THE UNIVERSITY OF CHICAGO

Greenhouse Gas Emissions Reduction Plan

FY2022 TO FY2030

APRIL 2022

THE UNIVERSITY OF CHICAGO | Office of Sustainability

Sustainability.UChicago.edu

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Executive Summary

The University of Chicago is committed to reducing emissions and creating a sustainable campus. To support this commitment, the University has established a goal to reduce its scope 1 and 2 absolute greenhouse gas (GHG) emissions by 50% by fiscal year 2030 (FY2030) from its target base year (average of emissions FY2012-2014). **This reduction goal replaces the 20% by 2025 GHG carbon intensity reduction goal supported by the 2018 GHG Emission Reduction Plan**.

To meet the 2030 goal, the University must reduce scope 1 and 2 GHG emissions. GHG emissions inventory data was collected for fiscal years 2009 through 2021 and can be reviewed in the 2021 **greenhouse gas emissions inventory report**.

Since natural gas and electricity consumed in campus buildings contribute to more than 70% of the University's GHG emissions, building energy efficiency is the focus of this emissions reduction plan. While the focus is to reduce scope 1 and scope 2 emissions, the University also assessed opportunities for scope 3 GHG emissions reductions related to waste and travel, as well as how best to engage the entire campus and broader community in sustainability.

Since natural gas and electricity consumed in campus buildings contribute to more than 70% of the University's GHG emissions, building energy efficiency is the focus of this emissions reduction plan.

UChicago and the City of Chicago from Rockefeller Tower | Tom Rossiter

After analyzing the GHG emissions inventory and other information about the campus and its energy use, including campus growth potential, existing building equipment and previously completed energy efficiency projects, the University of Chicago will pursue a comprehensive plan to reduce GHG emissions from new construction and major renovations, existing buildings, and fleet vehicles, while procuring renewable electricity from onsite and off-site sources to achieve the 2030 goal.

TABLE 1. RECOMMENDED INITIATIVES FOR ACHIEVING THE 50% BY 2030 GOAL

Opportunity	Description	GHG Emissions Reduction Contributions
Energy Conservation Measures (ECMs)	Energy conservation measures such as retro-commissioning, lab optimization, LED lighting and HVAC	49%
Distributed Energy Resources (DER)	Onsite renewable and electrification opportunities like solar photovoltaic (PV) panels and heat recovery chillers	4%
Fleet Electrification	60% conversion of University vehicles to electric or hybrid vehicles	<1%
Off-site Renewable Energy	Virtual power purchase agreement (VPPA) to purchase electricity from off-site wind or solar power	47%
	Total	**100%**

GREENHOUSE GAS EMISSIONS AND REDUCTION TARGET

Main Quadrangle | Jean Lachat

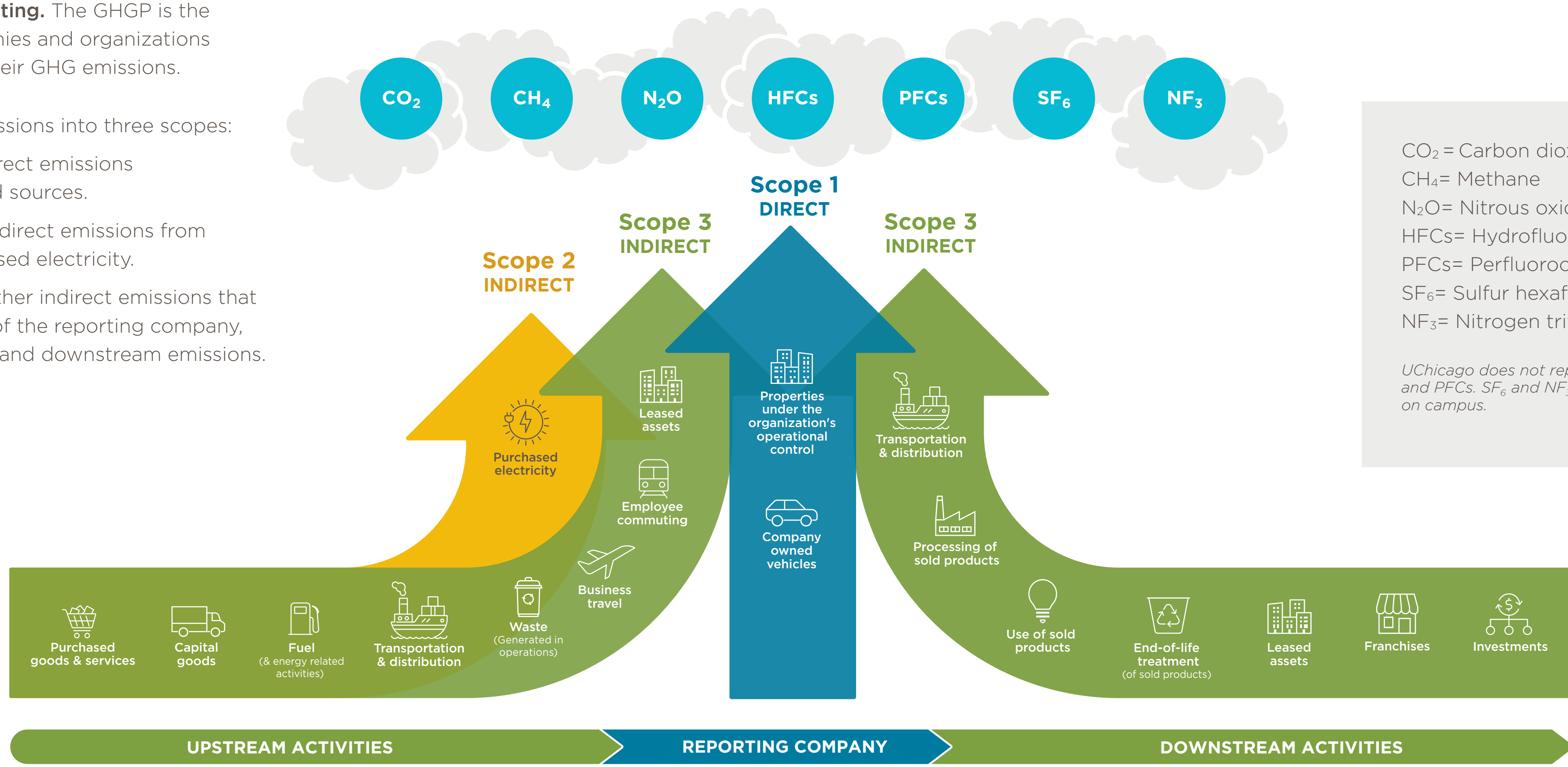
Introduction to the Greenhouse Gas Protocol

The University of Chicago uses the Greehhouse gas protocol (GHGP) as a a reference standard for its GHG accounting and reporting. The GHGP is the global standard for companies and organizations to calculate and manage their GHG emissions.

The GHGP categorizes emissions into three scopes:

- **Scope 1 emissions** are direct emissions from owned or controlled sources.
- **Scope 2 emissions** are indirect emissions from the generation of purchased electricity.
- **Scope 3 emissions** are other indirect emissions that occur in the value chain of the reporting company, including both upstream and downstream emissions.

