Collection

Through data collection, the team was able to identify which types of information were readily available and how these could be used towards the methodological approach. The team gathered invoices, sales data, and Faculty House menus. The team also conducted interviews with several experts, including Faculty House chef, Leo Michel.

Menus Selection

To capture the environmental impact of the food served at Faculty House, the team selected nine menus for analysis. The menus chosen were as follows: 'Seminar Buffet' 'American Buffet', 'Plated Dinner', 'French Buffet', 'Alma Mater', 'Italian Buffet', 'Healthy Lunch Buffet', 'The Thinker' and 'Blue Menu'. These menus were selected using 2019 Sales by Resource data, which demonstrated that a total quantity of 13,435 plates were served in FY19 from the aforementioned menus, representing 54% of all dinner buffet and plated dinners served during that period. These menus were also contrasted with the newly developed Sustainable Living Menu, established in partnership with the Earth Institute. This comparative evaluation looks to demonstrate the potential reduction of Faculty House's environmental impact when selecting for food with known sustainability factors in mind.

GHG Accounting Framework

The environmental impact of food served at Faculty House can be calculated using a methodology known as greenhouse gas accounting. This is a measurement tool that considers the carbon impact of a product throughout the various stages of its life, including its raw materials, transportation (inbound and outbound), processing, retail, use, and end-of-life. The final result of this methodology is a single value known as a carbon footprint and is measured in grams per carbon dioxide equivalent ($CO2_e$).

To begin the carbon footprint calculations, the team decided on defining a 'product' as one meal per person. The following 5 steps define the methodology followed to determine the carbon footprint of one meal served, per person, at Faculty House.

Step 1: Ingredient Inventory and Attribution per Dish

The team established that calculations would first have to determine the carbon footprint of each dish served by breaking it down into its ingredients. This created an inventory of ingredients per dish in their attributed, relative proportions. See Table 5 below for an example:

Table 5: Example of Ingredient Inventory and Attribution per Dish

Dish Name	Ingredients	Percentage of Ingredients Attributed to the Dish
Cucumber and Tomato Basil Salad	Cucumber	45%
	Tomato	45%
	Basil	10%

Step 2: Accounted Portions per Person

Through interviews conducted with Chef Leo Michel, the team was able to establish the per person portion of each dish served. The accounted portions are as follows:

Table 6: Accounted Portions (oz) per Dish per Person

	Dish Type	Portion Size (oz)
Plated	Appetizers	4
	Desserts	5
	Dinner	10
	Entrees	13
	Luncheon (Proteins)	8
	Salads	5
	Soups	12

Buffet	Appetizers	6
	Desserts	3
	Entrees	6

This allowed the team to calculate the weight, in ounces (oz), of each ingredient per dish per person.

Step 3: Carbon Impact of Ingredients using Emission Factors

To calculate each ingredient's carbon impact, the team used values called emission factors (EF) in the calculations. Emission factors represent the value of greenhouse gas emissions associated to the ingredient's life (EPA, 2019). For example, the emission factor for pasta considers all emissions associated with the growth of the wheat, milling, processing, retail, cooking, and consumption of the pasta. Although emission factors are based on representative averages, they remain highly specific to the production of a particular product and rely on key assumptions such as geography and culture. As a result, the Food team looked to gather the most relevant emission factors for the analysis, while maintaining enough granularity of food categories so that a comprehensive analysis of the menu ingredients could be conducted. This led the team to use a combination of emission factors from Italy, as calculated by Cerutti et al. (2017), as well as emission factors from the United States, as reported by the Environmental Working Group (EWG, 2011). The EWG report provided a list of 11 emission factors for various food categories whilst the Italian article provided a more comprehensive list of 19 food categories. The team selected the emission factors for the United States as most favorable while filling in the remaining gaps with the Italian emission factors. This methodology provides limitations to the accuracy of the results presented but hold relative values that remain beneficial for the comparative analysis. To make these emission factors useful for the entirety of the granular ingredients included in the Faculty House menus, the Food team adopted a methodology established by Cerutti et al. (2017), in which the carbon footprint of food is calculated through broad categorization of food types. In this method, the broad categorization acts as proxies for the granular ingredient data. For example, an apple may be categorized as a 'fruit', as the emission factor for 'apple' is not known. As a result, these provide relative, rather than specific, carbon footprints for each menu's ingredients. Table 7 below demonstrates the list of emission factors used in the Food team's analysis:

Table 7: Emission Factors

Food Category	EF Italy ($kgCO_2e/kg$)	EF U.S. ($kgCO_2e/kg$)
Pasta	1.05	-
Rice	1.34	2.70
Soup	2.26	-
Sauce	0.59	-

Tuna	13.58	11.89
Other Fish	3.12	6.06
Egg	1.78	4.83
Cheese	12.64	13.47
Mozzarella Cheese	10.04	13.47
Beef	19.47	39.25
Pork	15.89	12.12
Poultry	5.19	6.87
Cooked Vegetables	0.79	-
Fresh Vegetables	1.91	2.00
Fruit	0.14	-
Yogurt	0.18	2.17
Fruit Juice	0.51	-
Dessert	2.12	-
Bread	1.37	-

Step 4: Computation Carbon Footprint of Menu

The computation of the carbon footprint of each dish used the following equation:

Equation 3: Carbon Footprint Computation

Emission Factor for Ingredient	X	Percentage of ingredient attributed to dish	X	Portion (oz) per person of dish	=	Kg of CO2e per person, per dish
Repeat for all ingredients in dish						

The carbon footprint value is measured in kg CO_2e per dish per person. A sum of carbon footprints of all dishes in each menu then allowed the carbon footprint of the entire menu to be known. The methodology (Steps 1-4) was repeated across all 10 menus selected. The carbon footprint results facilitated comparative evaluation between environmental impacts of the different menus offered at Faculty House.

Step 5: Computing Carbon Footprint of Food Served at Faculty House

By multiplying the carbon footprint of each menu with the data from the Sales by Resource FY19, FY18, and FY17, the team was able to calculate the approximate greenhouse gas emissions associated to roughly 50% of the food served over the past three years at Faculty House.

Linens

The Linens team was tasked with measuring the impacts from the reduction in linen use over the last year for Faculty House, as the venue implemented a linen-less dining option for its events in 2018. The methodology to assess the environmental impacts of linen use can be divided into 6 steps:

1. Literary review & background research
2. Data collection
3. Greenhouse Gas accounting framework
4. Greenhouse Gas computations
5. Data analysis
6. Results and recommendations

Literary review and background research

The aim of the literature review was to have a holistic understanding of the linen use and washing industry to understand where the greatest impacts occur. This began by conducting research on peer-reviewed information on the environmental impacts of linen usage, notably in the following areas:

- Greenhouse Gas (GHG) emissions
- Water
- Chemicals used
- Air pollution

GHG Emissions

According to the Wall Street Journal, the carbon footprint of using UK detergent brand Tesco, varies from 1.3 lb. (0.6 kg) to 1.9 lb. (0.9 kg) per load (Ball,2008), depending on the form of the detergent that is used. Based on a study conducted by Procter and Gamble, the average American family does 300 loads of laundry annually, which sums to about 480 pounds of carbon emissions per year.

Water

Water usage and temperature are closely related to the type of detergent that commercial laundry facilities use. Conventional detergent tends to require more water to process and perform better at higher temperatures, which causes higher carbon-related emissions. For instance, linens in the medical services industry require higher temperature washes compared to those in the hospitality industry (Martin, 2016).

Chemicals

Chemicals used in commercial laundry practices affect aquatic ecosystems through wastewater. The inorganic phosphates may cause eutrophication in freshwater, decrease nutrients in the water and reduce oxygen for other marine life. Also, some detergents contain surfactants, which are toxic substances to aquatic life. More specifically, these affect the growth of algae and other microorganisms in the water, resulting in reduced primary productivity of water bodies, thereby undermining the food chain of aquatic organisms.

Air pollution
Detergents release volatile organic compounds and hazardous air pollutants during commercial laundry practices, which can be converted into carbon emissions.

Data Collection

Client background and screening
Data collection began with understanding which initiatives the client had taken to reduce its use of linens. For instance, they purchased linen-less dining tables which removed the necessity of tablecloths. To understand how these decisions impacted linen use, the team reviewed invoices from the two current vendors. A preliminary review of the invoices provided little information, as these were difficult to understand and mostly in acronyms.

The yearly FY2018-2019 orders provided information on characteristics of linens used by Faculty House such as

- Quantity, cost per unit ($), descriptions of color & dimensions
- Types of linens: Uniforms, Aprons, Pants, Blazers, Coats, Jackets
- Other items: Bags, Stands, Miscellaneous (Clips)
- Dry Cleaning
- Shipping & Delivery Charges

Informational interviews
To get more granular information regarding the beginning to end process of linen treatment, steps involved from placing the order to delivering the order, and relevant sustainability initiatives, the team had a call with the current vendor. The current vendor provided step-by-step guidance on how orders are processed and some high-level information about ways in which they qualitatively track sustainability measures, which ended by saying "*Yes, we do sustainability reporting, but these cannot be shared*" (see Appendix 8 for an overview of the call). However, the vendor's hesitation to provide detailed quantitative information presented key challenges for the team in performing the GHG emissions analysis.

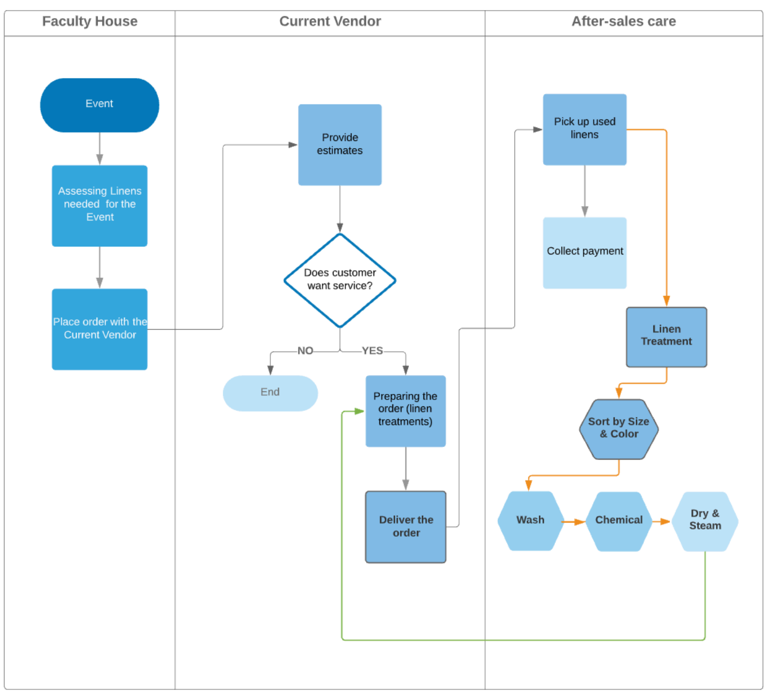
This roadblock led the team to think more deeply about alternative ways in which Faculty House could concretely improve their environmental impact from linen use related to its vendors. Further research on clean industry competitors enabled the team to locate the Textile Rental Services Association (TRSA) certification, which is an industry-wide sustainability measurement for linen rental and cleaning services. It administers quantitative, third-party certification programs for linen, uniform and facility services companies and their management teams and seeks to build confidence in their processes and outcomes. Based on this information, a total of nine TRSA-certified vendors located within a radius of 40 miles from Faculty House were contacted, with the hope to understand how their washing processes were superior to those without the TRSA certification. Out of nine vendors contacted, two replied and two interviews were conducted. Out of the two vendors the team spoke with, one TRSA-certified vendor was both comparable with FH's current vendor and willing to provide quantitative operational information on specifics such as electricity efficiency (kWh/weight), water efficiency (gallons/weight of linen), and fuel type sources (see Appendix 8 for an overview of the call). The successful informational call with the TRSA-certified vendor allowed the team to better comprehend how sustainability was being developed and applied in the linen industry, and how the TRSA certification helps them be more sustainable. More importantly, the robustness of the TRSA certification meant that the vendor had quantitative operational measurements needed to perform a full GHG accounting. This led the team to compare the environmental impact of linen use washing using data and proxies from the current vendor and if Faculty House had used the TRSA-certified vendor throughout the FY2018-2019.

GHG Accounting Framework

To determine the Greenhouse Gas emission sources from the linen procurement process, the team created a process map (

Figure 3) with the information obtained from the current vendor along with industry research. The map is essential to visualize the steps involved in completing a linen order, which allowed the team to Identify further types of detailed information needed from the current vendor, the TRSA-certified vendor, and from research on proxies.

Figure 3: Linen Orders Process



The process map indicates that potential GHG emission sources can occur at different points in the process: transportation (delivery), washing, chemical treating, and drying & steaming. Moreover, industry research outlined that water temperatures differ when treating white linens versus non-white linens. Therefore, the washing phase consists of two emission sources: electricity used to power washing machines and the fuel used to heat the water. Air emissions, which is another part of the client's request, mainly occur in the drying & steaming phase of the process.

Setting the Boundary

Before establishing the GHG inventory, the team determined that the boundary of this inventory will entail the moment the linens are ordered by the client and the operational activities which occur between Faculty House and the respective vendors' facilities. This means that all other upstream and downstream activities are not taken into account, such as the manufacturing of detergents and linens and the wastewater treatments.

Data Selection

The team analyzed invoices and annual sales reports from the current vendor and was able to migrate important data points such as style, color, quantity, and the price of the linen orders into the established Excel spreadsheet. However, due to the lack of quantitative data provided by the current vendor, the team used the TRSA-certified vendor's data and industry proxies for some key activity data such as the unit weight of each style of linen.

Greenhouse Gas Emissions Computations

The GHG footprint analysis evaluates emissions from transportation of linens, the washing process, and air pollutants. All the calculations follow the methodology provided in the GHG Protocol – Corporate Standard and use Global Warming Potentials from the IPCC 4th edition report. Due to unavailable data from the current vendor, the team was able to obtain activity data from the TRSA-certified vendor (and use it as a proxy), who kindly supported and enabled the progress of this analysis. The TRSA-certified vendor's transparency, availability of sustainable data tracking and their willingness to share this information highlighted the lack of those aspects in the current vendor. With more data available, the team was able to conduct a comparative analysis between the current versus TRSA-certified vendor had Faculty House used them separately throughout this year. Details of calculation methods and assumptions for each emission source are discussed below.

Transportation - Methodology

The linen team received information on the types of vehicles used for linen transportation from the initial call with Faculty House current vendor and TRSA-certified vendor. Both facilities use Hino Trucks, mainly in the category of "Heavy and Medium Duty" trucks which use diesel for fuel. Additionally, the TRSA-certified vendor owns two other types of gasoline-fueled vans: Ford E250 and Nissan NV1500.

Fuel Economy information for all types of vehicles (EPA, N/A) are obtained through research (MotorTrend, N/A) (Somerville, 2015) and emission factors (EF) are determined based on EPA's categories for mobile combustion. Both Ford and Nissan are categorized as light-duty trucks whereas all sizes of Hino Trucks are Heavy and Medium-Duty trucks. See Table 8 below for reference:

Table 8: Product Transport Emission Factors: Upstream and Downstream Transportation and Distribution

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Medium- and Heavy-Duty Truck	1.467	0.014	0.010	vehicle-mile
Passenger Car	0.343	0.019	0.011	vehicle-mile
Light-Duty Truck	0.472	0.019	0.018	vehicle-mile
Medium- and Heavy-Duty Truck	0.202	0.0020	0.0015	ton-mile

Most importantly, the team found that the models of Hino Trucks use the SCR technology, which is also called Diesel with DEF Catalytic Exhaust NOx Reduction. According to the EPA (USEPA, N/A), this technology enables trucks to reduce NOx emissions (including NO_2, N_2O, NO) by 70-90%. This reduction is applied to the analysis in two scenarios: Conservative (70%) and Optimistic (90%), as shown in Table 9.

Table 9: NOx Reduction Calculations

N_2O	Adjusted N_2O with SCR technology - Conservative	Adjusted N_2O with SCR technology - Optimistic	CO_2e	CO_2e with adjusted N_2O - Conservative	CO_2e with adjusted N_2O - optimistic	Unit
4.212	1.2636	0.4212	2020.4964	1141.8732	890.838	kg
4.212	1.2636	0.4212	2020.4964	1141.8732	890.838	kg
4.212	1.2636	0.4212	2020.4964	1141.8732	890.838	kg

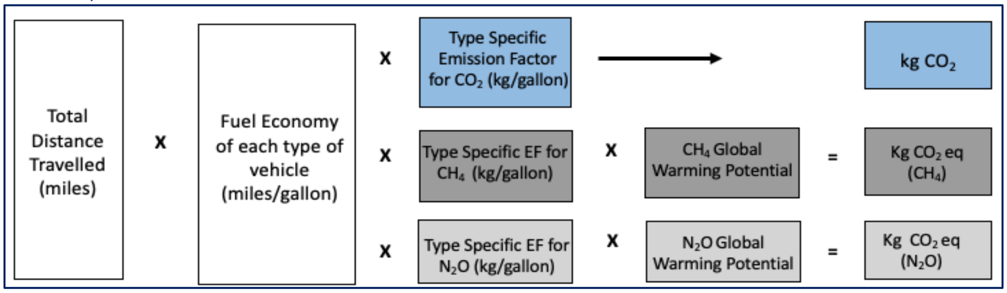
Step 1: Annual Deliveries

Equation 4: Annual Deliveries

Two-way Distance (from facility to FH) x Annual Delivery Frequency = Total Distance Travelled

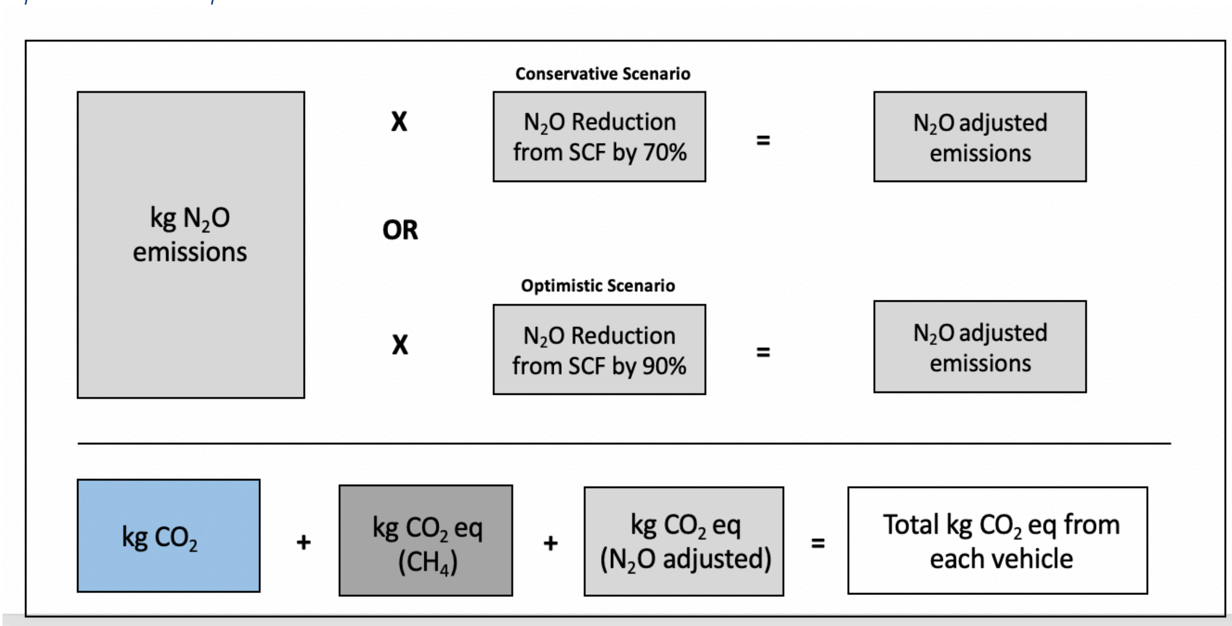
Step 2: Transportation GHG Emissions Calculations

Equation 5: Transportation GHG Emissions Calculations



Step 3 - Transportation NOx Reduction Calculations

Equation 6: Transportation NOx Reduction Calculations



Step 4 - Averaging

After calculating kg CO_2e for each vehicle type, the team took the average of all vehicles' kg CO_2e. The GHG emissions from order transportation were performed for fiscal years 2017 and 2018. One comparison was made between the two years for the current vendor, and the other comparison was made for FY2018 between the current vendor and the TRSA-certified vendor.

Limitations

Given the time constraint, data availability and data completeness, it was difficult for the team to assess transportation emissions and allocate to the number of linens ordered by Faculty House. Specifically, the following information was unknown which decreased the accuracy of the results.

1) Not knowing which type of truck delivered orders on any given date, 2) the weight proportion of the linen orders out of the total delivery volume, 3) the detailed routes the drivers took to deliver the linen (assuming they do not deliver only to FH on that

day). Therefore, the emissions were calculated by taking the average of the total CO_2e emissions from all types of trucks of each vendor. The limitation of this method is the inability to show reduction of transportation emissions from reduction of linen orders between fiscal years 2017 and 2018. Also, it could not show the emissions allocated to only the linens delivered for FH.

Electricity

Methodology

The team obtained information about model types and loads of the washing machines of the current vendor as well as the TRSA-certified vendor. The current vendor owns two sizes of the Braun Open Pocket washer extractor – 450 lb. and 650 lbs. Although the current vendor did not disclose detailed efficiency measures and energy usage (i.e. kWh/lb.) which challenged the process of the analysis, the team was able to identify common machine type (the 450-lbs model) and use the activity data from the TRSA-certified vendor to calculate the kWh usage per average load (225 lbs. for the TRSA-certified vendor) size. However, the efficiency measure of the 650 lb. model was obtained from a collaborative research conducted by the Institute for Applied Ecology and BIO Intelligence Services (Graulich, et al. 2011). Based on the study, the kWh usage per weight of washing capacity for the 650 lb. model was compared with the washer extractor with washing capacity above 40 kg (Table 8).

Table 8: Current vendor washing machines efficiency table

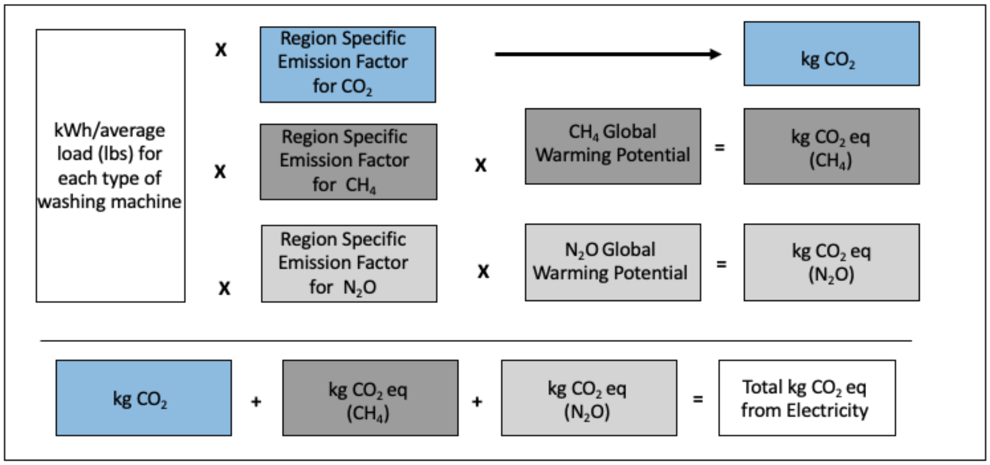
Machine Type	Quantity	Load Size	Unit	Efficiency	Unit	Energy efficiency adjusted by average load
450-pound Braun Open Pocket Machine	3	450	lbs.	2300	lbs./hour	0.013695652
650 - pound Braun open pocket washer	3	650	lbs.	0.190512	kwh/lb.	0.190512

The team calculated kWh usage/average load for the TRSA-certified vendor by converting the energy usage (7 kW/lb.) into kWh/lb. The emission factors for electricity usage were determined using the EPA eGrid tables together with the region and subregions of both vendors using the postal codes of their facility locations.

Equation 7: Electricity GHG emissions calculations

kWh/average load (lbs) for each type of washing machine	x	FY2017 – 2018 total weight of linens	=	Total kWh used for each machine

Equation 8: Electricity GHG emissions calculations



After calculating the total kg CO2e for each washing machines of both the current vendor and the TRSA-certified vendor, the team took the average of the total CO2e of all machine types.

Limitations

The calculations were based on accessible and available information; therefore, efficiency measures may not be the most accurate representations. Moreover, the final emission numbers are the average of all washer models which would affect the results. However, since it is difficult to know which model processes which types of linens and the percentage of FH's total order volume in their core business, the team considers the average method the most readily available measurement.

Natural Gas – Water Heating

Methodology

One of the major sources of emissions for any facility type is natural gas for heating. The current vendor uses an on-site boiler to generate natural gas for its facility. Boilers are generally used for water heating when processing and treating white linens and only the TRSA-certified vendor provided the water temperatures it uses to wash both white and non-white linens. Therefore, the team used 150 degrees Fahrenheit for non-white linens and 160 degrees Fahrenheit for white linens. To convert the temperature into heat produced (in BTU), the team used a formula Equation 9 that is commonly used to assess the energy required to heat water to certain temperatures (Dutton, N/A).

Equation 9: Formula to determine heat required

Heat Required	=	Mass of water heated (lbs.)	X	Heat Capacity of Water (1.003 BTU/lb°F)	X	Change in temperature*

**Change in temperature is represented by the temperature needed minus the room temperature of water (Leverette, 2019)*

Equation 10: Natural Gas - Step 1: Determine water usage

Total weight of white linens (lbs)	X	Water usage (gallons/lb.)	X	Conversion (from gal to lbs)	=	Water used for white linens
Total weight of non-white linens (lbs)	X	Water usage (gallons/lb.)	X	Conversion (from gal to lbs)	=	Water used for non-white linens

Equation 11: Natural Gas -Step 2: Determine heat required

Water used for white linens	X	Heat Capacity of Water (1.003 BTU/lb°F)	X	160 °F – room temperature	=	Heat required
Water used for non-white linens	X	Heat Capacity of Water (1.003 BTU/lb°F)	X	150 °F – room temperature	=	Heat required

Equation 12: Natural Gas -Step 3: determine GHG emissions from heating water

Heat required for white / non-white linens (BTU)	÷ 1,000,000	X	Kg CO_2 /MMBTU	→					kg CO_2
		X	Kg CH_4 /MMBTU	X	CH_4 Global Warming Potential	=			kg CO_2 eq (CH_4)
		X	Kg N_2O /MMBTU	X	N_2O Global Warming Potential	=			Kg CO_2 eq (N_2O)

kg CO_2	+	kg CO_2 eq (CH_4)	+	kg CO_2 eq (N_2O)	=	Total kg CO_2 eq from Heated Water

The emission computations of natural gas were only performed for the current vendor because the TRSA-certified vendor uses energy generated by the Waste to Energy plant (it only has on-site boilers for back-up purposes). It has a special contract with a nearby waste-to-energy plant and therefore, its natural gas emissions from water heating is zero for the TRSA-certified vendor.

Water Use reduction

Methodology

Both vendors provided the team with their average water usage in gallons per pound. However, the data from the current vendor seems unrealistic as it only uses 0.0175 gallons for every pound of linens. From the team's research, an average linen facility's water usage is between 2 and 4 gallons; therefore, the team decided to use the data from the TRSA-certified vendor for both vendors.

Equation 13: Formula used for water reduction

$$\boxed{\text{1.8 gallons/lb.}} \times \boxed{\text{Total weight of white/non-white linens in 2017 \& 2018 (lbs)}} = \boxed{\text{Water used (in gal)}}$$

Air Emissions

Methodology

Air emissions are divided into two categories: 1) air pollutants from combustion and 2) air emissions from the washing process. The proxies were obtained from an EPA case study report which was conducted with another commercial linen service provider (EPA, 2014). According to EPA's calculation methodology, it includes both Pollutant PTE (Potential to Emit) emissions and HAPs (Hazardous Air Pollutants) PTE. Potential to emit represents a facility's maximum capacity to emit air pollutants given considerations of operational and equipment limitations. Under the circumstances of lack of accessibility to data and on-site visits, the team considers this approach to be appropriate. Furthermore, the HAP PTE emissions only represent emissions from the washing phase since all HAP were treated before going into the drying phase. Before calculating the emissions, the team assessed the natural gas output based on the linen orders:

Equation 14: Air pollutants from combustion calculations

$$\text{Efficiency of boiler} \times \text{Total weight in 2017 \& 2018} \div \text{Washing machine efficiency (lbs/hour)} \times \frac{1}{\text{Heat input rate of boiler}} = \text{Natural Gas Throughput}$$

$$\text{Efficiency of steam tunnel} \times \text{Total weight in 2017 \& 2018} \div \text{Washing machine efficiency (lbs/hour)} \times \frac{1}{\text{Heat input rate of boiler}} = \text{Natural Gas Throughput}$$

Table 9: Boiler and steam tunnel activity data

	Quantity	Efficiency (MMBtu/hour)	Heat input rate (MMBTU/MMSCF)	2018 Natural Gas Throughput based on FH order (MMSCF)	2017 Natural Gas Throughput
On-site Boiler - no specific system	1	10.46	1020	0.225474634	0.277381258
Steam Tunnel	1,2	3	1020	0.064667677	0.079554854

**Using the heat value of the boilers in EPA case study & assuming steam tunnel matches EPA standard*

Following the guidance from the EPA case study (EPA, 2014), the team calculated tons of air pollutants per year using the process shown in Equation 15.

Equation 15: Air Pollutants Calculation

$$\text{Natural Gas Throughput (MMSCF)} \times \text{EF of each types of air pollutants (lb/MMSCF)} \times \text{Conversion (from lb to ton)} = \text{Ton of air pollutants per year}$$

These steps are repeated for both boiler and steam tunnel. The HAP PTE calculations also follow the same methodology.

The air pollutants emitted during the washing process are calculated based on the EF from EPA's case study. The emissions are from two main sources: HAP and VOC (Volatile Organic Compounds). The process is as listed:

Equation 16: Air pollutants from washing process

2017 & 2018 Total weight (lbs)	x	VOC Emission Factor (lb./1000lb)	x	Wash Cycle (*70% of the time are spend in washer)	=	VOC emissions (lbs)
2017 & 2018 Total weight (lbs)	x	HAP Emission Factor (lb./1000lb)	x	Wash Cycle (*70% of the time are spend in washer)	=	HAP emissions (lbs)

**70% is the percentage associated with linen type "Shop Towels"*

Table 10: VOC and HAP emission factors from EPA

Air Pollutant	Wash Cycle (Time spent in washer)	VOC	Federal HAPs
Shop Towels	70%	12	4.54
Print Towels	95%	127	18.8

Limitations

Due to time and resource constraints, the team used proxy data from the EPA analysis for chemical usage and air emissions from detergent use. The air emissions are associated with the washing process of shop towels versus print towels. The customers from the linen facility in EPA case are from automotive and industrial sectors, which processes different types of linens than our current vendor and TRSA-certified vendor. However, it is the closest match that could be found to date to measure released air pollutants. The proxies for VOC and HAP should include the impacts from detergent chemicals since VOCs are usually released during the washing phase when detergents are added to wash off soils. Due to lack of data accuracy, the team could not determine how many steam tunnels are present in each facility. Therefore, for air pollutants from steam tunnels, the calculations are based on one steam tunnel in each facility.

General Limitations

Weight Information

The total weights are computed using some estimated weight data provided by the TRSA-certified vendor regarding different dimensions of the linen ordered. However, some of the linen categories are not offered by TRSA-certified vendors. Thus, those gaps are filled by the team's online research. Few of the products are allocated with zero weight because of less information found. This lack of information affects the accuracy of the final results but the team believes that this will not be material.

Dry-cleaning and Miscellaneous

Based on the annual order report provided by the current vendor, there are services charged for dry-cleaning, embroidery, and other uniform alterations. These services are not accounted for in the GHG accounting due to the fact that these were rare orders believed to have minimal impacts and time consuming to calculate.

Only Quantitative Measurements Used

Both the current vendor and the TRSA-certified vendor provided the team with qualitative data on their sustainability initiatives. For example, the current vendor has wastewater treatment and heated-water reuse systems which allow them to save water usage and ensure the discarded water is free from chemicals, but was unable to provide quantitative aspects related to these. Moreover, both vendors have automatic management systems which monitor and manage the quantity of linens treated per day to reduce unnecessary operating hours. This initiative could help to reduce electricity usage. Both vendors also use eco-friendly detergents to reduce harmful chemicals for the biodiversity such as surfactants and phosphates. However, all of the above initiatives are difficult to be translated in meaningful ways with an individual proxy and will require a full lifecycle analysis of the facility and the products used. Due to the time sensitivity of this project, the team is unable to perform such analyses.

Findings

Energy Efficiency

Lighting

Summary of Lighting Audits

The team conducted two lighting audits, on October 6th and October 14, respectively. During the first visit, the team met with building manager Damien Nolan to conduct the lighting audit of most of the rooms in Faculty House. The lighting audit was completed after the second visit when the team met with an electrician from CUFO, and a representative from Faculty House, who provided insights on lighting fixtures and unrestricted access to the previously closed off storage and electrical facility rooms, respectively.

Overall, the lighting audits were successful. The team was able to document the type and quantity of lighting fixtures, the quantity of lamps in each lighting fixture, type of lighting control, illuminance levels, color temperature of lighting, mounting height of the lighting fixtures, and other more general observations (for details, please see Appendix 1). However, the team was not able to determine the type of lamps and ballasts used in each fixture due to access restriction. Thus, reasonable assumptions had to be made, as discussed in the methodology section, in order to conduct the analysis. Due to lack of information, exterior lighting and interior cove lighting were excluded in this audit.

When the team started walking around the physical environment, it was observed that a great many of the lighting lamps were Compact Fluorescent Lamps (CFL), which are not as cost-effective, energy-efficient, or long-lasting as the Light Emitting Diode (LED). The audit revealed the storage areas had mostly CFLs with a light switch, the common areas were recessed downlight and pendant lighting connected to the Lutron system, and most of the offices were either CFL with manual switches for smaller offices or CFL with occupancy sensors for larger offices.

Observations

Based on the two on-site audits, the team made the following observations regarding the lighting set-up and the operation:

1. **Illuminance Levels:** The team evaluated the appropriateness of the illuminance levels by comparing the recorded illuminance with the recommended levels according to the latest Lighting Handbook published by the Illuminating Engineering Society of North America (IESNA). This study was not quantitative because the appropriate level of lighting would vary with the physical condition of the space and the occupant's needs. However, the

evaluation provided some insight into the illuminance levels of the current lighting set-up in the Faculty House:

- Event spaces were generally underlit for the purpose of conferences and presentations. Based on an interview with an event planner, however, it was problematic not to be able to dim the lighting near the projection screen during the presentation.
- Office spaces in general had adequate ambience lighting but low task-level illuminance, caused by inadequate task lighting.
- Auxiliary spaces such as the cloak room, locker rooms, and restrooms were underlit, while the emergency stairwells were slightly overlit. The darker wall surfaces in some of the restrooms rendered the space even darker.
- Cellar corridors were over lit, with illuminance levels multiple times of the recommended level.
- Both the cellar and the fourth-floor kitchens were over lit, with task-level illuminance more than double the recommended level of 500 lux.
- Inconsistent illuminance levels of the store rooms throughout the facilities.

→ The comparison shows that the current lighting set-up in the Faculty House did not fully align with the tasks to be performed on many occasions. While it was unclear how this would impact the energy consumption, and hence the operation cost, the likelihood to cause discomfort and dissatisfaction from the occupants in the building warrants attention from the Faculty House.

2. **Dissatisfaction of the control system:** Both CUFO and the administrative office in Faculty House said the control system in place was a complicated interface experience and preferred a more user-friendly alternative. The surveys and interviews with the operations staff indicated that they did not have an affinity to the Lutron control system and preferred more comprehensive options.

3. **Lack of inventory tracking:** The operations staff would respond to lighting issues and replacements on an ad hoc basis without conducting an inventory audit to account for changes and upgrades within Faculty House.

4. **Cost-driven lighting management:** It seemed to be a disorganized and cost-driven approach where CUFO took the orders from the administrative office from a budgetary stance to manage the lighting in Faculty House.

5. **Communication barriers:** The unionized CUFO do not have much say in the matter in influencing widespread decisions, and have their own directives to

focus on, limiting their attention and efforts directed towards the needs of the team and auditing process, proving a laborious process.