FIGURE 1. GREENHOUSE GAS PROTOCOL, CORPORATE VALUE CHAIN (SCOPE 3) ACCOUNTING AND REPORTING STANDARD



Source (page 5): **WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard** (PDF)

CO_2 = Carbon dioxide
CH_4= Methane
N_2O= Nitrous oxide
HFCs= Hydrofluorocarbons
PFCs= Perfluorocarbons
SF_6= Sulfur hexafluoride
NF_3= Nitrogen trifluoride

UChicago does not report on HFCs and PFCs. SF_6 and NF_3 do not exist on campus.

The University of Chicago's GHG Emissions to Date

The following charts summarize the University of Chicago's GHG emissions to date. The full Greenhouse Gas Emissions Inventory Report for 2012–2021 can be **viewed here** for further details. From the baseline year of FY2012–2014 to FY2021, campus square footage increased by 15% while absolute scope 1 and 2 GHG emissions decreased by 2.3%. The University offset 10,000 MT eCO_2 through a partnership with Climate Vault in FY2021, resulting in a net 10% reduction in absolute scope 1 and 2 GHG emissions.

FIGURE 2. ABSOLUTE GREENHOUSE GAS EMISSIONS BY SCOPE AND FISCAL YEAR

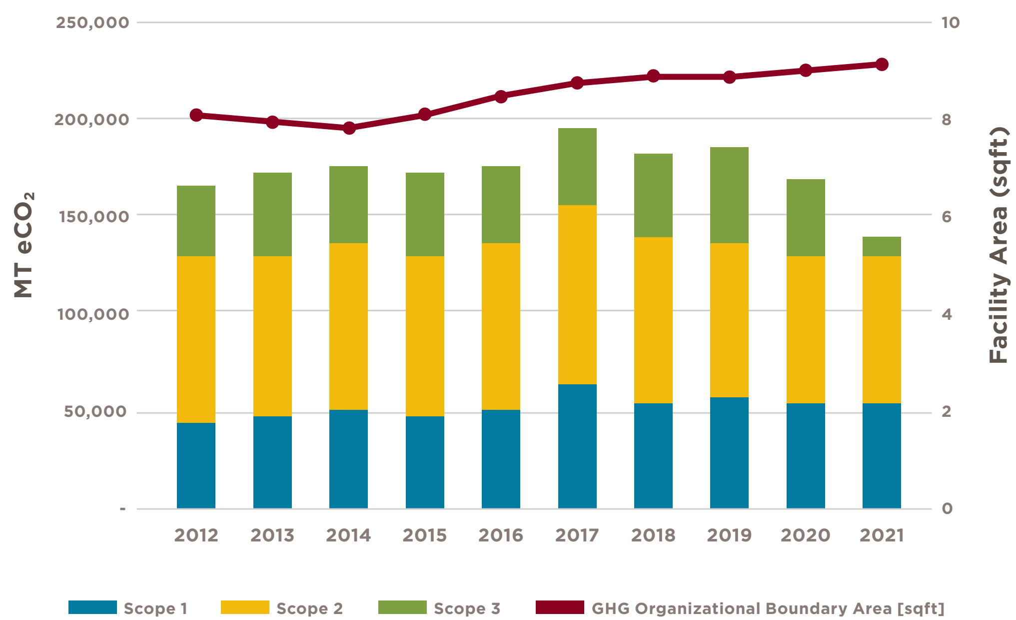
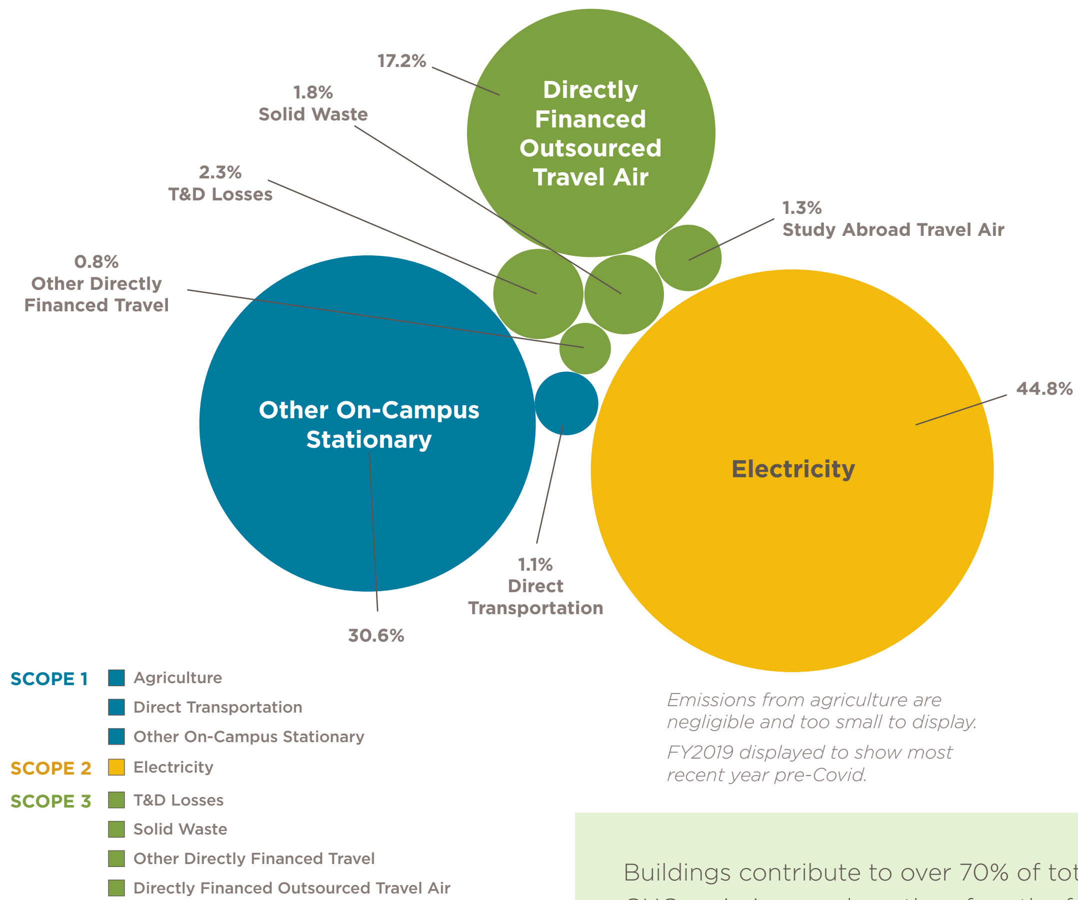


Figure does not include impact to carbon offsets

FIGURE 3. ABSOLUTE GREENHOUSE GAS EMISSIONS BY SOURCE FY2019



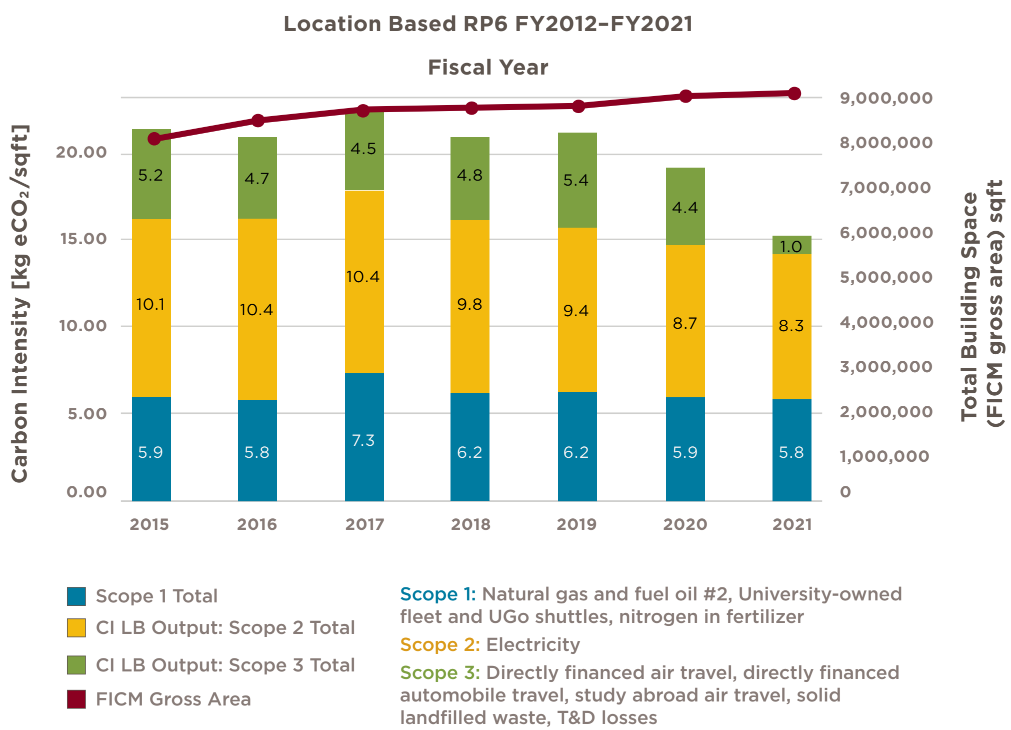
Emissions from agriculture are negligible and too small to display.

FY2019 displayed to show most recent year pre-Covid.

Buildings contribute to over 70% of total GHG emissions and are therefore the focus of the GHG emissions reduction plan.

The University of Chicago's Greenhouse Gas Emissions Reduction Goal

FIGURE 4. CARBON INTENSITY BY SCOPE AND FISCAL YEAR [kg eCO_2/sqft]



The University of Chicago's 2030 goal calls for a 50% reduction of scope 1 and 2 absolute emissions compared to the target base year, where the target base year is the average GHG emissions from fiscal years 2012, 2013, and 2014.

This raises the ambition over its previous goal of reducing carbon intensity by 20% by 2025.

The University saw a 13% reduction in carbon intensity from the target base year to FY2019, leading to consideration of a more aggressive GHG emissions reduction goal. The University's new goal to achieve a 50% reduction in absolute greenhouse gas emissions across all University operations by 2030 expands both the magnitude and scope of the original goal. Changing the goal from carbon intensity to absolute emissions will make the University a better steward of the environment and will lead to a greater impact on climate change.

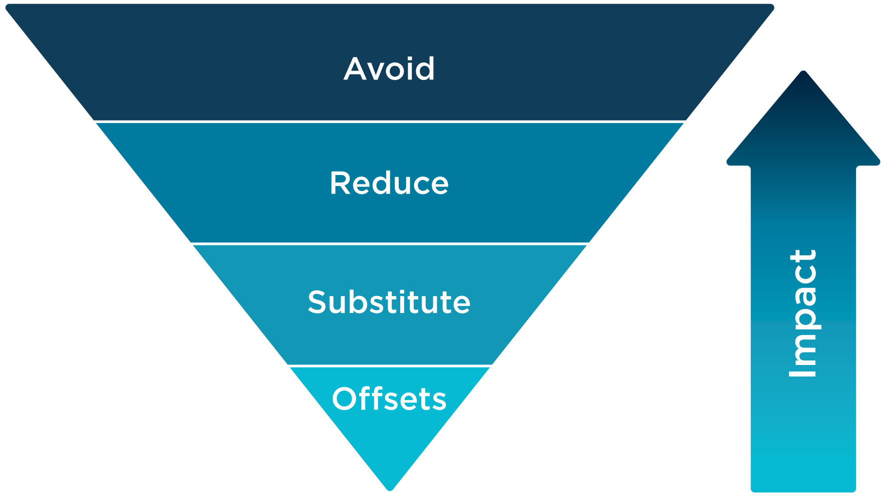
The organizational boundary includes everything within operational control. This includes every building but excludes the medical campus and third-party owned and operated buildings.

General Approaches to Reducing Greenhouse Gas Emissions

Achieving the 2030 goal requires action and collaboration across all areas of the University. The general strategy for reducing emissions is to **avoid**, **reduce**, **substitute** and **offset**, in that order.

Keller Center East Garden | Tom Rossiter

FIGURE 5. GREENHOUSE GAS EMISSIONS MITIGATION HIERARCHY



Pathways to Achieving Goals:

- **Avoid** future emissions by focusing on energy efficient design of new buildings
- **Reduce** on-campus energy consumption
- **Substitute** electricity emissions (scope 2) with renewable energy and gasoline/diesel fueled fleet with electric/hybrid conversion
- **Offset** emissions using carbon emission permits from Climate Vault, as one option
- **Develop** teams to focus on scope 3 awareness and goal creation

GHG EMISSIONS REDUCTION PLANNING PROCESS

Neubauer Collegium for Culture and Society | Tom Rossiter

GHG Emissions Reduction Planning Process

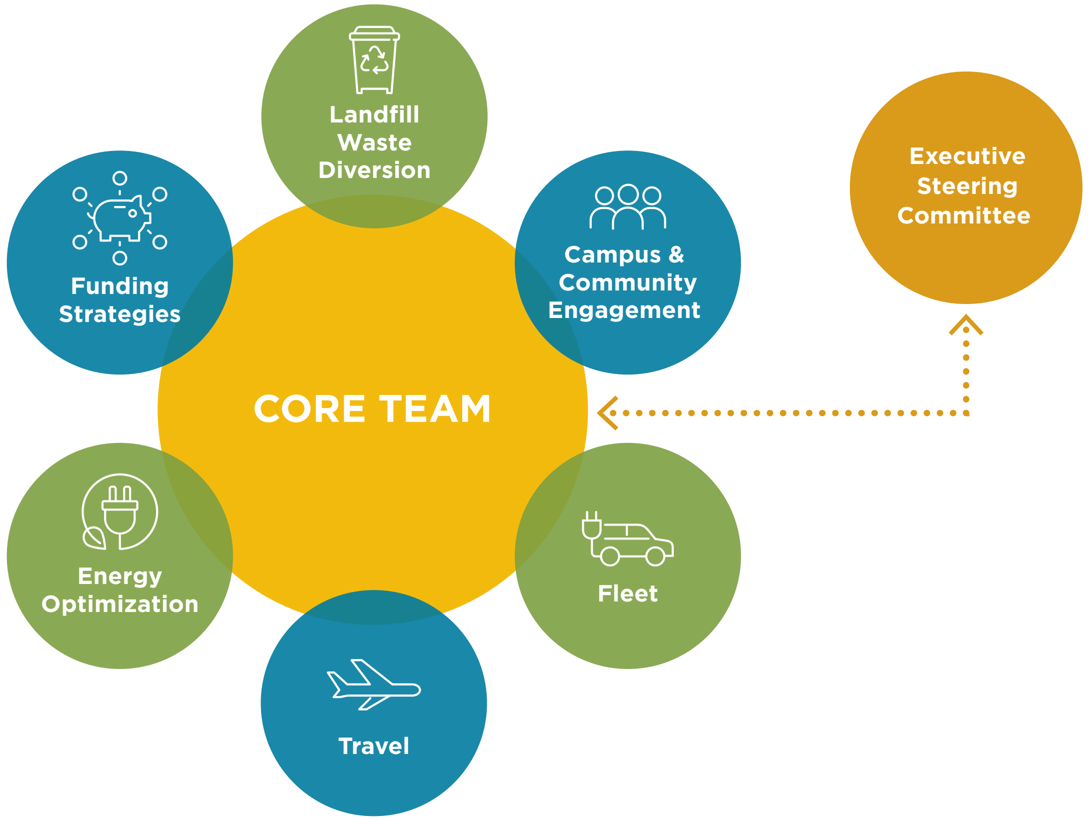
The University of Chicago targeted six areas to achieve GHG emissions reductions and make an impact:

- **Energy optimization**
- **Business travel**
- **Fleet**
- **Campus and community engagement**
- **Landfill waste diversion**
- **Funding strategies**

Six working groups, led by subject matter experts and one to two University of Chicago staff member co-chairs for each group, had focused knowledge-sharing discussions.