Energy and Cost Analysis

Historical Performance - Baseline

Initial analysis revealed considerable variation in monthly energy consumption at Faculty House between 2017 and 2019 (Table 13), ranging from a low of 77,600 kWh to a high of 92,000 kWh. This variability is likely due to the changing event schedule at Faculty House, which caters/hosts a variety of events at different times throughout a given year. On an annual basis, however, consumption remained relatively stable over the same time interval. A total of 1,008,800 kWh of electricity was consumed at Faculty House during 2018, resulting in roughly 291.5 tonnes of CO_2e (Table 13).

Figure 4: Monthly Energy Consumption at Faculty House (2017-2019)

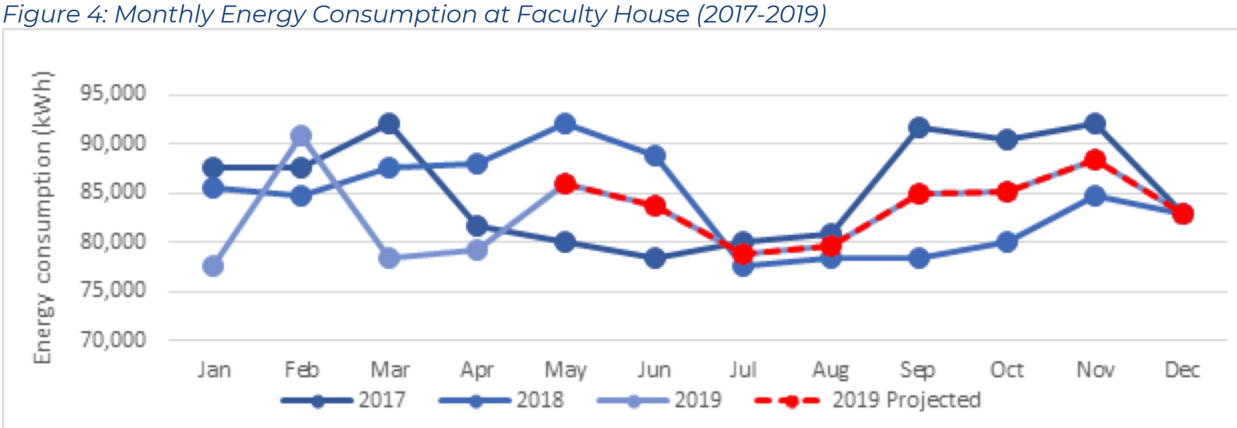


Table 11: Annual Energy Consumption & GHGs at Faculty House (2017-2019)

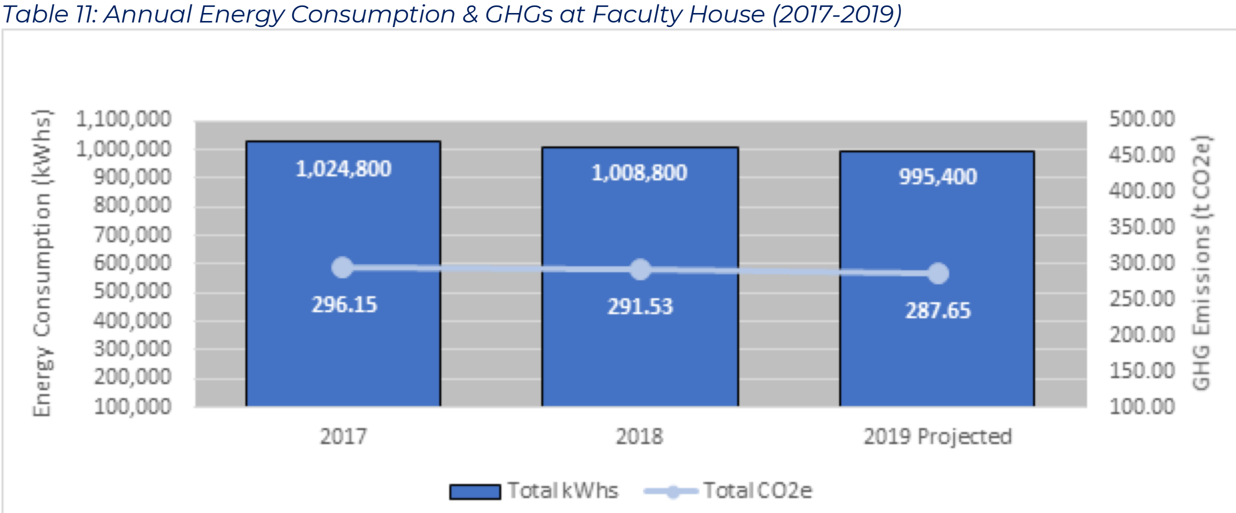
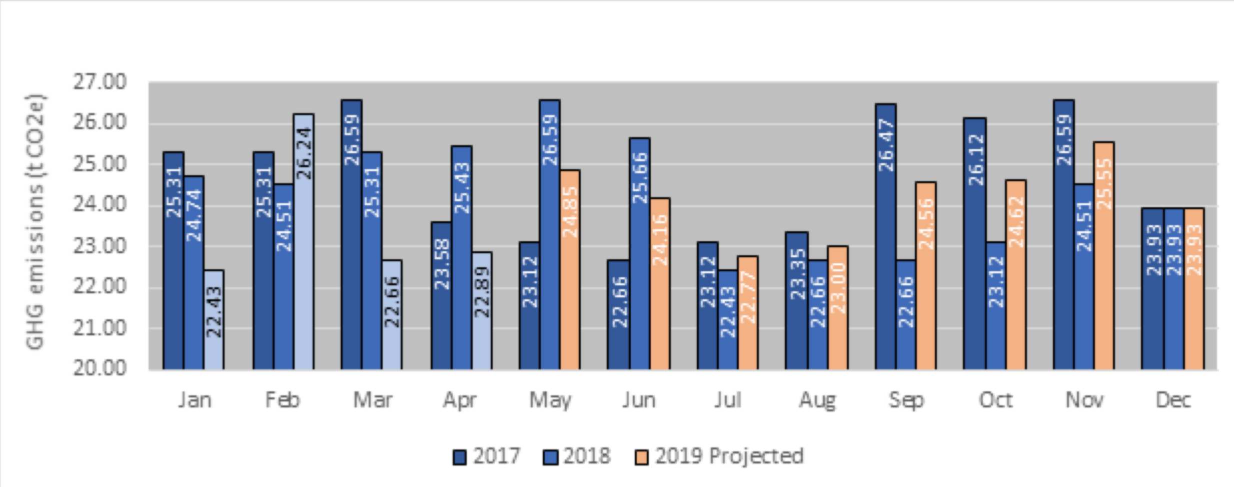


Table 12: Monthly GHG Emissions at Faculty House (2017-2019)



Taking a closer look at the 2018 annual energy costs, direct consumption charges accounted for roughly 60% ($71,674) of Faculty House's utility bill, while transmission, distribution (T&D), and fixed charges made up the remaining 40% ($47,300), as illustrated in Table 13 below. While consumption charges fluctuate in tandem with on-site consumption patterns, T&D and fixed charges are substantially less affected by changes in on-site energy use. Alas, the cost breakdown between these billing categories helps provide insight into how much of the total energy costs can be targeted for reduction by switching to LED lighting.

Figure 5: Annual Breakdown of Energy Expenses (2018)

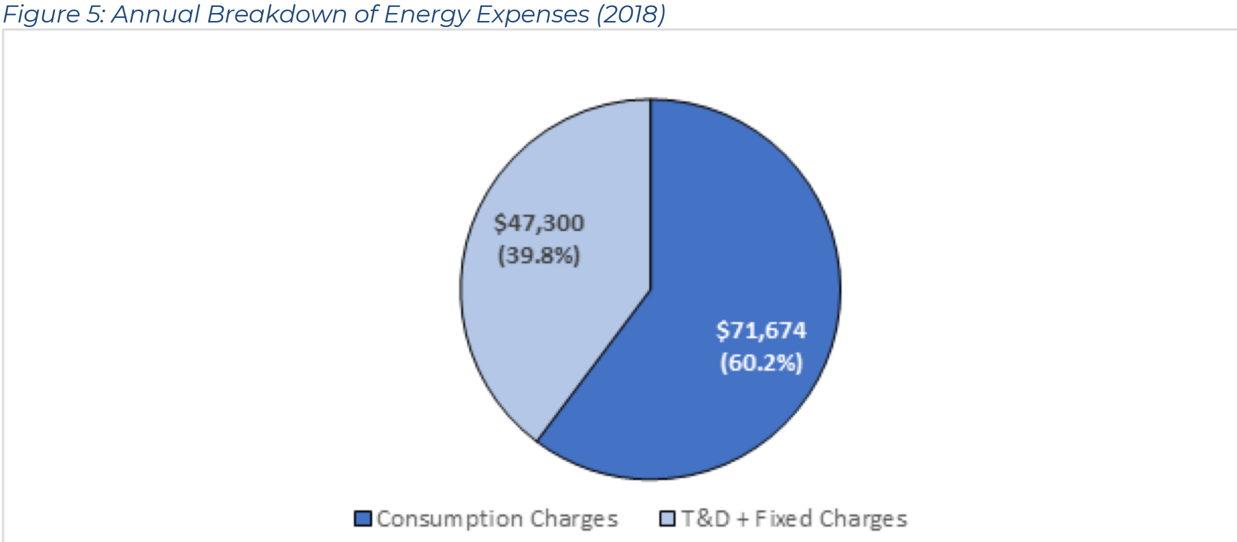
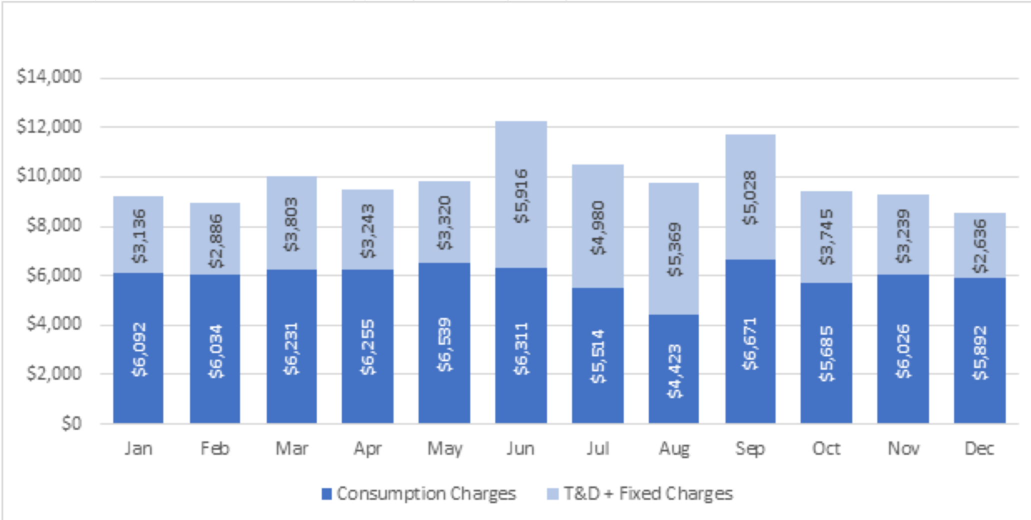


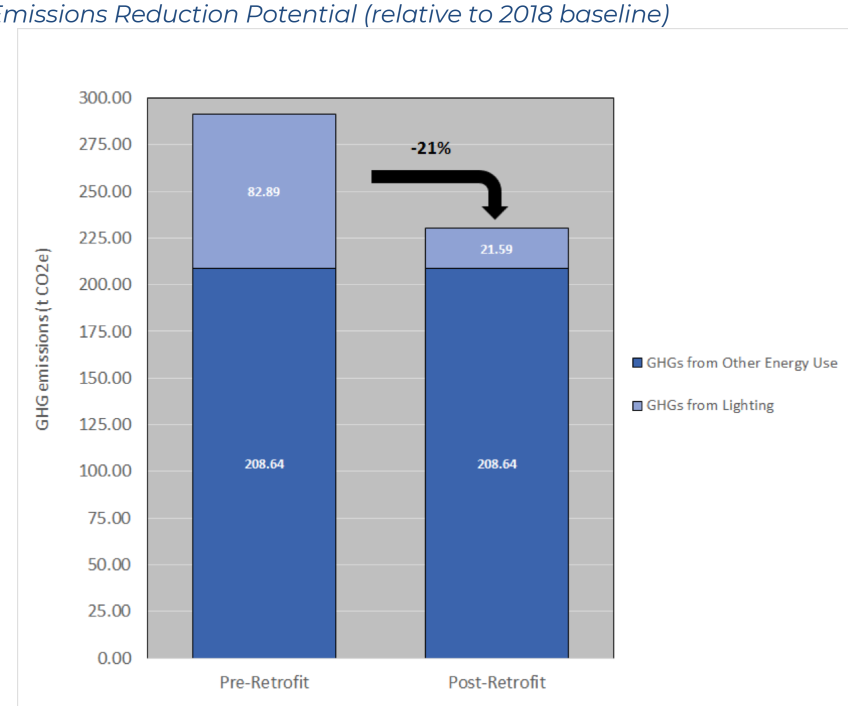
Figure 6: Monthly Breakdown of Energy Expenses (2018)



Reduction Potential – Energy Costs, Consumption and GHG Emissions

After the physical lighting audit was concluded, data analysis revealed how much energy was being consumed by the existing lighting system relative to the total amount of energy consumed at Faculty House. Using figures from the 2018 baseline year, analysis revealed that roughly 28.5% of the total 1,008,800 kWh of energy consumption was used for lighting needs, while the remaining 71.5% was attributable to all other remaining electricity uses at Faculty House, including heating, plug-load consumption for computers and other electrical equipment, kitchen appliances, refrigerated storage space, and other ancillary services.

Figure 7: GHG Emissions Reduction Potential (relative to 2018 baseline)



Of the 286,849 kWh of energy consumption used to operate the existing lighting system, it is projected that converting to LEDs could help Faculty House reduce approximately 212,157 kWh of energy consumption - equivalent to a 74% reduction relative to current lighting system, and roughly 21% reduction in the building's total energy consumption. In terms of energy costs and GHG emissions, this would be equivalent to reducing over $15,000 in utility charges and 61 tonnes of CO_2e per year, respectively (Table 13).

Table 13: Reduction Potential for Annual Energy Use, Costs and GHG emissions

2018	Faculty House Total	Existing Lighting System	Proposed LED System	Total Annual Reduction	Overall % Change
Annual Energy Consumption	1,008,800 kWh	286,849 kWh	74,691 kWh	212,157 kWh	-21.0%
Annual Energy Consumption Costs*	$71,674.28	$20,366.25	$5,303.10	$15,063.15	
Annual GHG Emissions	291.53 t CO2e	82.89 t CO2e	21.59 t CO2e	61.31 CO2e	

**Annual consumption costs exclude T&D + fixed charges.*

Capital Expenditure and Return on Investment

Using price quotes the team received from Faculty House's current lighting vendor, up-front capital expenditure requirements for LED bulb and fixture replacements are estimated to cost $99,370 with an additional $3,040 in installation costs. Additionally, the utility provider, ConEdison, provides a one-time commercial and industrial rebate program for qualifying customers who install energy efficient equipment, including heating, ventilation, and air conditioning (HVAC), refrigeration, and lighting and lighting controls. Electric incentives are offered at $0.30 per kWh, up to 50% of the customer's eligible project cost, and rebate payments are based on kWh savings. All installed equipment must meet or exceed specifications described in the 2019 Commercial and Industrial Energy Efficiency Program Manual, and must follow the application process noted therein.

With projected annual energy savings of 212,157 kWh (relative to 2018 baseline levels), Faculty House could be eligible for a one-time rebate of $63,647 after Year 1. Assuming a discount rate of 9%, an investment time horizon of 10 years, and no increase in the unit price of electricity, the cost-benefit analysis and discounted cash flow models below illustrate that the project offers as Net Present Value (NPV) of $52,651, an Internal Rate of Return (IRR) of 26.2%, and a payback period of 2.53 years (Figure 8, Figure 9, and Table 14).

It's important to note that these financial analyses contain some conservative assumptions which may understate the potential returns of an LED retrofit at Faculty House. For example, while this analysis used a 9% discount rate in the NPV calculations, it is likely that Columbia University has access to inexpensive capital (and thus, uses a lower discount rate for investment decisions), which would improve the financial returns on an NPV basis. The analysis also assumes that the unit price of electricity will not increase over the 10-year investment horizon. However, if prices were to increase incrementally, this would translate into greater savings for Faculty House. Similarly, due to data insufficiency, the team was unable to decipher the rate schedule for other utility charges, like transmission and distribution (T&D) fees. However, it can be assumed that pursuing an LED retrofit would also help Faculty House to reduce their peak demand usage and, by proxy, a portion of its T&D charges. Alas, while these savings were not captured in this report, it is assumed that these avoided T&D charges will also improve the financial value proposition of converting to energy-efficient lighting. Finally, many new LED bulbs are rated for up to 50,000 lighting hours, meaning they can last well beyond the 10-year investment horizon used in this cost-benefit analysis and discounted cash flow model. Therefore, when extending the analyses over a longer investment horizon, it is expected that the returns would be greater than noted herein.