The six working group co-chairs and several other strategic partners made up a cross-functional core team that directed the overall process and assured deliverables aligned with the University's goals. Once recommendations were approved by the core team, they were reviewed with an executive steering committee made up of Facilities Services senior leadership and representatives from the Office of the Provost. Input from these teams informed the 2030 GHG Emissions Reduction Plan.

FIGURE 6. CROSS-DISCIPLINARY CORE TEAM STRUCTURE ACROSS UCHICAGO CONSTITUENTS



Searle Chemistry Laboratory | Anton Grassl

Center for Care and Discovery | Tom Rossiter

Educational Workshops

UChicago hosted seven educational workshops with subject matter experts presenting topics similar to each of the working groups. The workshops not only provided insights on GHG reduction best practices and considerations, but also a collaborative forum to discuss ideas.

Workshop Topics:

1. **Energy Program Operations:** Exploring how organizational structures and goals can achieve energy optimization, as well as a look into low cost, no-cost and behavioral energy optimization opportunities
2. **Landfill Waste Diversion:** Best practices for higher education
3. **Funding Mechanisms:** Traditional and creative financing options for high-impact, high-capital projects
4. **Fleet, Travel and Commuting:** Opportunities for GHG emissions reductions and current best practices
5. **Sustainability:** Deep dive on GHGP defined scope 1, 2, and 3 emissions across value chain and best practices for higher education
6. **Onsite Generation and Distributed Energy Resources:** Onsite GHG emissions reduction opportunities such as solar photovoltaics (PV), and options for electrification
7. **Energy Efficiency and Capital Projects:** Energy efficiency measures such as LED lighting, laboratory optimization, HVAC upgrades, and building envelope

SWOT Analysis

Near the beginning of the engagement, each working group completed a strength, weakness, opportunity, threat (SWOT) analysis. The SWOT analysis review allowed for discussion on what has and has not worked to date with the current 2025 GHG Emissions Reduction Plan.

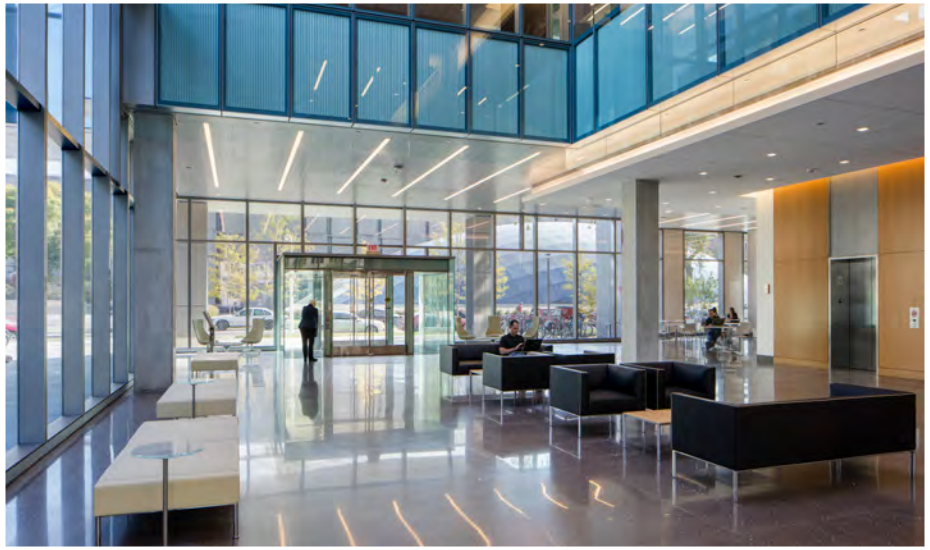
Campus Effects Matrix

For each on-campus energy efficiency and renewable energy measure, the University considered impacts beyond economics and GHG emissions reduction. A score was given for criteria such as safety, occupant comfort, campus disruption, resiliency, and operation and maintenance impacts.

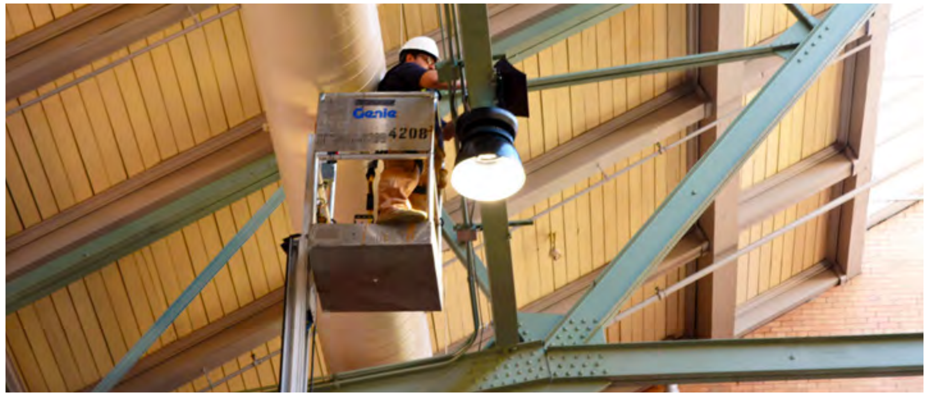
IMPLEMENTATION PLAN, FY2022 TO FY2030

Keller Center | Tom Rossiter

The 50% GHG Emission Reduction Plan



William Eckhardt Research Center | Tom Rossiter



Bartlett Dining Commons

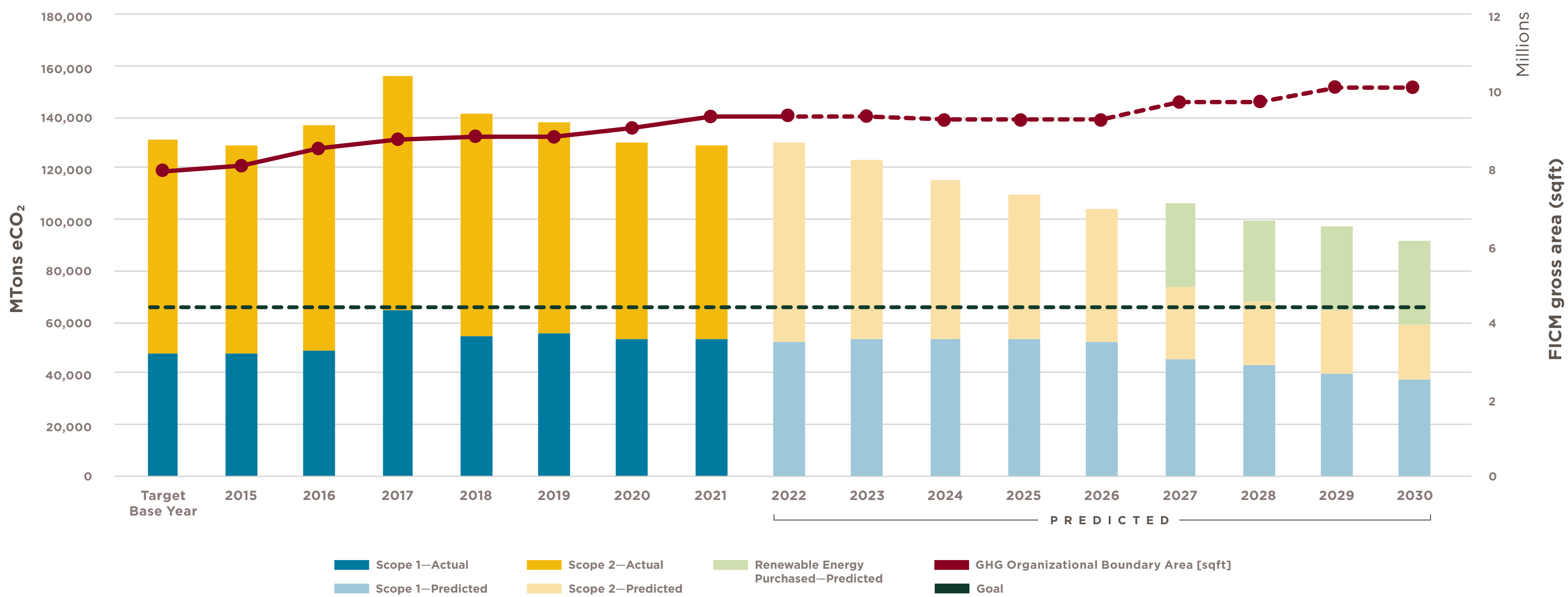
The 50% GHG emission reduction plan focuses on onsite best practice energy optimization opportunities with the best payback, and expands on previously implemented energy management programs and energy saving retrofits. This plan also includes heat recovery chillers at two buildings as a pilot for elecrification of space heating for the campus. On-campus opportunities will make up an estimated 27% GHG emissions reduction by FY2030, so renewable energy procurement via a virtual power purchase agreement (VPPA) will support the remaining 24%.

Strategy

- **Increase the scope and scale** of cost-effective onsite energy optimizations to reduce electricity and natural gas consumption
- **Complete capital energy efficiency measures** including HVAC upgrades, building automation system modernization and potential building electrification strategies
- **Pursue onsite solar** where feasible
- **Invest in fleet electrification** to reduce gasoline use for on-campus vehicles by FY2030
- **Procure renewable energy** via a VPPA

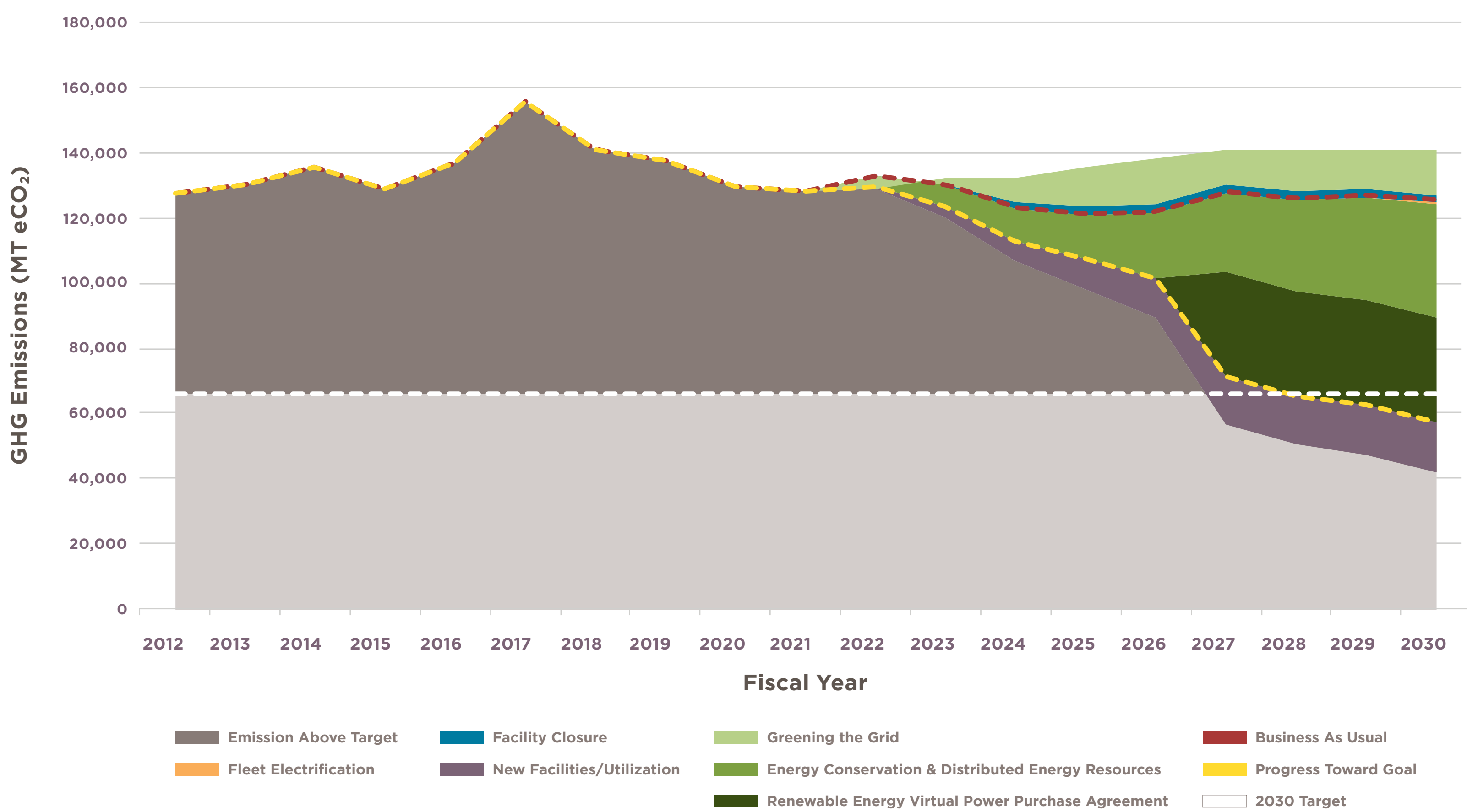
Figure 7 visualizes how UChicago will achieve the 50% reduction by 2030 goal

FIGURE 7. ANNUAL SCOPE 1 & 2 GREENHOUSE GAS EMISSIONS: ACTUAL AND PREDICTED



Plan Overview—Achieving 50% by 2030

FIGURE 8. 50% SCOPE 1 & 2 EMISSIONS REDUCTION PLAN OVERVIEW



This chart shows how each respective pathway will combine to achieve the University's 50% emissions reduction goal. "Business as Usual" is the red line reflecting if the University made no GHG reduction efforts and where emissions would be in FY2030. The yellow line models progress toward the FY2030 goal annually as the plan is executed.