Figure 8: Cost Benefit Analysis of LED Retrofit with Fixture Replacement

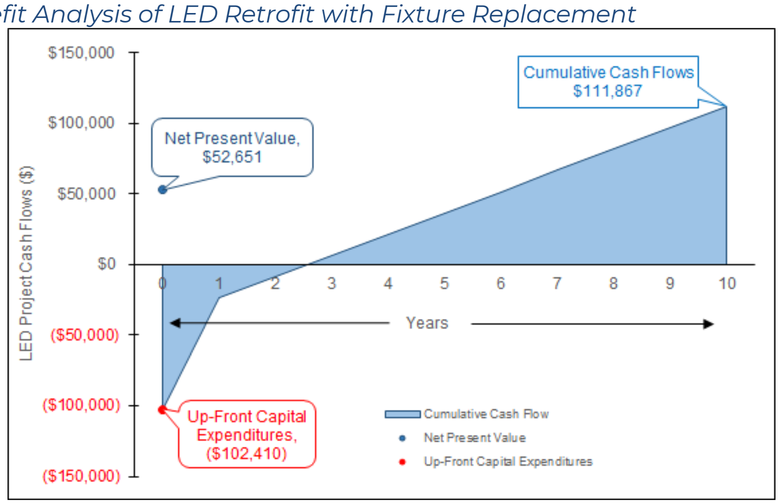


Figure 9: Cumulative Cash Flows for Proposed LED Retrofit with Fixture Replacement

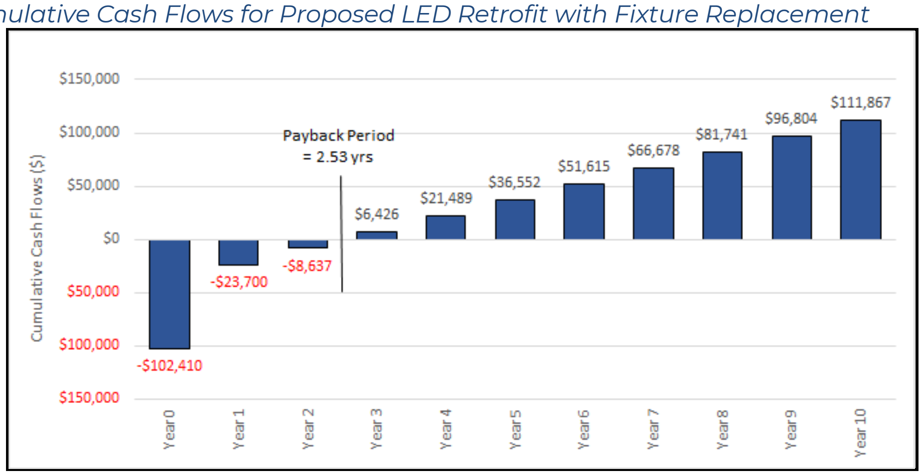


Table 14: NPV and IRR Analysis of LED Retrofit with Fixture Replacement

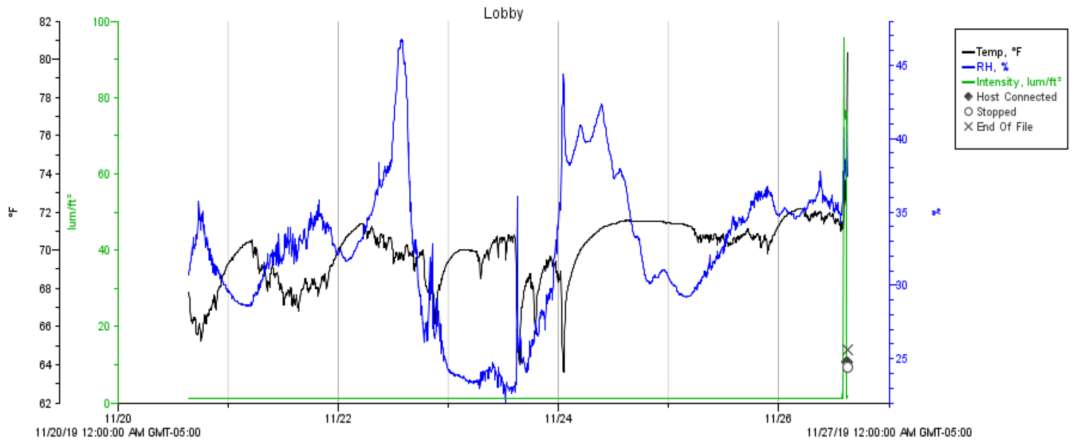
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Replacement Costs ($)	-99,370	-	-	-	-	-	-	-	-	-	-
Installation Costs ($)	-3,040	-	-	-	-	-	-	-	-	-	-
Annual Savings ($)	-	15,063	15,063	15,063	15,063	15,063	15,063	15,063	15,063	15,063	15,063
One-Time Rebate ($)	-	63,647	-	-	-	-	-	-	-	-	-
NPV @ 9%	$52,651										
IRR (%)	26.2%										

Hobo Tracker Analysis (charts and commentary)

Lobby

The greatest drop in temperature in the lobby during the 6-day period is during the middle of the day, between 12p.m. - 2p.m. This is when there is the greatest foot traffic going in and out, causing the drop in internal temperature. During that same time frame, the humidity experienced wide fluctuations depending on the external conditions (high humidity during the rainy days and lower humidity during the drier days), all evident that the relative humidity and temperature were most affected during the middle of the day during high foot traffic. There also seems to be an inverse relationship between temperature and relative humidity where when the temperature goes up, the humidity goes down and vice versa. The same observation can be observed in the Right-side vestibule shown below.

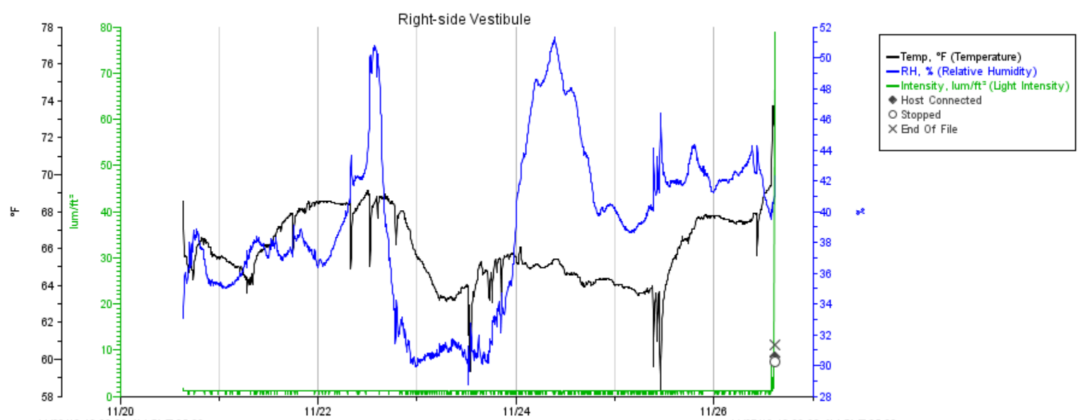
Figure 10: Lobby Hobo Tracker Analysis



Right-Side Vestibule

The results in the right-side vestibule are highly correlated with the temperature and relative humidity data for the front entrance lobby vestibule, another signal that when people are moving around most (in and out of the building), the lowered internal temperature and volatile relative humidity is highest during the middle of the day, based on the data results below.

Figure 11: Lobby Hobo Tracker Analysis



Best Practices

Building Occupant Comfort

Overall, the building occupancy survey had a high response rate (67%). With these results, the team was able to determine a baseline of the occupants' perceptions in four of the building features and identify areas of improvement for each. Due to the difficulty of getting a 100% response rate from the staff, and considering some surveys were not fully completed, under the recommendation section of the report, the team included some relevant information Faculty House should take into consideration in the future when the building occupancy survey (Appendix 4) is carried out, to improve the effectiveness of the responses and obtain more accurate information.

Figure 12: Staff-Responses

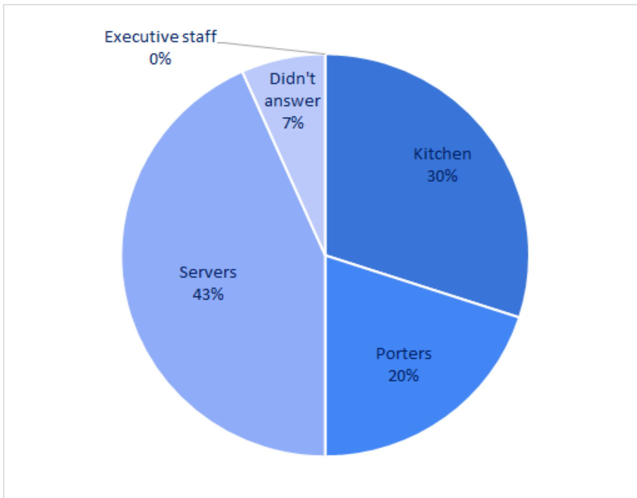
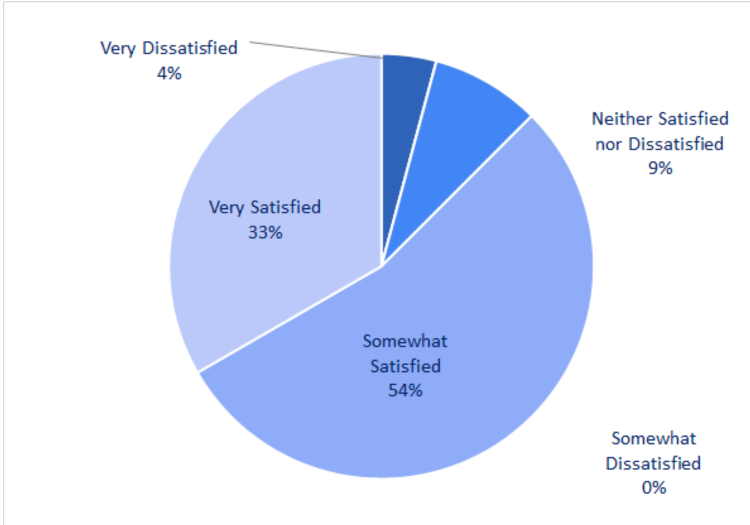


Figure 13 illustrates the number of responses obtained by each of the different staff groups that Faculty House has. 42% of responses were from the "Servers", followed by people working in the kitchen with 30% and the "Porters" with 20% of total responses. It is important to recognize that no response was obtained from the "executive team" and two people (7% of the responses) did not identify themselves on a specific team. Initially, the team expected to find differentiated answers between the staff who do their work in one place of the building and the people who work in different parts of it. However, the answers obtained did not show differentiation and thus it was not necessary to segregate the results.

Figure 13: Overall Satisfaction



As mentioned before, one of the difficulties when analyzing the obtained responses, was that not all required answers were responded to. Although the survey response rate was high, some important questions such as the "Overall Satisfaction" was only answered by 80% of the participants, and 53% of total staff of Faculty House. This suggests that the results obtained are less accurate than expected.

Disregarding the different response each answer had, the team assessed the performance of the built environment independently for every one of the specific features: lighting, air quality, thermal comfort, and acoustics, as well as the overall question. Below are the results obtained from the survey in each category and some possible areas for improvement.

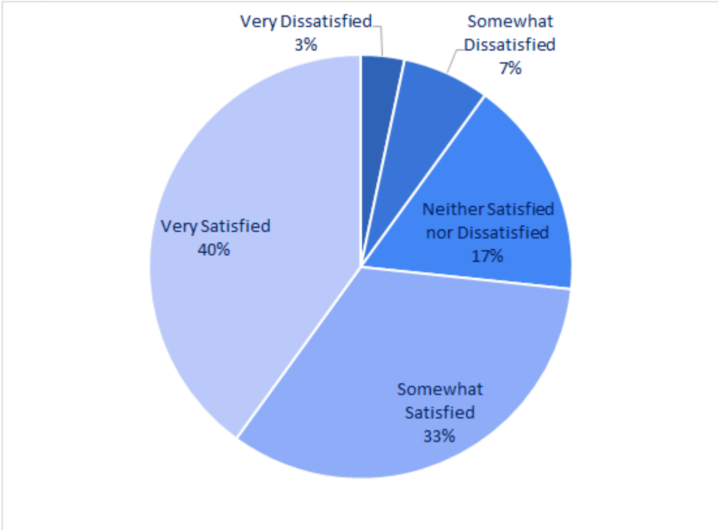
Lighting

According to various studies, the lighting conditions of a space impact human visual and mental health, and behavior. It is important to evaluate and understand the visual needs, people have and meet those needs by integrating daylight and artificial light, to create an effective and healthy environment (Elliot AJ, N/A).

The total number of respondents answered how satisfied they are with the lighting conditions of the building, and most of them (40%) are very satisfied or somewhat satisfied (33%). Only 3 people that represent 10% of respondents are dissatisfied. The two main sources of discomfort associated with the lighting quality (visual comfort) included brightness of light and lack of daylight. Specifically, 8 staff identified that the "light is too dark" and 6 staff identified that there is "not enough daylight".

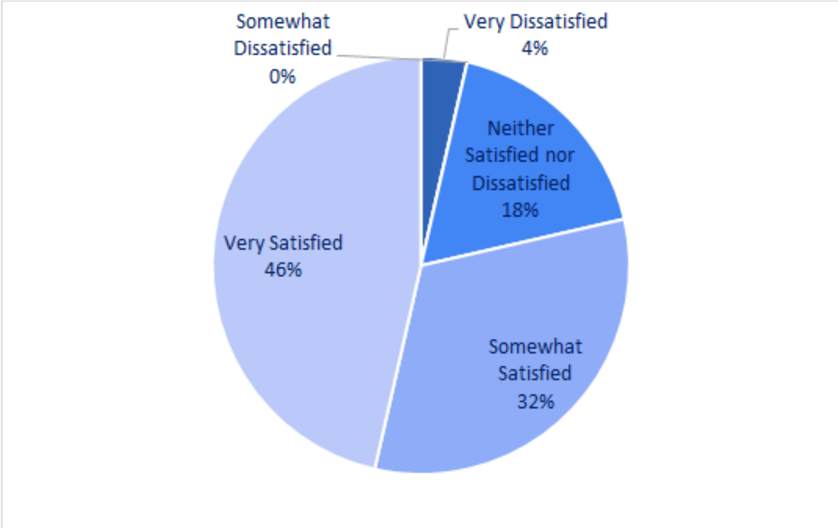
Some of the spaces in the building staff identified as areas that are too dark and areas that do not have enough daylight include the kitchen located in the basement, the locker room for employees, the Ivy lounge, and in general the 2nd floor. However, according to the lighting audit conducted by the team, the interior illuminance levels are for the most part in conformity with the standards and best practices. Figure 14 represents the results Faculty House staff has regarding visual comfort.

Figure 14: Lighting Quality - Visual Comfort



In addition to all of the above, it is important to mention that although 22 people are satisfied with the sensors available in the building, when asked them about the different controls they have over the lighting system of the building, most of the respondents did not distinguish the controls. This should be a priority for Faculty House, since controls are an essential part of effective systems, and can help optimize energy use and occupant comfort (Lighting the Way, 2017).

Figure 15: Lighting Sensors

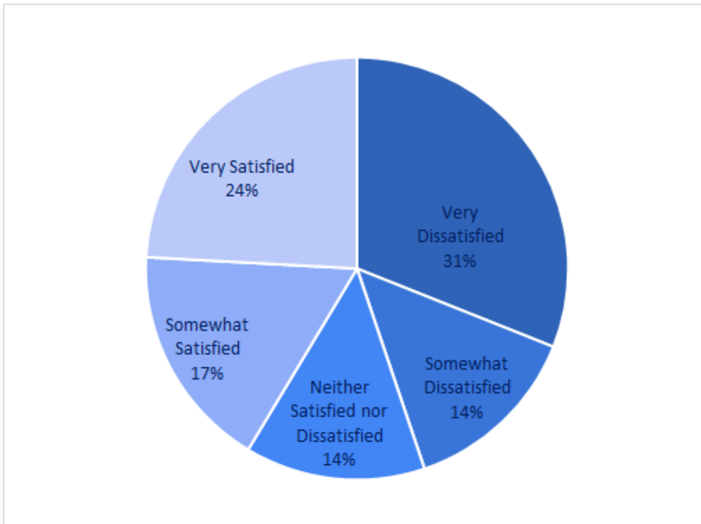


Air quality

According to multiple studies, inhalation of indoor air pollutants can lead to a variety of discomfort and health problems, such as headaches, dry throat, eye irritation, and runny nose (Fundamental Air Quality, N/A). The main purpose of the four questions included in the survey related to air quality was to identify patterns and sources of pollutants inside Faculty House.

Air Quality is the feature with which more people show dissatisfaction. 97% of the people answered the question regarding the air quality satisfaction the survey had, and 45% are somewhat or very dissatisfied. Although the dissatisfaction rate is relatively higher than the satisfaction rate (41%) which indicates that the answers seem to be somewhat evenly distributed between satisfied and dissatisfied, the most common answer was very dissatisfied (31%). In addition to that, the team identified that 3 of the 12 people who were satisfied with the air quality of the building, express some discomfort regarding unpleasant odors in the kitchen, men's locker room, and the fourth floor.

Figure 16: Air Quality



The carbon monoxide, as well as other pollutants that result from the combustions made in Faculty House kitchens, could represent an important source of air contaminants and should be examined, since many people are exposed to it (Meier P, Holloway T, Patz J, et al., N/A).

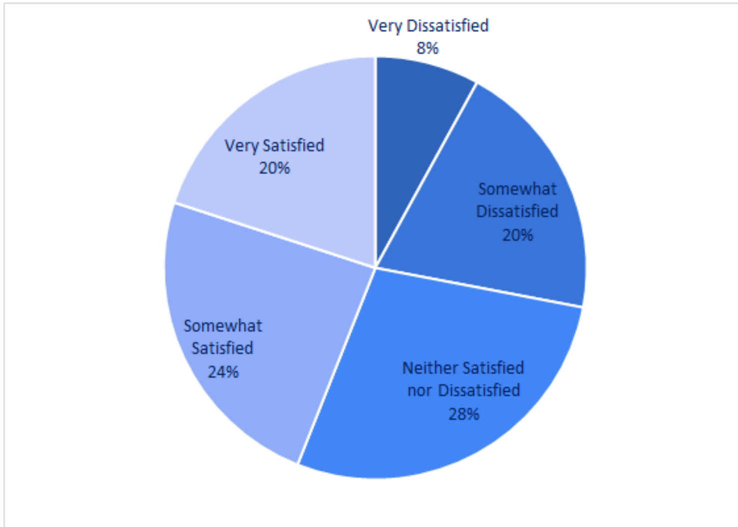
Thermal Comfort

The thermal comfort section in the survey was intended to provide feedback on the temperature and the air movement and comfort in the built environment. With 6 different questions, the building occupants were asked to identify some of the different controls they have, specifically in adjusting the environment (temperature), how satisfied they are with the temperature in the environment in general and during the different seasons (summer and winter). Ultimately, they were asked to named sources of discomfort, if any.

The results reveal that most of the building occupants are satisfied with the temperature overall (44%), while only 28% show dissatisfaction. However, the fact that "neither satisfied nor dissatisfied" was the most common answer among the building occupants (28%), and that 66% of the people expressed a source of discomfort regarding the temperature in the building, there is evidence that there is not a general satisfaction regarding the overall temperature in the building. The source of discomfort most common is related to how cold the environment can get with a 36%

response rate, followed by the perception that it gets too warm and too frequent temperature shifts with a 12% response rate each.