EMISSIONS REDUCTION STRATEGIES—SCOPES 1 AND 2

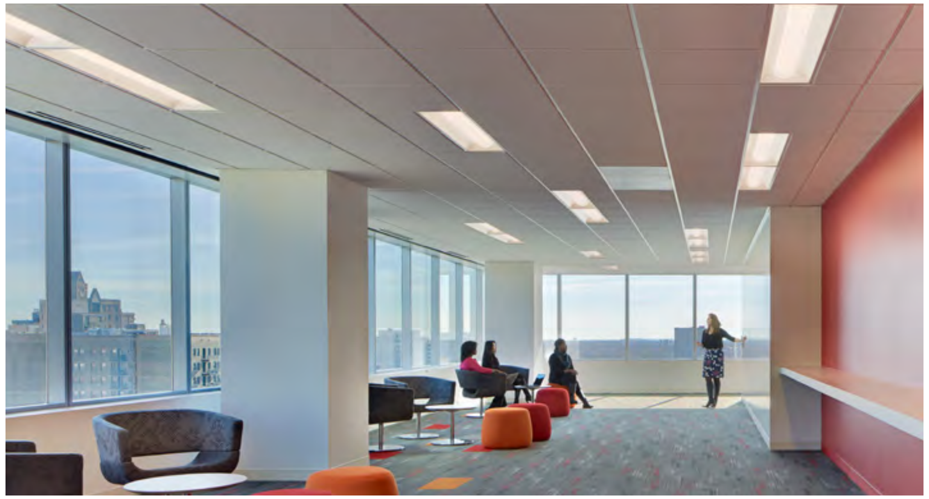
Keller Center | Tom Rossiter

Energy Program Opportunities

Energy program opportunities are ongoing efforts using software, equipment, and team structures to maintain and drive efficient operation of building systems.

In addition to GHG emissions reductions, these programs improve comfort for students, faculty, and staff while helping to increase the useful life of equipment. These benefits are realized via resolving air infiltration, and increased monitoring of comfort and functional parameters, allowing for proactive identification and correction of issues.

- **Retro-Commissioning plus Continuous Commissioning (RCx + CCx)**
- **Lab optimization**
- **Compressed Air Leak Program**
- **Plug Load Management Program**
- **Building weatherization**



5235 South Haper Court
Christopher Barrett Photography

Student Wellness Center | Kendall McCaugherty © Hall+Merrick Photographers

Capital Energy Efficiency Measures

LED lighting uses less than half the energy of older lighting technologies and has a longer useful life

The following measures are upgrades to University of Chicago mechanical controls and electrical systems that are larger in scope. These investments will make substantial improvements to energy efficiency and system reliability on campus for many years to come.

- **LED lighting**
- **HVAC Variable Air Volume Conversions**
- **HVAC controls upgrades**
- **Central Utility System improvements**

The capital measures targeted will modernize key aspects of the campus's infrastructure, leveraging the significant technology advancements in lighting and HVAC for both energy and operational improvements.

LED lighting uses less than half the energy of older lighting technologies and has a longer useful life; this measure expands the use of LED lighting on campus from a few discrete buildings to campus wide, interior and exterior. Aging Heating, Ventilation, and Air Conditioning (HVAC) systems, which use outdated controllers and are not equipped with a means to vary their output based on loads, are both wasteful and can affect occupant comfort. These measures upgrade these systems, providing energy, maintenance, and thermal comfort improvements. Additional opportunities to improve central utility plant efficiency will be pursued.

Neubauer Collegium for Culture and Society | Tom Rossiter

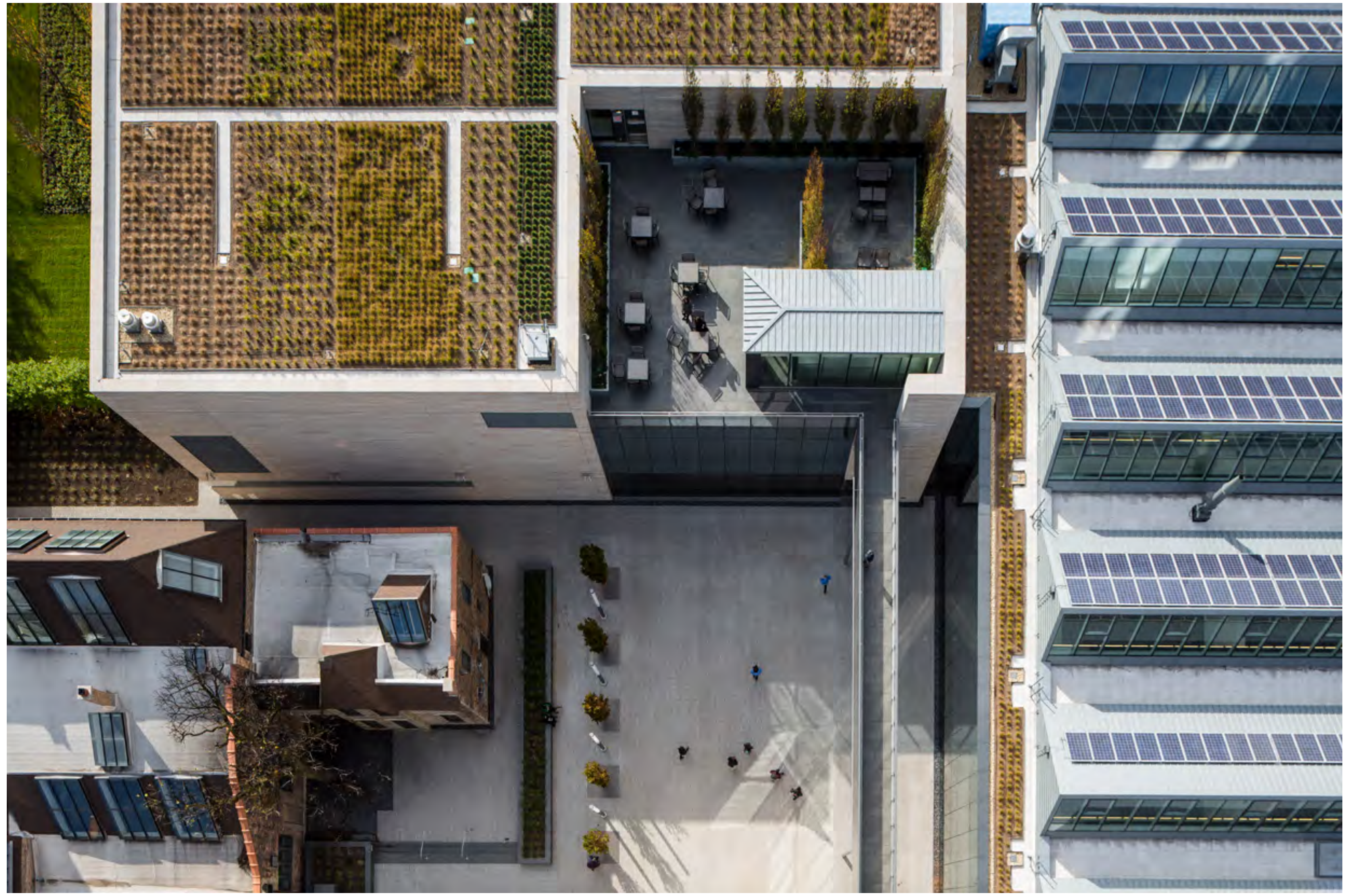
Searle Chemistry Laboratory | Anton Grassl

Neubauer Collegium for Culture and Society | Tom Rossiter

Distributed Energy Resources

Distributed Energy Resources are a classification of technologies that generate or store energy that are not centrally located but rather installed directly where the energy is needed.

This section identifies opportunities to install solar PV panels to renewably generate electricity on campus.



Logan Center Facilities | Tom Rossiter

Renewable Energy Procurement

The University of Chicago is actively exploring options to procure renewable energy to offset its scope 2 emissions associated with purchased electricity for campus operations, including large-scale solar and wind projects off-site.

Procuring renewable energy as a substitute for traditional power would reduce the University's scope 2 emissions and contribute to the 2030 reduction. Additionally, renewable energy options such as VPPAs, on-site solar, renewable energy certificates, and other procurement structures may be scaled further to achieve the current goal.

Carbon Offsets

In FY2021, the University of Chicago offset 10,000 metric tons of equivalent carbon dioxide (MT eCO_2). These 10,000 metric tons of carbon allowance permits were acquired and vaulted on the RGGI cap-and-trade market. UChicago purchases carbon permits from multiple cap-and-trade compliance markets and vaults them so emitters cannot use them. Because the number of permits is capped, this decreases the amount of global carbon dioxide pollution allowed by government regulators.

> **Carbon offsets are often considered a "bridge strategy" for organizations like the University of Chicago to support carbon reduction projects off-site while working toward decarbonizing emissions on campus.**

Campus North Residential Commons
Steve Hall © Hedrich Blessing Photographers, Courtesy Studio Gang

Fleet Vehicle Planning

Scope 1: University Fleet and Direct Transportation

The University fleet is composed of cars, SUVs, passenger and work vans, pickup trucks, shuttle and other buses, and equipment for special tasks such as snowplowing and grounds work. Vehicles are located in many departments, including Department of Safety and Security, Facilities Services, and the many administrative and academic departments. Fleet-related emissions from University-owned vehicles and UGo shuttles represent 1% of the University's scope 1 emissions. **Though a small contributor to overall GHG emissions, campus vehicles have a high level of visibility**. Vehicles are a rolling billboard for organizational values, and fleet efficiency improvements can serve as an example for vehicle choices in the greater community.

Transitioning to a Low-Carbon Fleet Future

The fleet and commuting working group recommended several actions.

- Institute a procurement hierarchy—select electric, plug-in hybrid, or hybrid vehicles where viable
- Install additional electric vehicle (EV) charging stations
- Pilot anti-idling software for vehicles
- Plan for decarbonizing of UGo shuttles
- Join Chicago Clean Cities Coalition and monitor other EV and charging infrastructure grant funding opportunities

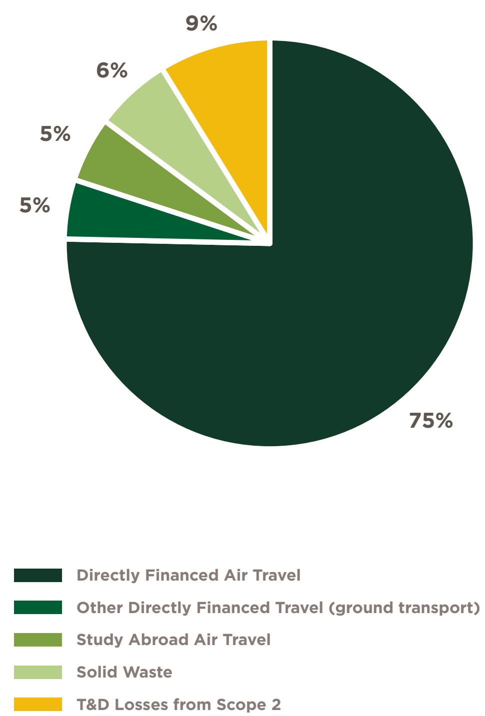
More information on **fleet vehicle planning found in the Appendix**.

STRATEGIC IMPLEMENTATION PLAN—SCOPE 3

Ratner Athletic Center | Tom Rossiter

Strategic Implementation Plan—Scope 3

FIGURE 9. SCOPE 3 EMISSIONS CONTRIBUTIONS (FY2019)



Scope 3 includes business air and automobile travel, study abroad air travel, solid waste, and transmission and distribution losses from scope 2 electricity.

Emissions from business air travel and from solid landfilled waste are of particular interest.

Business Air Travel

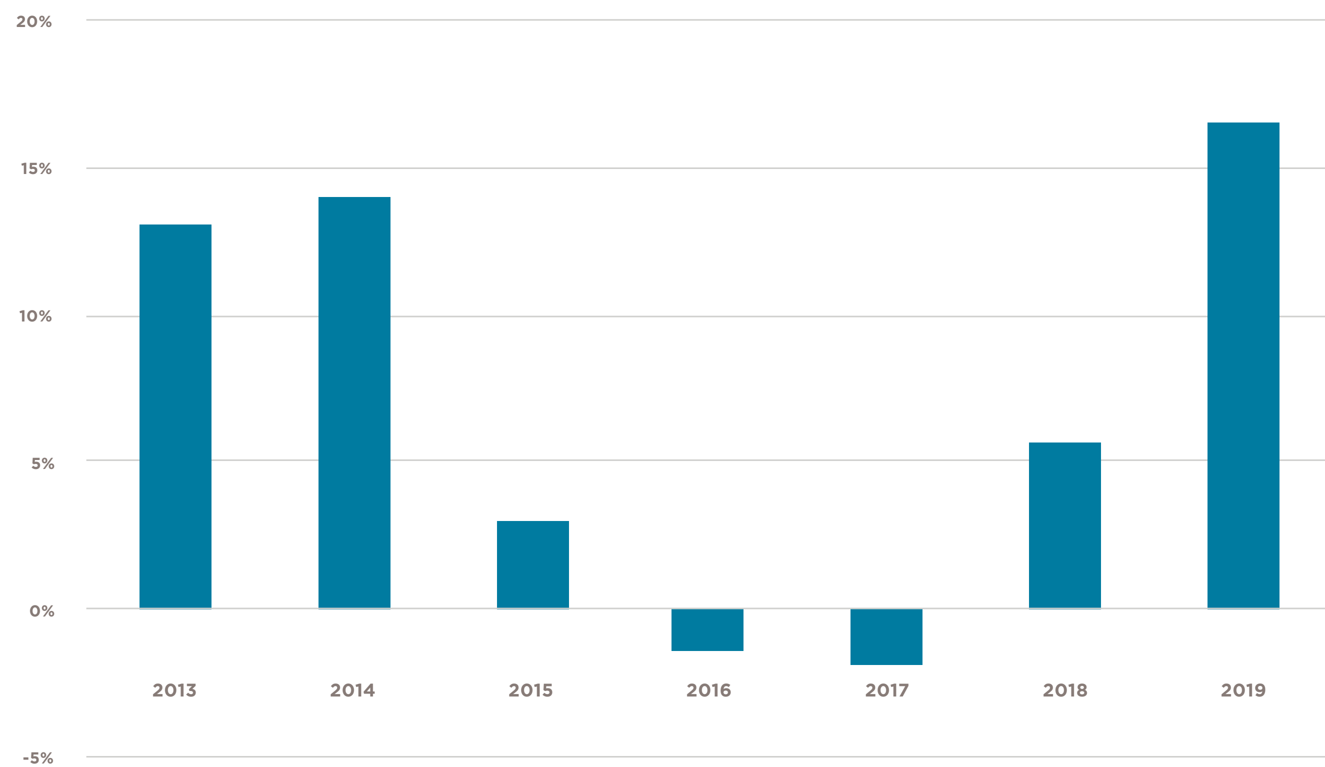
Business air travel represents a significant portion of the University's overall emissions at 20% in FY2019, pre-COVID-19.