Figure 17: Thermal Comfort

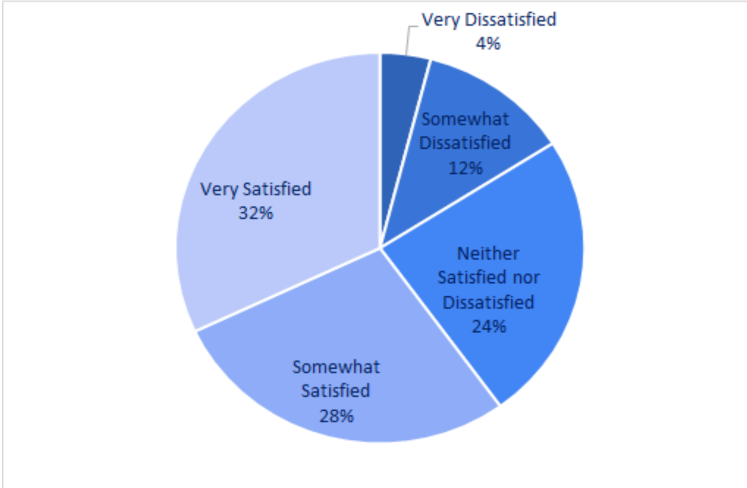


The perceptions of the occupants during winter and summer tend to be similar, since the bulk of the responses is that it is comfortable during both times of the year. However, during the summer, the second most common answer is that it gets too warm (31%), while during the winter, it is the opposite and 37% of the respondents say it gets too cold. Faculty House should take into consideration these insights, and the fact that more than half of the staff who answered the survey stated some source of discomfort regarding the thermal comfort in the building.

Acoustic

With the purpose to understand how noise levels and the way sound is transmitted in the Faculty House affects the staff's comfort and privacy, the team included a fourth section in the survey called Acoustics. The key findings associated with this feature were that there's a satisfaction of 60% of the respondents, against only 16% of displeasure. The only source of discomfort is a high rate (32%) responded that the noise generated by the Mechanical System (heating, cooling and ventilation) is too loud. The place where most people identified the noise was the Boardroom. Other places the staff mentioned were the kitchen (general), 1st, and 3rd floors.

Figure 18: Acoustic Comfort



The report does not include the results obtained from the qualitative answers the staff gave related to the "ability to get the job done". After a conversation with an expert from WELL, the capstone team decided not to take into consideration these responses since they can be too subjective. However, all staff responses are included in the scorecard and will be delivered to the client, and the scorecard format created in an Excel file will also be a useful tool that can be used by the Faculty House management office in the future to generate reports and identify trends.

Roadblocks

It was challenging to collect key technical information from facilities and administration. In addition, the team did not have enough information on the lamp type while conducting the audit (relating to the process). Other challenges included lack of information and knowledge on the lamp intensity wattage per unit, so the team was unsure as to what alternatives would match the pre-existing lamps currently in place. The Facilities representative that accompanied the team throughout Faculty House during the second lighting audit had to manually open up packaged lighting boxes to ascertain whether the voltage was what it was presumed to be or not, so the data assisting in the lighting audit was not as comprehensive as it could have been.

Sustainable Operations

Food

In order to assess the environmental impact of the newly developed Sustainable Living Menu with respect to the existing menus offered at Faculty House, the team created a weighted average baseline menu by utilizing the 10 most popular menus and aggregating their total GHG emissions. The results of this developed baseline menu include consumption data for the last three years, and represents more than 50% of the total menu sales and event attendance.

Each menu consists of a selection of Buffet and Plated menus, which include different kinds of dishes such as entrees, salads, soups, desserts, etc. To make a fair comparison, the team calculated the average of CO_2e emissions for each kind of dish and added them together to get the total average emissions per menu (Table 15).

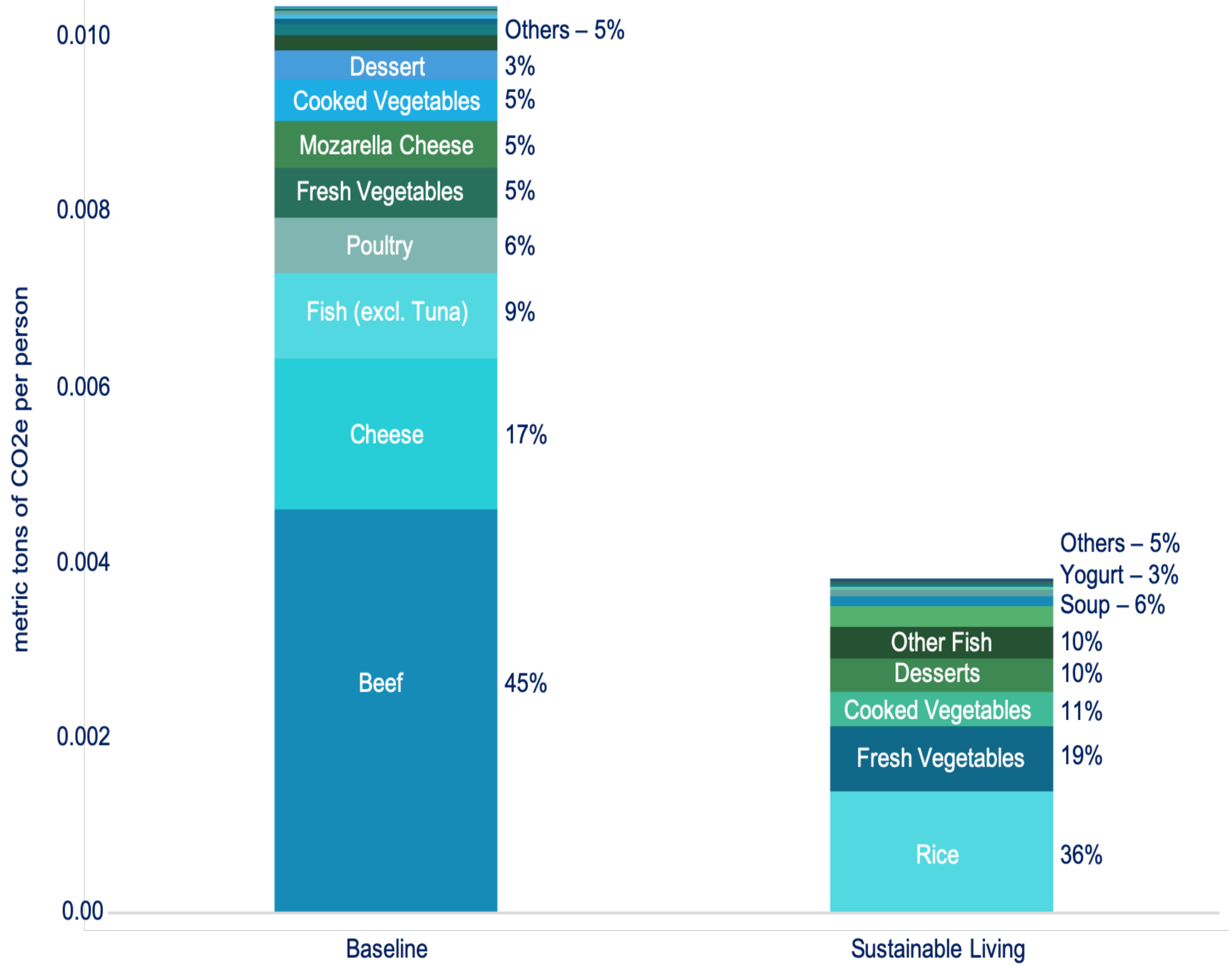
Table 15: Average emissions per type of menu

Category/ Menus	Baseline Average Emissions (CO_2e)	Sustainable Living Menu Average Emissions (CO_2e)	Emission intensive difference (CO_2e)
Buffet	7.82	2.89	63%
Dessert	0.29	0.14	51%
Entrees	0.97	0.36	63%
Salad	0.27	0.23	14%
Soup	0.99	0.20	80%
Total	**10.34**	**3.82**	**63%**

This first approach shows that the Sustainable Living Menu is 63% less emitting than the baseline menu. As we can see in (

Figure 19) most of the emissions in the baseline menu come from Beef, Poultry, Tuna, Other Fish, and Eggs. The Sustainable Living Menu consists mostly of plant-based options, as well as one fish option. This fish option is the most emitting dish on the sustainable living menu, representing around 14% of the total emissions for that menu.

Figure 19: Baseline vs. Sustainable Living Menu: GHG emissions in metric tons of CO2e per person



When comparing the proportion of emission by Buffet, Entreés, Salads, Soups and Desserts, it is interesting to note that emissions are mostly concentrated in the Entreés (64%), while Salads contribute only 3% of the total.

In

Table 16, a comparison of the average emissions per plate of each menu is presented. It is clear that the Sustainable Living Menu is the least emitting menu offered at the moment, emitting 0.26 kg of CO_2e per plate on average. The difference between the menu with the most and least emissions per plate shows that a plate of the Thinker Menu emits 4 times more than the Sustainable Living option. Similarly, the French Menu emits 3 times more than the Sustainable Living Menu. The American Buffet appears as one of the closest options to the Sustainable Living Menu, emitting only 31% more.

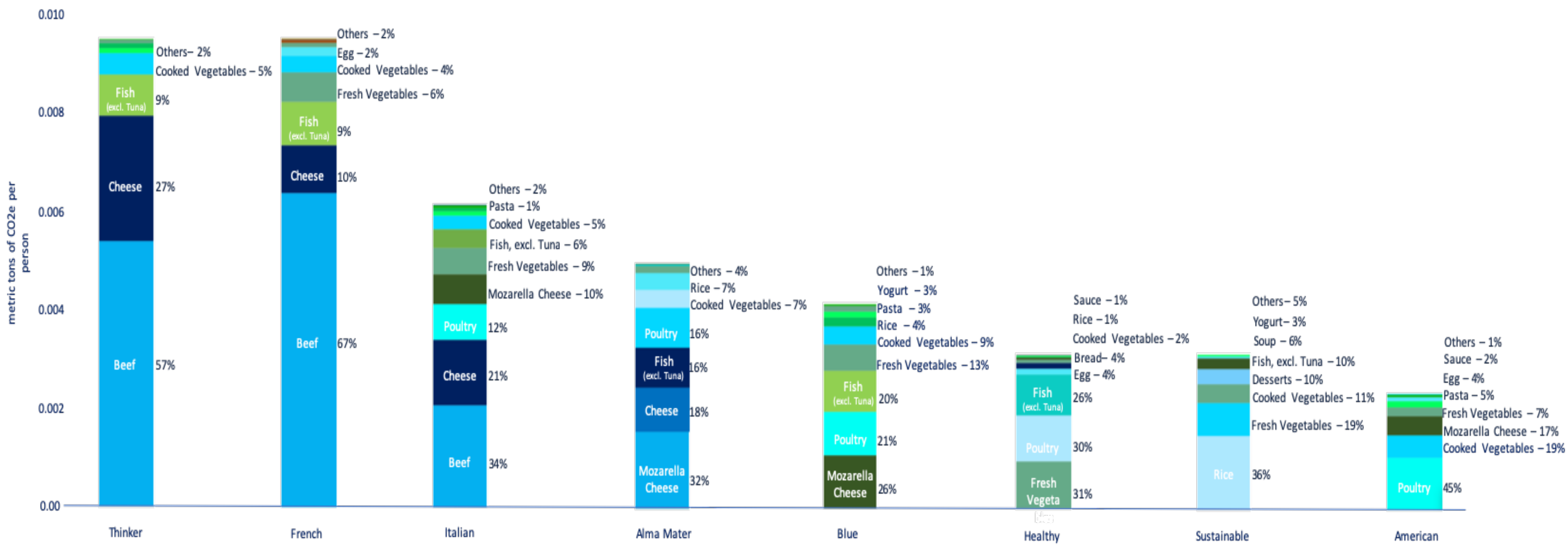
Table 16: Average Emissions per plate by Menu & Emission Comparison with Sustainable Living Menu

Menu	Average Emissions per plate (kg of CO_2e)	Emission Comparison with Sustainable Living Menu
Thinker	1.34	411%
French	1.28	386%
Italian	0.84	221%
Alma Mater	0.72	175%
Blue	0.52	97%
Healthy	0.45	70%
American	0.34	31%
Sustainable Living	0.26	0%

The composition of the emissions per menu shown in

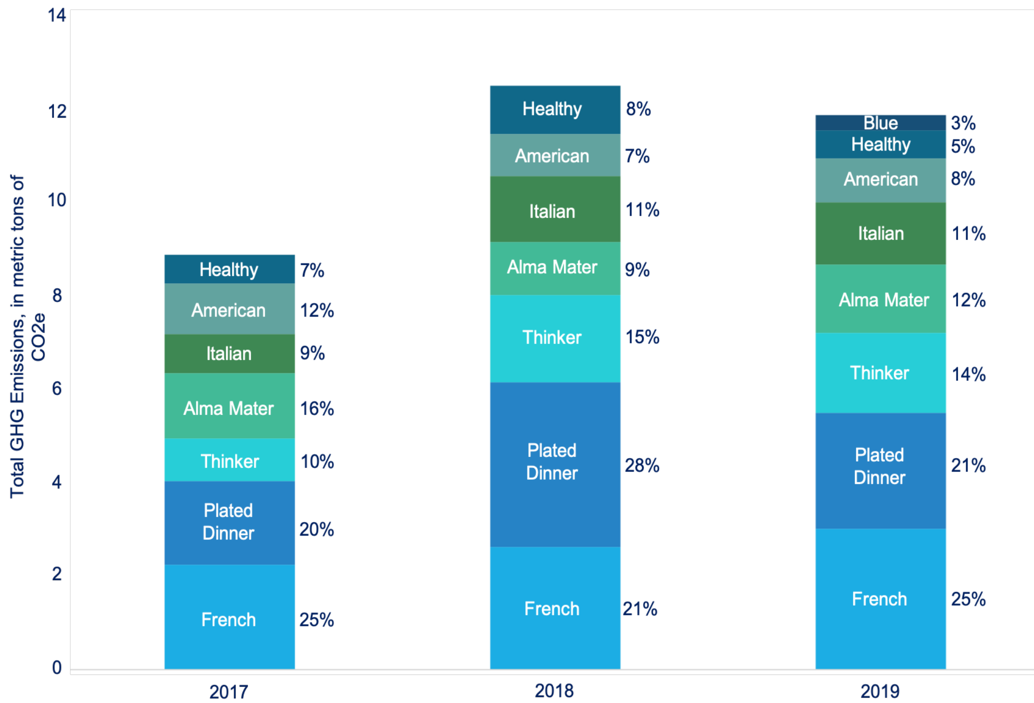
Figure 20 indicates that beef and cheese are the food categories that contribute most of the CO_2e emissions for the Thinker and French Menu. The reduction of animal-based ingredients in a menu makes a drastic reduction of the emissions, which is the main reason that the Sustainable Living Menu is at the bottom of the list.

Figure 20: Emissions per plate per Buffet Menu



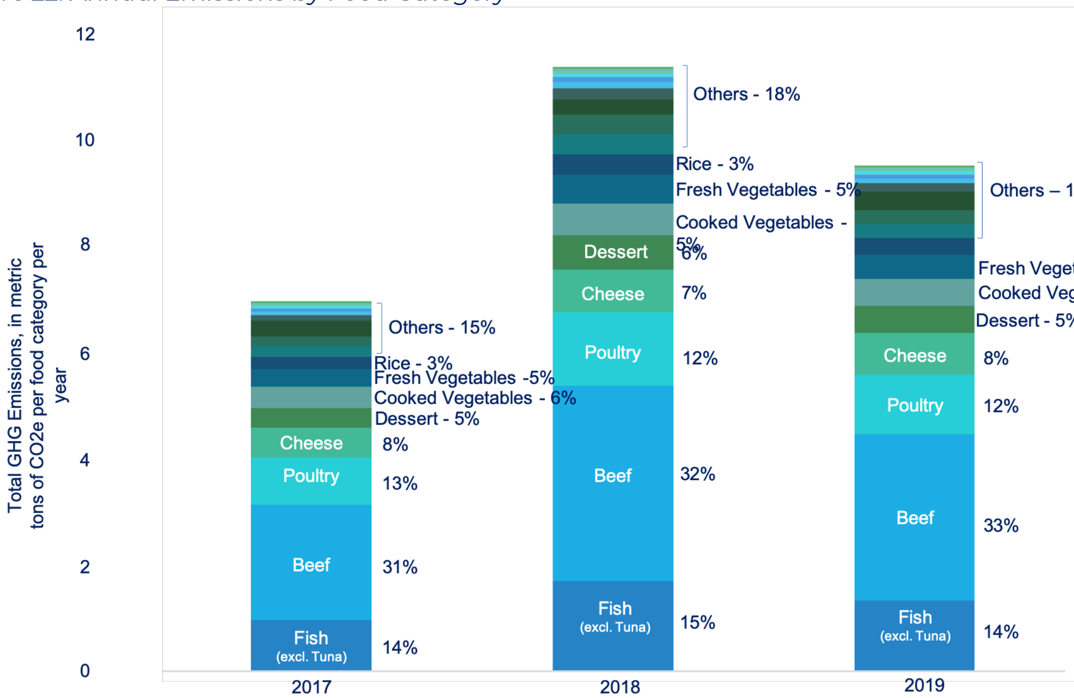
When analyzing the demand of each menu in the last three years and the underlying emission of each menu, it appears that a plate from the French Menu and a Plated Dinner contribute the most when compared to other menus emissions average (See Figure 22). When comparing the increase and decrease of total emissions per year, the difference is due to the demand increase or decrease rather than a change in the emissions itself. Sales participation of different menus stays constant over time.

Figure 21: Annual Emissions by Menu



Further, the team conducted an aggregation of total GHG emissions per year, on all food categories of the top 10 menus analyzed. This analysis shows once again that Fish, Beef, Poultry and Cheese are the biggest contributors to GHG emissions (Figure 22).

Figure 22: Annual Emissions by Food Category



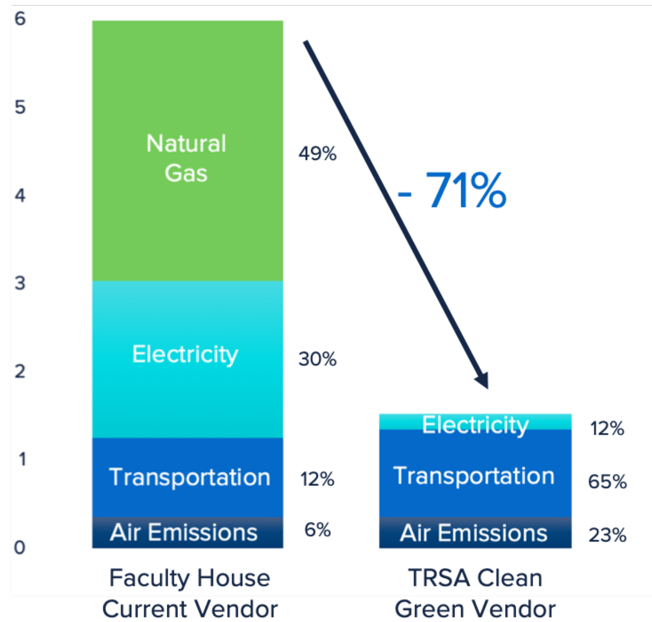
After analyzing GHG emissions of food served in Faculty House using a proxy methodology, the results highlight the importance to focus efforts on reducing and improving the use of animal-based products. Whether analyzing a baseline menu, comparing each menu separately, or evaluating the yearly emissions, food categories such as beef, fish, poultry, and cheese are the biggest contributors across all menu analyses. Reducing use of animal-based products can be accomplished by promoting the new Sustainable Living Menu or the American Menu more. Even though the highest impact would be in reducing the use of these products, adopting sustainable procurement practices when buying animal-based products could also reduce some of the underlying emissions. Procuring free-range meats through local suppliers are some of the practices that could help in reducing the impacts.

Linens

Due to the absence of natural gas production and the operations of an on-site boiler to heat water, this specific TRSA-certified vendor's emissions are significantly lower than the current vendor by 71%. The reason behind this significant discrepancy is that natural gas tends to be the highest contributor to the overall emission profile as well as a key air pollutant emitter. Natural gas and other fuel oils have high emission factors, meaning they emit hazardous air pollutants when under combustion. Thus, one could see that the TRSA-certified vendor shown in Figure 23 has lower air pollutant emissions compared with the current vendor due to the absence of the on-site combustion practices. Moreover, another key contributor to the overall GHG emissions is electricity usage. In this case, the TRSA-certified vendor achieved fewer emissions from electricity not only because of its energy efficiency practices, but also because it purchases and receives electricity from a cleaner grid. The emission factor for the TRSA-certified vendor's subregion eGRID is lower than the current vendor's subregion eGRID (NYCW vs. RFCE). According to the team's call with the TRSA-certified vendor, they are planning to substitute their electricity usage partially with solar energy in the coming year. The substitution of renewable energy will also help to bring down the proportion of electricity emissions. As shown in Figure 23, the current vendor's natural gas emission occupies about 39% of the overall profile and electricity occupies 36%, which make them the two largest contributors to the overall environmental impacts. Therefore, though the TRSA-certified vendor is located further from Faculty House, which results in higher transportation emissions, the low proportion of emissions from natural gas and electricity significantly drive down their overall profile.

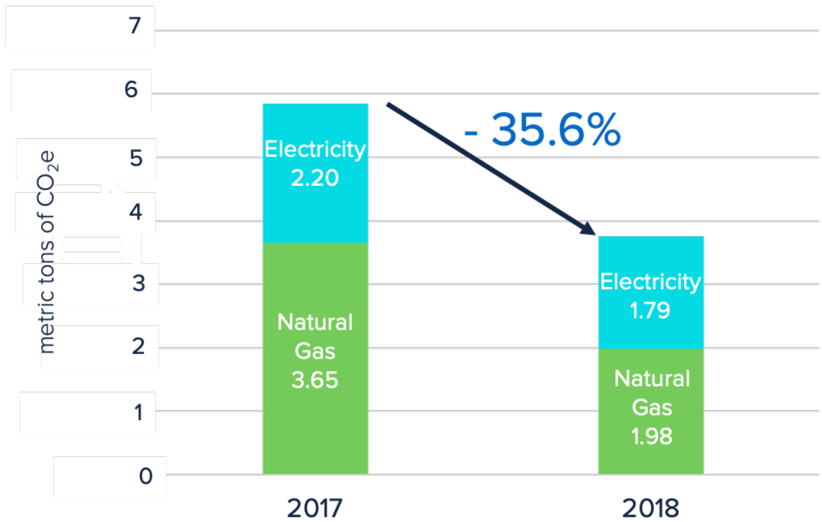
The TRSA clean certification for linen services requires all certified facilities to report and track their energy, water, and chemical performance on an annual basis. Representatives from the program perform physical on-site audits every four years to review progress over time. Therefore, although the lack of natural gas emissions is a characteristic that only applies to the current TRSA-certified vendor that the team surveyed (Figure 23), other certified facilities will potentially use cleaner sources or more efficient energy practices due to the demands of the certification.

Figure 23: GHG Emissions and Air Pollutant Emissions Comparison Between Vendors with 2018 Linen Ordered



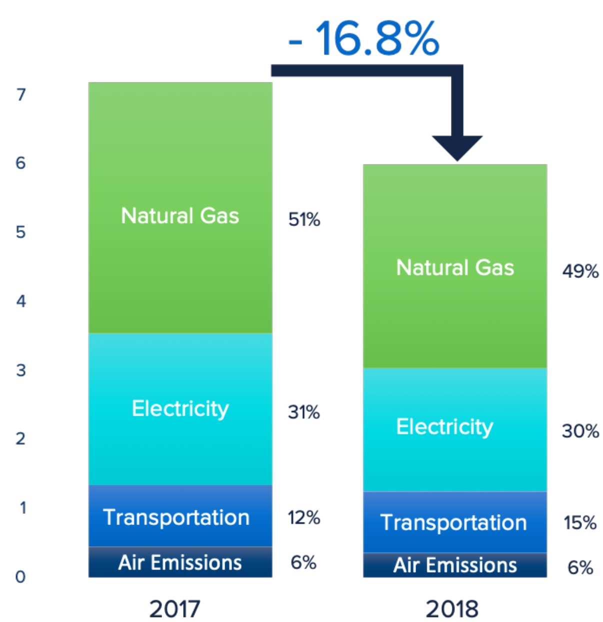
By comparing 2017 and 2018 total emissions, one could see that simply by reducing linen ordered, the environmental impacts and water usage also diminished respectively (Figure 24-Figure 26). Specifically, the natural gas combustion which is used to heat water decreased by 45% due to the reduction in pounds of linens treated. Moreover, electricity usage also diminished with the reduction in pounds of linens washed (Figure 24).

Figure 24: 2017 and 2018 Natural Gas and Electricity Emissions Comparison



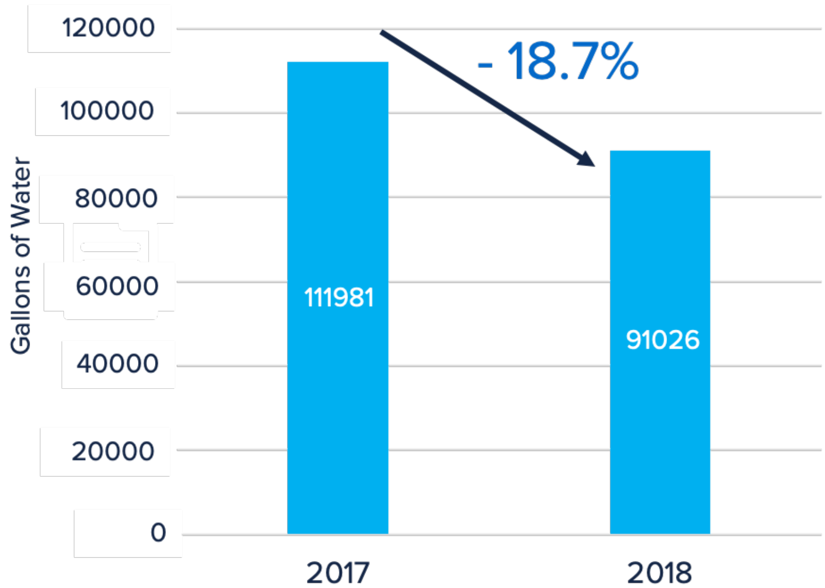
The reductions of the largest two emitting sources brought down the overall profile by 16.8%, as shown in Figure 25.

Figure 25: 2017 and 2018 GHG + Air Pollutant Emissions' Comparison



Similarly, with the reduced linen orders between 2017 and 2018, Faculty House has successfully helped to reduce the water used in gallons by 18.7%.

Figure 26: 2017 and 2018 Water Usage Comparison



Recommendations & Next Steps

Energy Efficiency & Best Practices

The city of New York set the ambitious target to reduce carbon emissions by 80% by 2050 compared with 2005 levels. Since energy use from building accounts for 68% of the total emissions, the city has undertaken several legal initiatives to achieve this goal. The Greener, Greater Buildings Plan (GGBP), is a comprehensive attempt to make large existing buildings become more energy efficient. The plan is comprised of different legal requirements that call for building owners to report annual measurements of the energy and water consumption, conduct an energy audit and perform retro-commissioning once every 10 years, and establish lighting upgrade and submetering requirements by 2025. Faculty House has indicated to the team that it is not required to comply with the Local Law 88, given its square footage falls below the required 25,000 square feet. According to the property data obtained from the Department of Buildings, however, Faculty House is shown to belong to a tax lot along with two more buildings under BBL 1019610001, amounting to more than 200,000 gross square feet in total. It would require Faculty House's compliance to Local Law 88 as part of the tax lot. We recommend clarifying the compliance status of Faculty House with regard to these laws outlined in GGBP. Meanwhile, the team identified some of the best practices in Local Law 88 to be adopted in a lighting upgrade.

Local Law 88

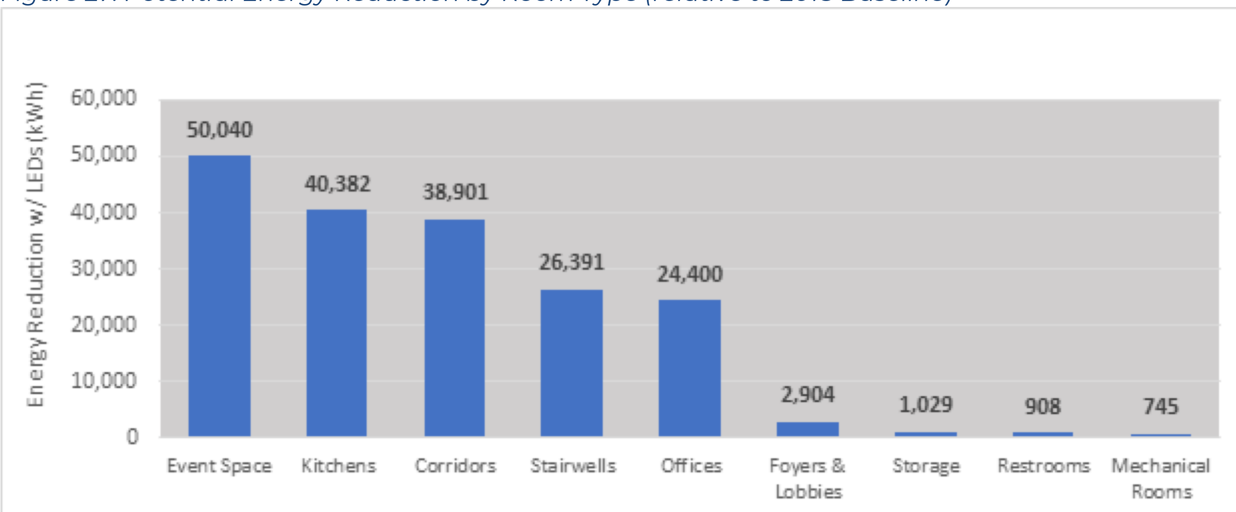
Local Law 88 requires any stand-alone building that exceeds 25,000 gross square feet, or two or more buildings in the same tax lot that exceed 100,000 gross square feet, to perform a lighting upgrade and install submeters by 2025, with the purpose to improve building energy efficiency and to give tenants better visibility of their energy consumption. The upgrade requirement consists of two components to energy code lighting standards: compliance to the current energy code regarding the lighting power densities, and the lighting controls used (switches, sensors, timers). A first good practice Faculty House can embark on, is following the requirements established in Local Law 88, and developing a lighting retrofit plan for the entire building.

Lighting Retrofit to LED Lamps

Prioritizing LED Retrofit According to Room-Type

If the client opts for an incremental approach to retrofitting Faculty House with LED lighting, it is recommended that efforts be prioritized for event spaces, kitchen areas, and corridors. These rooms would result in the largest energy-use reductions, as shown below in Figure 27. Given the fact that 28.5% of Faculty House's energy consumption is from lighting (Figure 4), this means that switching to LED bulbs with energy efficient advantages has promising potential to reduce their consumption each year dramatically (note: the team will not know that metric until LED light is fully integrated throughout Faculty House to benchmark those changes against the baseline of Faculty House's current lighting set-up).

Figure 27: Potential Energy Reduction by Room Type (relative to 2018 Baseline)



Challenges of an LED Retrofit

One of the challenges for the lighting retrofit is how to dispose of the existing fluorescent lamps containing mercury. Mercury is both a persistent bioaccumulative toxic (PBT) and a neurotoxin which affects the central nervous system, damages the brain, spinal cord, kidneys and liver if present in an organism (EPA). A small amount of mercury in one standard compact fluorescent lamp (CFL) "is enough to contaminate up to 6,000 gallons of water beyond safe drinking levels" (Johnson, 2008). Mercury leaked from breakage of fluorescent lamps emerges as mercury vapor or very small beads of mercury, which are difficult to contain. However, only 23% of the mercury-containing lamps are being recycled in the U.S., leaving much possibility of mercury contamination in the environment. (Silveira et al., 2011) During the lighting retrofit, Faculty House should enforce careful recycling of fluorescent lamps by disposing them to local lamp recyclers. In addition, to protect the users and employees of Faculty House, Facilities staff need to adhere to strict compliance with the clean-up protocol of broken fluorescent lamps according to the EPA guidelines (details can be found in the Appendix 2).

Guidelines of a lighting retrofit

Developed by the Building Energy Exchange (BE-Ex), the six steps outlined in Appendix 4 address the different issues every organization should consider before determining which lighting upgrade to perform. This guide was adapted with the purpose to give Faculty House an overview of what has been done, and what should be the next steps if conducting a lighting retrofit.

Immediate actions

Task Tuning

According to on-site observations, the current lighting set-up in Faculty House did not align with the tasks being performed on many occasions. The building satisfaction survey conducted by the team also indicated minor dissatisfaction with the lighting in certain parts of the facility. Therefore, the team recommends conducting task tuning in Faculty House to accommodate the needs of the occupants while potentially reducing energy use and operation costs. Task tuning is a procedure to set the light dimming level in a space so that the average illuminance on the working plane is appropriate for the type of use in that space. When the high-end of the lighting level is capped below the design lighting level, it will result in permanent energy savings. With programmable scheduling, the occupants can also adjust the cap point by time of day. It is important to balance energy savings with the occupant's visual comfort. Task tuning should be conducted with occupants' feedback. Since most of the light fixtures are dimmable in Faculty House already, task tuning can be easily performed. The cost of task tuning can be further minimized if it is done in conjunction with the lighting retrofit.

Recommendations for Future Building Occupant Comfort

Oftentimes, building owners have been more focused on measuring the efficiency of the resources in a building, and less on how properly the buildings meet their design intention for the occupants (Center of the Built Environment). Based on this, the Building Occupancy Survey developed and conducted for the first time in Faculty House, is a helpful source of information regarding occupant satisfaction and a way to assess the success of the design of the building as a working space. The purpose is to compare the obtained results of the survey with the findings from the evaluations Faculty House usually does on the different resources of the building, such as the lighting and heating systems.

For the lighting system, the team was able to contrast with the findings of the lighting audit done and the results of the survey in the visual comfort section. In this first exercise, the team found how there is a correlation of user satisfaction with the fact that the light intensity and color are adequate in most of the areas of the building. Only 10% of the staff that respond to the survey (6% of the total staff) show discontent, especially in some areas of the building such as the basement and lockers. The team recommends Faculty House to do the same assessment for other resources of the building such as the heating system. It can be done using the results obtained from this first survey or by conducting additional ones. However, employing these types of tools can generate expectations in the people who answer the survey and in general, the occupants of the building. For this reason, this tool should be used carefully, and based on best practices, always inform the people about the purpose of the survey.

Regarding the challenges when conducting the occupant comfort survey, the biggest difficulty was that most of the staff did not answer all the required questions in the survey. With the purpose to have a better rate of responses and more accurate results in future evaluations, the team suggest Faculty House to:

1. If conducting the survey without the assistance of a third party, try to avoid questions/answers that can be too subjective. As mentioned before, the team decided to remove the questions that initially tend to provide an insight about the effectiveness of the building in the productiveness of the occupants. Even if these questions were important. Instead the team only focused on evaluating the quantitative aspects of the temperature, light, sound and air quality. But for future implementations it is recommended to assess some qualitative aspects and understand building occupants' perceptions about the building's design features regarding Indoor Environmental Quality (IEQ), that are relevant to their day to day and their needs.
2. When implementing the survey in the future, it is necessary that the staff knows the purpose of the survey and not generate any expectations associated with some improvement of the space without having this within the short-term plans.
3. When conducting the survey, it is essential that someone guide the participants. In order to give an overview of it, explain how many questions are, which are mandatory, and what is being evaluated in each of them to avoid confusion.

The survey initially had 25 questions, and after the adjustments, was reduced to 18, and only 10 of them are required.

Since Air Quality had higher dissatisfaction answers associated with it, it is important that Faculty House use more comprehensive tools to make a better evaluation of the heating and cooling system as well as a calculation of the emissions generated at the kitchens. According to various studies, reduced CO_2 concentrations are closely correlated with increased cognitive function. This is pertinent since Faculty House is a venue used for conferences and seminars.

It is important that Faculty House be able to maintain a comfortable temperature to create a high-performance environment. It is also important to consider the building envelope as well as the mechanical system when evaluating the features of the building and the occupant needs, especially in kitchens and the Board room.

It is also important to note that noise from mechanical equipment can impact comfort. The identification and mitigation of noise sources should also be a priority for Faculty House. A more extensive assessment on the functionality of the mechanical systems mentioned and their location should be done to minimize disturbance.

Transparency in Procurement Process

The procurement of lighting components at Columbia University currently goes through a third-party supply chain platform called Synovos. According to Synovos, they strive to streamline the procurement process to deliver savings and efficiency to their clients by optimizing the inventory, identifying usage trends, eliminating duplicates, and easing transaction processing. Currently, facilities managers of each building place order of the procurement directly on the platform. However, the Lighting Installation and Service team pointed out that they have little information of what is being procured and hence have little control on the quality and efficiency of the lighting components. While there is immense value to the procurement service of Synovos, energy efficiency may not be one of their metrics. The team recommends enhancing the internal transparency of the procurement data of the lighting components so that it can be managed effectively from the energy saving perspective. A designated staff should ensure the most energy efficient lamps or fixtures are being procured, and flag any switching out of the components that may increase energy consumption. This will enhance the energy saving persistence in the long run.

Short-term measures

Advanced lighting control system (ALCS)

Lighting control systems can improve energy savings and occupant comfort in different ways. Today's lighting control technology offers countless options, including real-time programming, occupation, and response to daylight, task adjustment, color adjustment and circadian programming. (Building Energy Exchange, 2017)

Advanced lighting control systems that provide daylight harvesting, occupancy sensing, personal control and demand response can improve efficiency, and can save 30% to 70% in energy use within these spaces. Installing individually addressable ballasts along with an automated, high-efficiency lighting control system will maximize these potential benefits.

Based on the inquiry with Lutron, the current Quantum Vue control system is outdated. The latest version provides many new features that not only enhance its user-friendliness of the interface, but also offer better management tools. It can measure energy use, generate reports in terms of energy saving, occupancy trends and space utilization. It allows the operations staff to change lighting scene and schedule easily without the presence of Lutron field service team, while alerting the staff on any type of system failure down to the level of individual light fixtures. The upgrade of the control system mostly concerns the software, minimizing disturbance to the daily operation of the Faculty House. The team recommends further inquiry with Lutron for price quote and detailed scope of work for the upgrade.

Alternatives to the Lutron's advanced lighting control systems include DALI and Encelium. It is suggested to work with Con Edison's Manage Energy Program which provides cash incentives for installing energy-efficient electric and gas equipment and technologies. Participating Distributors for lighting efficiency can be found under Con Edison's participating distributors list under their Instant Lighting Incentive Program. Name brand distributors include GE's Current, Willdan, and WESCO, to make it easy for commercial and multifamily customers to purchase qualifying ENERGY STAR products.

Energy Loss at Front Entrance Door

The initial mandate required the team to determine the energy loss from Faculty House's front entrance vestibule and automatic door which releases heat in the winter and air conditioning in the summer. The team determined that calculating energy loss from this was out of the team's scope of work. However, after completing desktop research, and speaking to architectural design and sustainability experts, the team determined, low, medium and high-cost alternatives for preventing energy loss at the main entrance, and provided temperature fluctuation data as a result of the entryway.

The low-cost options include a temporary vestibule otherwise known as sidewalk vestibules. These have an average cost about $2,400, while interior renovations can cost around $20,000. Intermediate cost options include updating the automatic doors to an automatic swing door concept. This eliminates motor resistance when opened manually, so even heavy panels are effortless to open and safer to use, but also provide the automatic opening option. Product examples include the STANLEY M-Force™ Automatic Swing Door Opener. Finally, the higher cost options would be to build upon the current vestibule to make it large enough so the first automatic door closes before the second automatic door opens.

Light Switch Alternatives

According to the best practice research, control systems are the core of lighting retrofits because they ensure the functionality of the lighting system is aligned with the needs of the occupants. That is why lighting controls should be adapted to integrate the existing requirements of the occupants and the conditions of the built environment.

Currently, in Faculty House there are 16 rooms with manual switches (out of the total of 114 rooms we examined) which is 14% of the rooms. The room types with manual switches are typically storage and mechanical rooms, with couple exceptions as offices. The team recommends replacing these switches with occupancy sensors in rooms that do not operate all day. With occupancy sensors monitoring whether a space is occupied, this technology will prevent electricity from being wasted by turning off the lights which would otherwise be unnecessary or mistakenly left on.

Long-term Measures

Energy Audit and Retro-commissioning

Faculty House went through a gut renovation with all new mechanical, electrical and plumbing upgrades in 2009. It resulted in 21% energy saving from the baseline, scoring 7 points out of the 44 points in the LEED Gold certification for New Construction, signifying great improvement in energy efficiency. (Columbia, 2010) Nevertheless, study shows that LEED certified buildings do not always perform better than non-certified buildings (Amiri et al., 2019). In addition, ten years after the renovation, the building may not be operating as intended and that problems may have arisen due to the aging of the equipment. Therefore, energy audits and retro-commissioning are recommended to evaluate the current energy performance of Faculty House. A full energy audit provides a robust understanding of energy use of the building and identifies energy efficient opportunities. On the other hand, retro-commissioning address problems in building equipment and systems developed through the lifetime of the building. When combined, it ensures continual high performance in energy efficiency.

Since the lighting accounts for 28.5% of energy use of Faculty House, the lighting analysis conducted by the team constitutes only a small part in the energy-saving possibilities of the building. Energy consumption for other electrical loads such as HVAC and plug loads, etc. as well as by fuels other than electricity need to be accounted for. As part of GGBP, Local Law 87 mandates buildings over 25,000 sq ft undergo energy audits and retro-commissioning every ten years. Building owners are required to resolve any problems on the existing equipment identified during retro-commissioning while encouraged to adopt energy efficiency measures recommended by the energy audit. Studies show that the costs of retro-commissioning activities range from $0.13 to $2.00 per square foot, while payback ranges from 0.2 to 2.1 years. Overall energy savings can reach approximately 15%. (Mills et al., 2005) Therefore, it would be beneficial in terms of energy efficiency, cost savings, and above all, occupant's comfort.

Energy Management Through Smart Building Solutions

Besides periodic auditing and retro-commissioning, continuous and effective monitoring of the energy usage is equally crucial in enhancing energy efficiency. The poor quality of data measurement impedes effective management of the energy use. Currently, the energy usage of Faculty House is being measured by a utility meter on a monthly basis. However, the data from the utility bill provides little valuable and timely insights into operations to inform energy-saving actions. Thus, the team recommends investing in smart building systems to manage the energy use of the Faculty House, as well as the entire campus.

Real-time energy management (RTEM) refers to a combination of internet-enabled systems that monitor and optimize building energy use. RTEM systems continuously collect real-time energy performance data through a cloud-based or on-site system for monitoring, reporting, and optimizing. It can improve traditional evaluation, measurement, and verification accuracy by collecting more granular building systems' energy performance data in real time than utility bills. The granularity and frequency of data allow building owners, managers, and tenants to make smarter decisions about building energy use and to detect issues before they lead to costly inefficiencies. The continuous monitoring and analysis of the data can unlock energy use optimization opportunities, turning them into actions in a semi-automated or fully automated way. In addition, automated system optimization can make strategic decisions about how to control the building systems in response to an external condition in advance (King et al., 2017).

Integrated with the existing building management system, the RTEM systems can optimize energy use and reduce operational and utility costs. The team interviewed

John Gilbert, COO of Rudin Management Group, on his experience of Nantum OS, one of the portfolios RTEM systems for commercial real estate. It identifies correlated trends by analyzing data from disparate building systems (including BMS, utility & power quality meters, and access control) and combining with data from third-party sources (such as weather, occupancy, and IoT sensors) in order to prescribe real-time operational adjustments that improve building performance and tenant comfort. Building systems, therefore, can be remotely centralized managed and optimized, anomalies detected and preventative maintenance alerted, which greatly enhances the productivity of the operations staff. The deep learning algorithm can analyze occupancy and weather data to predict optimize setpoints of heating and cooling to minimize energy waste. In addition, it allows Columbia University to manage the peak load and participate in demand response events to considerably relieve the burden of the utility grid (prescriptive data). All in all, the energy saving could be substantial, amounting to over 40% of energy use reduction of a portfolio of ten million square feet of office space in New York City as an example. (Gilbert, 2019)

Despite the benefit of deep energy saving, the implementation of such a comprehensive system is a huge undertaking that demands cross departments and interdisciplinary coordination. The university should establish a task force comprising of decision makers, property management personnel, operations staff and engineers to develop an implementation plan. Cost may be another major barrier of RTEM. As a reference, the Nantum OS systems costs around $30,000 upfront, and $0.1 per square foot per year operation cost (excluding any costs for additional sensors or hardware). (Gilbert, 2019) The university can take advantage of the financial incentives offered by state and local governments or utilities. For instance, NYSERDA cost share up to 30% of the overall RTEM expense and ongoing third-party software services. (NYSERDA) Nonetheless, the robust IT infrastructure on campus and capability of the operations and IT staff plays in the advantage of Columbia University to effectively implement RTEM on campus. Provided the complexity of the building systems on campus, we recommend further inquiry with vendors of smart energy management platforms to verify the feasibility and cost implication of this strategy.

LEED Certification Strategy

From an energy efficiency, best practices standpoint, the team suggests that Faculty House (as an existing building in operation), focus initially on the LEED Operations & Maintenance (O&M) certification and its requirements. Faculty House's LEED Gold Certification does not need to be recertified, so because of this, Faculty House should focus on the LEED O&M certification requirements. LEED's framework outlines two incomplete prerequisites for Faculty House within energy efficiency management and energy performance. These two prerequisites are required in order to move forward in obtaining a LEED O&M certification.

The first LEED's requirement outlines the energy efficiency best management practices. This prerequisite promotes 'continuity of information to ensure that energy-efficient operating strategies are maintained and provide a foundation for training and system analysis'. This prerequisite requires preliminary energy use analysis and an ASHRAE Level 1 energy audit walk-through, the significance of which has been pointed out in the aforementioned recommendation. Preparation and maintenance of an operations and maintenance plan is necessary as well, and should contain the following information:

- A current sequence of operations for the building;
- Project occupancy schedule;
- Equipment run-time schedules;
- Setpoints for all HVAC equipment;
- Setpoints for lighting levels throughout the project;
- Minimum outside air requirements;
- Any changes in schedules or setpoints for different seasons, days of the week, and times of day;
- A system narrative describing the mechanical and electrical systems and equipment in the project;
- A preventive maintenance plan for equipment described in the system's narrative.

The second prerequisite is energy performance, which supports energy management in order to 'reduce environmental and economic harms associated with excessive energy use by reducing greenhouse gas emissions and achieving higher levels of operating energy performance'.

In order to meet this requirement, the building will need to have permanently installed energy meters or submeters that measure total building energy consumption including electricity, natural gas, chilled water, steam, fuel oil, and propane. For interiors, the installation of sub-meters that measure all electricity and fossil fuels for equipment within the scope will be required. This will allow the building to prorate energy use, using occupancy and base building energy use over twelve consecutive months. These twelve months of energy use data will determine the building's energy performance score, which will be based on project energy performance across greenhouse gas emissions and source of energy. This metering system is also a prerequisite for the aforementioned RTEM energy monitoring and optimization system.
The LEED Certification for Operations & Maintenance requires a $1,500 registration fee and $5,000 flat fee, with a rate of $0.057 for a building less than 250,000 sq. ft. Considering Faculty House is approximately 38,000 square feet, a conservative LEED Certification cost estimate would be around $8,700. (excluding any implementation cost incurred to meet the LEED requirement)

Sustainable Operations

Food

Recommendation 1: Reduce Beef Options from All Menu Dishes

After analyzing Faculty House's most popular menus, the team found that there is a wide array of beef options in both buffets and plated dishes. Since beef is very carbon intensive, it would be strategic to start by reducing beef options and selecting either plant-based proteins or less emitting animal-based proteins as an alternative.

Further, as shown on the GHG emissions results per menu per plate, beef takes up a large amount of the total GHG emissions. Replacing beef dishes with plant-based or alternative animal-based proteins has the potential to reduce overall menu GHG emissions per plate by roughly 40% to 60%, especially for the Thinker, French, and Italian Menus.

Recommendation 2: Stakeholder Trainings on Food Sustainability

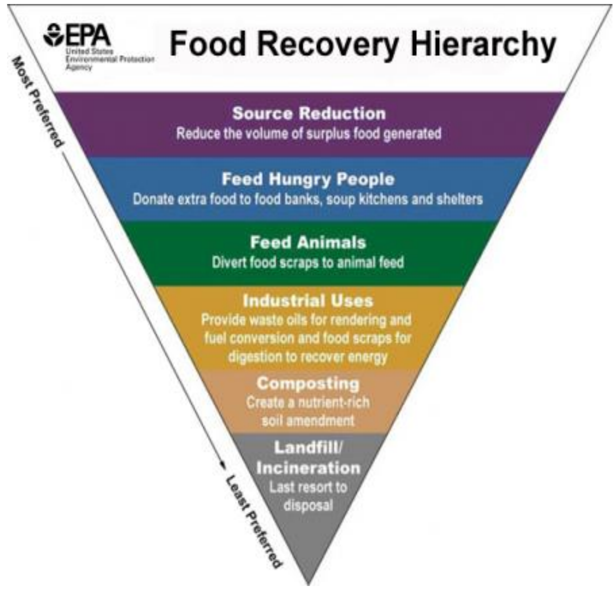
When there is sustainability buy-in from top-down, businesses can advance in environmental initiatives a lot faster and ensure sustainability is engraved in all decision-making at the organization. To ensure sustainability is taken into account when making decisions around food at Faculty House, the team recommends Faculty House incorporate required annual sustainability training for all food-related internal stakeholders such as the chefs, cooks, and the administrative staff that is responsible for bringing in new vendors.

Our team has put together a list of service providers in the NY area that offer sustainability educational employee training that relates to food. Please find the detailed list, along with costs and contact information in Appendix 5.

Recommendation 3: Reduce Food Waste – Adopt the Food Recovery Framework by the USDA and EPA

The team highly recommends Faculty House adopt the U.S. Environmental Protection Agency (EPA) and United States Department of Agriculture (USDA) *Food Recovery Framework* (Environmental Protection Agency, 2019 Figure 28), as it will help track data on food waste diversions and reductions, composting, and more. This data can be used to track progress and set future food loss reduction goals and indicators.

*Figure 28: Food Recovery Framework**



**The top levels of the hierarchy are the best ways to prevent and divert wasted food, the lower levels are the least preferred options.*

Source Reduction

The best way to reduce waste is by reducing the volume of surplus food generated. In order to be able to reduce this surplus, our team recommends that Faculty House conducts an annual waste audit by measuring the amount, type, and waste reasons for each food type or dish. This will also help Faculty House to know where and how money could be saved. Conducting an audit once a year, on the same month and for the same events will allow Faculty House to measure their success on food recovery initiatives, set food recovery goals, and track year-to-year progress.

Our team has included a food loss inventory template for Faculty House to use, including categories like food loss weight, estimated food costs, food type, reasons for waste, costs, etc. This template can be found in Appendix 6, and includes simple steps that must be followed to conduct a successful annual food waste audit.

Feed Hungry People and/or Feed Animals

Reducing wasted food by feeding hungry people is the second best environmentally friendly alternative after reducing the amount of generated food waste. The U.S. Department of Agriculture estimates that sometime in 2017, 11.8% of American households – the equivalent to roughly 15 million households, had difficulty providing enough food for all their members due to lack of resources (United States Department of Agriculture, 2019).

Our team put together a list of Food Recipient Organizations in the NYC area that are interested in accepting wholesome excess food. The detailed list with a detailed description of each organization and website link are found in Appendix 7. Further, if pursuing this alternative, there is no need to be concerned with liability issues. According to the U.S. EPA site on food donations, *"Corporate donors are protected from liability under the Bill Emerson Good Samaritan Food Donation Act"*

(Environmental Protection Agency, 2019). Essentially, what this means is that Faculty House will not be liable for damage incurred as a result of illness as long as it did not act with negligence or intentional misconduct. Last but not least, there are potential tax benefits for organizations that donate food. Find out more about the tax benefits here.

Industrial Uses

In the case where Faculty House is not able to donate the wasted food for human or animal feeding, the fourth-best alternative is to use the wasted food for industrial uses. As stated before, food is a valuable resource, where it can be converted into energy and be used to power a car or generator by creating biofuels from food scraps.

Our recommendation for Faculty House is to partner with any City of New York State which has an anaerobic digester, in order to send food scraps to be processed and transformed. All information on anaerobic digestion facilities and locations in the NY state can be found here. Further, an interactive web-based mapping tool of organic waste facilities, anaerobic digesters, food banks, and composting sites in the NY State can be found here.

Composting

If leftover food or ingredients are inedible and cannot be donated and will not be used for industrial uses, the next best alternative is composting. During the team's interview with the Chef, the team learned that Faculty House used to compost food scraps, but since it was lacking organization and management of the composting site, the initiative got suspended. The team recommends Faculty House reincorporate such initiative, where a specific person is assigned the role of supervising and managing the composting site. The next option after composting is sending the food to landfill, which is the most carbon-intensive option and the least recommended.

By incorporating the Food Recovery Hierarchy, Faculty House will immediately benefit from cost savings by efficient procurement of the food that will be consumed only, and from labor cost savings by increasing efficiency on the preparation, storage, transportation, and handling of food. Further, adopting these initiatives, Faculty House will be able to mitigate the overall greenhouse gas emissions that come from food production (from fertilizer and pesticide use, to growing preparing and transporting food) and reduce the overall methane emissions that come from non-diverted food waste. Finally, following these frameworks has proven to be cost-efficient and environmentally friendly.

Recommendation 4: Adopt Sustainable Catering Best Practices

Adopt Menu Seasonality

Seasonal menus adapt to harvests, allowing each meal to use the freshest, tastiest produce available while respecting natural cycles. Further, sourcing seasonal ingredients often translates into cutting costs. As non-seasonal fruits and vegetables require more energy to be made, prices are often much higher than seasonal fruits and vegetables and are also often more carbon intensive. Additionally, fruits and vegetables contain the highest nutritional value when they are freshly harvested, meaning that procuring seasonal fruits and vegetables not only cuts costs and greenhouse gas emissions, but also translates into healthier eating habits by event attendees.

Promote Plant-Based Options

Alternative proteins such as meat substitutes or natural vegetable proteins are great alternatives to animal-based proteins. This best practice goes hand-in-hand with the first recommendation to replace beef dishes with either alternative less carbon intensive animal-based proteins or plant-based proteins.

Create Vendor Code of Conduct and Conduct Sustainability Questionnaire and Verification Audit

A well-known best practice for any business is to have a Supplier Code of Conduct to ensure a responsible business value chain. The team recommends Faculty House develop a Food Vendor Code of Conduct so that vendors are aware that the client expects them to act with integrity and to always demonstrate commitment to fair trade, ethics, safe working conditions, and environmentally responsible business practices.

The second step to responsible sourcing is to communicate and engage with vendors about the new Faculty House sustainability standards. The first recommended step is to send a short questionnaire to each vendor where simple but relevant information on food sustainability such as certifications on organic ingredients, non-GMO, sustainable farming, fair trade, ethics, and on safe working conditions can be provided.

Ensuring a sustainable supply chain to your customer is not easy, and a Code of Conduct and questionnaire are maybe not enough. A recommendation from the team to Faculty House is to follow up on the questionnaires by verifying the information. There are several inspections, verification, tastings, and certification companies that organizations can rely on to provide specialized solutions on ensuring responsible supply chains. The team recommends Faculty House uses the leading companies such as SGS and/or Sedex.

Recommendation 5: Gather Valuable Data and Set Measurable Goals

The team recommends Faculty House starts tracking all possible data, so in the near future, measurable goals can be set.

1. *Employee Education*
    1.1. Number of employee training on food sustainability per year (from recommendation #2).
2. *Food Waste Reduction*
    2.1. Total food diverted from landfills, by weight per year. This includes all food diverted from landfill which was either recovered, donated for human/animal feeding or industrial uses, or composted (from annual audits on recommendation #3).
    2.2. Food recovered by weight per year

2.3. Food donated for feeding human/animals, by weight per year. This can also include # meals donated per year.
2.4. Food donated for industrial uses, by weight per year. This can include the amount of energy and or biofuels generated from FH food donations per year.
2.5. Food composted, by weight per year.

3. *Carbon – or CO2e – Footprint*

3.1. GHG emissions saved from the food diverted from landfills, in CO2e, per year.
3.2. Total lifecycle GHG emissions per kg of each dish from all FH menus.
3.3. Total lifecycle GHG emissions saved per kg of each dish from newly developed more sustainable menus.

4. *Sustainable Catering*

4.1. Number of food vendors inspected, out of the total food vendors, per year.
4.2. Number and percentage of food vendors audited, out of the total food vendors, per year.
4.3. Number and percentage of food vendors certified organic
4.4. Number and percentage of food vendors certified fair trade
4.5. Number and percentage of food vendors certified non-GMO

For future reference, these are some examples of goals along with key indicators for each goal that can be set, having collected the previous data:

- *Example Goal #1: "Divert from landfill 100% of Faculty House food scraps through our food recovery, donations and/or on-site composting initiatives by 2025."*
    - *Indicator 1 – Total Faculty House food wasted to landfill, by weight, per year.*
    - *Indicator 2 – Total U.S. non-diverted food waste, by weight, per year.*
    - *Indicator 3 – Total Faculty House food waste diverted from landfill by weight, per year.*
- *Example Goal #2: "Reduce total lifecycle GHG emissions, in kg CO2e per dish, from Faculty House most ordered menu in 2019 by 30% from a 2019 baseline by 2030."*
    - *Indicator 1 – Total lifecycle GHG emissions per kg of each dish from Faculty House most ordered menu in 2019.*
    - *Indicator 2 – Total lifecycle GHG emissions in the U.S. that come from the food industry.*
    - *Indicator 3 – Total lifecycle GHG emissions reduced per kg of each dish from Faculty House most ordered menu in 2019.*
- *Example Goal #3: "Perform third-party supplier audits and have vendors sign the Vendor Code of Conduct, to 100% of Faculty House food vendors by 2025."*
    - *Indicator 1 – % of Faculty House food vendors which have not signed the Vendor Code of Conduct and that have not been audited, per year.*
    - *Indicator 2 – % of food providers in the U.S. not being screened on sustainability*
    - *Indicator 3 – % of Faculty House food vendors which have signed the Vendor Code of Conduct and that have been audited, per year.*

Linens

Vendors should have at minimum some sustainable industry standards and commit to these publicly. The TRSA certification is a well-known environmental standard in the dry-cleaning and washing industry which should be a starting point for vendor selection. Examples of TRSA certified vendors can be found in Appendix 9. Faculty House should aim to engage with vendors and require them to have quantitative environmental tracking and management systems as well as a key sustainability point of contact from the facility.

Based on the team's analysis on the current vendor, by accounting for emissions from on-site natural gas combustion that is used only to heat water to treat the linens, the overall GHG emissions profile enlarges, not mentioning that on-site boilers may have other functions such as space heating. Although the TRSA certification ensures certain levels of energy efficiency and fuel usage, the team recommends that during vendor screening, Faculty House ask and do on-site visits to check the facilities' on-site combustion sources and make sure they have energy efficiency or heated water retreatment practices to capture additional heat and reuse it.

Based on the analysis, transportation plays an important role in the environmental impacts. Both the current vendor and the TRSA-certified vendor own/rent the same types of trucks with the nitrous oxide (NOx) reduction technology. However, since the TRSA-certified vendor is located further from Faculty House, they incur higher emissions from transportation. Since vendors deliver rented linens to multiple customers on specially designed routes, it is challenging for Faculty House to only assess the emissions associated with its orders. To mitigate the impacts from transportation, the team recommends Faculty House to engage with the selected vendor and work on a transportation strategy. Faculty House could reduce the number of deliveries per week or shift to biweekly to avoid unnecessary trips and should plan the linens needed for events and request delivery of linens for several events at once. Finally, Faculty House should track deliveries' data to monitor the process and improvement over time.

As shown in Figure 25, linen-less dining has decreased the environmental impact associated with linen use from 6Mt CO_2e to 3.8Mt CO_2e. The greatest decrease was linked to natural gas consumption, which is especially relevant for the current vendor who uses natural gas for electricity generation. Had the vendor been the TRSA-certified vendor, switching to linenless dining may have had less of an impact. The team recommends that Faculty House continues to promote their linen-less dining options as these have proven to have substantial impacts.

If the goal for Faculty House is to have an impact which can be measured across time, the team recommends that Faculty House switch vendors to one which has transparency. This will not only decrease the environmental impact of linens through its value chain but will also lead to cost savings. Throughout this process, the team developed a GHG accounting framework that Faculty House can use when selecting a new linen vendor. The team hopes that this framework can be applied Columbia-wide in order to help the University achieve its sustainability goals

A Centralized Columbia

A major challenge faced throughout this project was access to data. The lack of more robust data hindered the ability to perform more thorough analyses. For instance, had the team been able to access and obtain food procurement invoices in both a more timely fashion and usable format, a more thorough analysis of GHG emissions related to food procurement could have been accomplished during the time frame of this project. Columbia University cannot analyze and manage what it does not properly track. If the University at large wants to better track environmental performances regarding operations, it needs to implement campus-wide data collection and sharing mechanisms.

More comprehensive university-wide data collection and sharing mechanisms will require a top-down approach that begins with one entity, possibly the Office of Environmental Stewardship, establishing clear guidelines for data collection for various operations. The recommendations set forth in this report help support Columbia University Stewardship in determining these guidelines and standards for data necessary to better analyze associated environmental impacts.

The implementation of the more comprehensive data collection and sharing processes will necessitate clearer communication and more collaborative engagement overall among University entities. Workshops and training will need to be held for parties responsible for the data collection and sharing. Not only will the entities directly working on the data collection processes need to be trained, but the efforts will need to be communicated to all parties involved with University operations, from those establishing the goals to those on the ground doing work to help achieve those goals.

Figure 29: Recommendations for a Centralized Columbia

Conclusion

The main goals of this project were to assess improvements in environmental performance to date and develop operation tools and processes that equip Columbia University's Faculty House in advancing its leadership in sustainability. Through advancing sustainability at Faculty House, a premier public-facing venue, Columbia University will be able to showcase its commitments to sustainability to both the University community and the broader community in which the University operates. Further, advancing sustainability at Faculty House will help in achieving the goals set forth in the University's campus-wide sustainability plan, *Sustainable Columbia*.

This report provides step-by-step guidance for better understanding and then improving energy efficiency and sustainable operations of Faculty House. The report is also accompanied with various tools, which the clients can utilize moving forward to better track performances around energy efficiency and operations. Specifically, the team has equipped the clients with tools to be able to:

1. Conduct a full-building lighting audit
2. Conduct a building occupancy survey
3. Complete GHG inventories for
   - 3.1. Electricity consumption
   - 3.2. Food menus served
   - 3.3. Linen procurement

Each project component (Lighting, Best Practices, Food, and Linens) analysis and results are followed by a series of recommendations for further improving sustainability leadership in those areas. Recommendations and resources for implementing them include but are not limited to upgrading to LEDs, reducing animal-based ingredients in menus, and setting standards for linen procurement using the TRSA certification as a screening. The tools and recommendations should prove useful to the University as it establishes its next sustainability plan, which is expected to launch April of 2021. It is critical that the University establish more comprehensive campus-wide data collection and sharing mechanisms in order to be able to track these efforts and improvements, as they will be contributing to the goals of *Sustainable Columbia* as well as Columbia University's broader efforts to be a leader in its community in the face of climate change.

References

- "Adjusting Lighting Levels in Commercial Buildings." Summary of Findings From a Field Study, Seventhwave,2015. https://www.seventhwave.org/tasktuning
- "Benefits of RETM." Real Time Energy Management (RETM) Program, NYSERDA, https://www.nyserda.ny.gov/All-Programs/Programs/Real-Time-Energy-Management/Customer
- "Faculty House Awarded LEED Gold". Columbia University, 2010.
- "Learn about Brightness." Energy Efficiency Products, Environmental Protection Agency, https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_brightness.
- "Lighting Efficiency Input Wattage Guide." Xcel Energy, Xcel Energy, 2013, https://www.xcelenergy.com/staticfiles/xe/Marketing/MN-Bus-Lighting-Input-Wattage-Guide.pdf
- "Toxics Release Inventory (TRI) Program." EPA, Environmental Protection Agency, 11 Dec. 2019, https://www.epa.gov/toxics-release-inventory-tri-program.
- "What are the Connections between Mercury and CFLs?" Compact Fluorescent Light Bulbs, Environmental Protection Agency, https://www.epa.gov/cfl/what-are-connections-between-mercury-and-cfls
- Amanda Moore. "Energy-efficient design. MIT researchers are helping architects optimize both design and energy efficiency." SA+P. January 23, 2017
- Amiri, Ali; Ottelin, Juudit; Sorvari, Jaana. "Are LEED-Certified Buildings Energy-Efficient in Practice?" Sustainability, 2019.
- Ankush Nikam "Demand for Air Curtains Market Research Driven by Shifting Consumer Perceptions and Growing Awareness". A Rapid News Network. September 19, 2019
- Ball, Jeffrey. "Six Products, Six Carbon Footprints." The Wall Street Journal, Dow Jones & Company, 7 Oct. 2008, https://www.wsj.com/articles/SB122304950601802565.
- Bell, Lorne. "DESIGNING FOR HUMAN HEALTH IS THE NEXT FRONTIER IN SUSTAINABLE BUILDING". 2018, http://plus.usgbc.org/designing-for-human-health-is-the-next-frontier-in-sustainable-building/.
- Cerutti, Alessandro K., et al. "Modelling, Assessing, and Ranking Public Procurement Options for a Climate-Friendly Catering Service." The International Journal of Life Cycle Assessment, vol. 23, no. 1, 2017, pp. 95–115., doi:10.1007/s11367-017-1306-y.
- Clark Howard, Brian. "5 Surprising Ways Buildings Can Improve Our Health". 2017, https://www.nationalgeographic.com/environment/urban-expeditions/green-buildings/surprising-ways-green-buildings-improve-health-sustainability/
- Columbia University Office of Work/Life, "Healthier Columbia Food and Beverage Initiative". 2019. Accessed on Dec, 2019. https://worklife.columbia.edu/healthier-columbia
- Dutton, John A. "Energy Required for Water Heating." Energy Required for Water Heating | EGEE 102: Energy Conservation and Environmental Protection, Pennstate University ., https://www.e-education.psu.edu/egee102/node/2003.
- EAT-Lancet Commission. "Summary Report: Healthy Diets From Sustainable Food Systems". pp 1-34. 2019. Accessed on Nov, 2019. www.thelancet.com/commissions/EAT.
- EPA, U.S. Environmental Protection Agency. "Reducing the Impact of Wasted Food by Feeding the Soil and Composting". November 18th, 2019. Accessed on Nov, 2019. https://www.epa.gov/sustainable-management-food/reducing-impact-wasted-food-feeding-soil-and-composting
- EPA, U.S. Environmental Protection Agency. "Sustainable Management of Food: Food Recovery Hierarchy". November 18th, 2019. Accessed on Nov, 2019. https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy
- EPA, U.S. Environmental Protection Agency. "Sustainable Management of Food: Industrial Uses For Wasted Food". November 18th, 2019. Accessed on Nov, 2019. https://www.epa.gov/sustainable-management-food/industrial-uses-wasted-food#AD
- EPA. "Basic Information of Air Emissions Factors and Quantification." EPA, Environmental Protection Agency, 25 July 2019, www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification.
- EPA. "Find and Compare Cars." Www.fueleconomy.gov - the Official Government Source for Fuel Economy Information, EPA, https://www.fueleconomy.gov/feg/noframes/34366.shtml.
- EPA. "Technical Support Document Air Quality Construction Permit ." EPA, EPA, Feb. 2014, https://www.epa.gov/sites/production/files/2015-07/documents/gk49-revised-draft-tsd-20150716-23pp.pdf.

- EWG. Meat Eater's Guide to Climate Change and Health: Lifecycle Assessments: Methodology and Results. Environmental Working Group, 2011, Meat Eater's Guide to Climate Change and Health: Lifecycle Assessments: Methodology and Results.
- Fundamental Air Quality". WELL V2™ Pilot, https://v2.wellcertified.com/v/en/air/feature/3.
- Gilbert, John. Class Lecture. Nov 20, 2019.
- Graulich , et al. Preparatory Studies for Eco-Design Requirements of Energy-Using Products Lot 24: Professional Washing Machines, Dryers and Dishwashers. Öko-Institut E.V. Institute for Applied Ecology, BIO Intelligence Service, May 2011, https://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Working_Documents/EuP_Lot24_Wash_T4_Report_ENER_clean_01.pdf.
- Johnson, M. Alex. “Shining a light on hazards of fluorescent bulbs”, NBC News, Apr 7, 2008. http://www.nbcnews.com/id/23694819/print/1/displaymode/1098/40824086
- Kerby Lecka, “Low Energy Automatic Door Openers for Ada Compliance”. DOORS + HARDWARE, 14 JANUARY 2017.
- King, Jennifer and Perry, Christopher. Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings, American Council for an Energy-Efficiency Economy, 2017
- L. Wang, “Investigation of the Impact of Building Entrance Air Curtain on Whole Building Energy Use Short Summary”. Air Curtain Study. Undated.
- Leverette, Mary Marlowe. “Hot, Warm, or Cold Water for Laundry?” The Spruce, The Spruce, 15 July 2019, https://www.thespruce.com/wash-with-the-right-water-temperature-2146348.
- Lighting The Way Upgrading Lighting Systems For Commercial Offices. Building Energy Exchange, 2017.
- Lopes, Catia, et al. “Analysis of Sustainability in Hospital Laundry: The Social, Environmental, and Economic (Cost) Risks.” Resources, vol. 8, no. 1, 2019, p. 37., doi:10.3390/resources8010037.
- Martin, Melanie J. “The Effects of Laundromats on the Environment.” Home Guides | SF Gate, 7 Oct. 2016, https://homeguides.sfgate.com/effects-laundromats-environment-78883.html.
- Mills, Evan; Bourassa, Norman; Piette, Mary Ann; Friedman, Hannah; Hassl, Tudi; Powell, Tehesia; Claridge, David. “The Cost-Effectiveness of Commissioning New and Existing Commercial Buildings: Lessons from 224 Buildings.” National Conference on Building Commissioning: May 4-6, 2005, 2005
- MotorTrend. “2014 Nissan NV1500 Reviews - Research NV1500 Prices & Specs.” MotorTrend, Motor Trend, 14 June 2019, https://www.motortrend.com/cars/nissan/nv1500/2014/.
- Nantum Building Operating System. Prescriptive Data. https://www.prescriptivedata.io/nantum-building-operating-system
- Natural Resources Defense Council. “Food Waste”. Accessed on Nov, 2019. https://www.nrdc.org/issues/food-waste
- Playbook for Sustainably Healthy Workplaces. 2018, Sustainability Roundtable, Inc., 2018, http://www.sustainround.com/library/sites/default/files/SR%20Inc_Playbook%20for%20Sustainably%20Healthy%20Workplaces_4-3-18.pdf.
- Powell, Greg et al. Health And Wellness: The Next Disruption In Sustainable Building Design. Industry Focus. Powerful Results, 2017, https://www.fminet.com/wp-content/uploads/2017/12/7_HealthandWellness_FINAL.pdf. Accessed 6 Dec 2019.
- Ranganathan, Janet et al. World Resources Institute, “Shifting Diets for a Sustainable Food Future”. pp 5, 22-33, 53. April, 2016. Accessed on Nov, 2019. https://www.wri.org/publication/shifting-diets
- Rea, Mark Stanley, IESNA 9th Edition Handbook, Illuminating Engineering Society of North America, 2000.
- Schwartz, David M. “Group: 65 Products Test Positive for 1,4-Dioxane.” Newsday, Newsday, 27 Mar. 2019, https://www.newsday.com/long-island/environment/1-4-dioxane-household-products-1.28968339.
- Silveira, G.T., and S.Y. Chang. Fluorescent lamp recycling initiatives in the United States and a recycling proposal based on extended producer respon- sibility and product stewardship concepts. Waste Manage. 2011.
- Somerville, Brenden. “SCR Systems - All You Need to Know about the SCR System in Your Hino Truck.” Somerville Hino, 15 June 2015, https://www.somervillehino.com/hino-blog/2015/06/15/scr-systems-all-you-need-to-know-about-scr-systems-in-your-hino-truck.
- US EPA. “Air Pollution Control Technology Fact Sheet .” US EPA, https://www3.epa.gov/ttncatc1/dir1/fscr.pdf.
- USDA, United States Department of Agriculture. “Food Waste FAQs”. 2019. Accessed on Nov, 2019. https://www.usda.gov/foodwaste/faqs
- What We Measure | Center for The Built Environment". Center For The Built Environment, https://cbe.berkeley.edu/resources/occupant-survey/what-we-measure/.

Appendices

Tools & Templates

Energy - Lighting
- Audit Form 2019 – Filled
- Audit Form – Blank
- GHG Template
- LED Financial Analysis Tools
- LED Retrofit Analysis – Cost, Energy Use and GHGs

Energy - Building Occupancy Survey
- Building Occupancy Survey
- Occupancy Survey Scorecard - Filled
- Occupancy Survey Scorecard - Blank

Sustainable Operations – Food
- Carbon Impact Analysis Calculations – Filled
- Carbon Impact Analysis Calculations – Blank
- Food Loss Inventory Template – Example
- Food Loss Inventory Template - Blank

Sustainable Operations – Linens
- GHG Inventory for Linens - Filled
- GHG Inventory for Linens - Blank