The travel working group assessed best options for reducing GHG emissions from air travel. The working group is an inter-disciplinary team, including the Office of Sustainability, Central Procurement, the University of Chicago Booth School of Business, the Office of the Provost, Biological Sciences Division, and academic faculty members.

The recommended options are:

- Create and implement a pilot program on travel choices and GHG awareness with an amenable department
- Create an overall sustainability-led awareness campaign regarding the University air travel's contribution to overall GHG emissions
- Create and foster awareness around the benefits of booking trips through the University system
- Foster tele-conferencing modalities to defer travel
- Create a university-wide initiative for group travel related to conferences and other large meetings, with plans to incorporate a GHG awareness component

FIGURE 10. PERCENT CHANGE AIR TRAVEL EMISSIONS YEAR-OVER-YEAR



Direct travelled airline emissions have increased 57% from 2012 to 2019

Landfill Waste Diversion

The University of Chicago's current waste management practice includes **campus-wide single stream recycling, off-campus composting of landscape waste, and utilizing eco-digesters for food waste in campus dining halls**. Combined, these practices diverted approximately 40% of campus waste from the landfill in FY2019.

Given its universal creation, high visibility, and low scope 3 emissions footprint, landfill waste presents challenging dynamics that will require close collaboration, frequent assessment of programing, and informed involvement of students, faculty, staff, and vendors across campus.

Landfill Waste Diversion Pathways

Based on site visits at several University of Chicago facilities, waste management best practices and engagement with students, staff, and the waste vendor, over 20 landfill waste diversion recommendations were developed to foster impactful waste reduction and landfill diversion improvements.

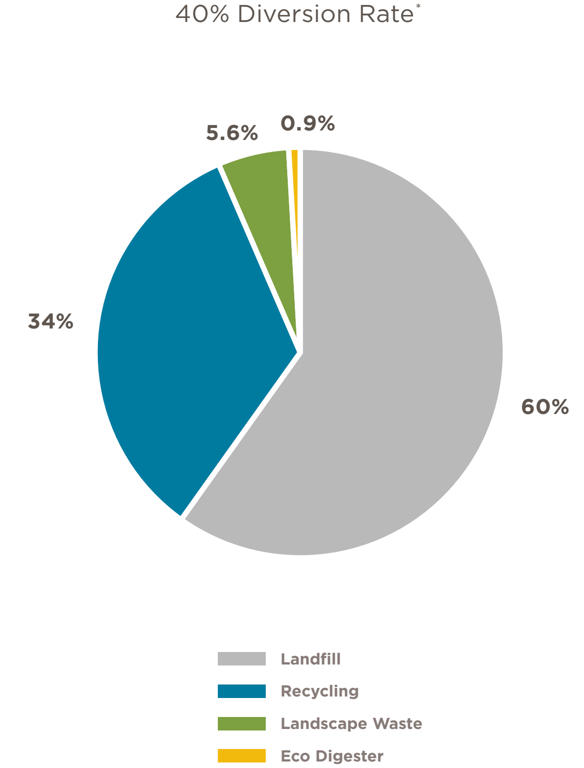
If all pathways identified are pursued, it is anticipated that 560 U.S. tons of landfill waste would be reduced, landfill waste GHG emissions would decline by 14%, and the campus waste diversion rate would increase from 40% to 55% from the target base year to FY2030.[1]

1 Consistent with the University's emission reporting, "target base year" reflects the average emissions footprint and diversion rate from fiscal years 2012, 2013 and 2014.

It should be noted that the potential reduction in GHG from all these recommendations is <1% from the target base years.

> **Diversion Rate: Accounts for the percentage of solid waste channeled away from the landfill via source reduction, reuse, recycling, or composting. Also known as landfill diversion rate and waste diversion rate, it is a key performance indicator that is typically tracked annually.** Per **EPA** and **AASHE**

FIGURE 11.
FY2019 CAMPUS WASTE FROM LANDFILL



CAMPUS AND COMMUNITY ENGAGEMENT

Terra Baer

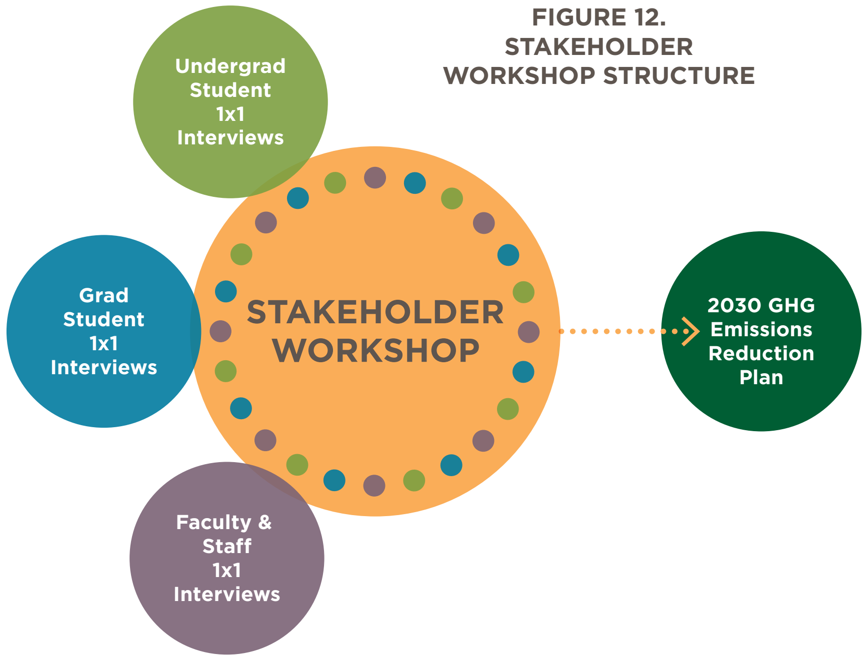
Campus and Community Engagement

Campus and community engagement increases awareness and enhances understanding of the importance of GHG emissions reduction, while shaping behaviors that can help with GHG emissions reductions. This engagement empowers stakeholders to have input on plans that affect their surroundings.

> **When stakeholders contribute to the discussion and the decision-making process, a deeper, stronger, and more trusting relationship between the University of Chicago and its stakeholders is created.**

The team held one-on-one interviews with select students, faculty and staff, and a workshop with a broader group of stakeholders to capture insights and opinions related to the 2030 GHG Emissions Reduction Plan. The aim of the exchange was to ensure the thoughts of the campus and community were considered during development of the GHG emissions reduction plan.

FIGURE 12.
STAKEHOLDER WORKSHOP STRUCTURE



Next Steps

A high-level overview of proposed next steps from engaging stakeholders through enhancing communications is outlined below. A detailed outline of each element has been **provided in the Appendix**.

Engaging Stakeholders

- Student Body
- Faculty
- Staff
- Alumni
- Vendors
- Hyde Park Community

Information Transparency

- Marketing of public sustainability dashboards
- Proactive training
- Crowd source future improvements

Leveraging University Work

- UChicago ECo
- EPIC
- Faculty Committee on Climate and Energy
- Research and innovation

Enhancing Communications

- Social media
- In-Person plan
- Coordinating with other key communication channels

ACKNOWLEDGEMENTS

Acknowledgements

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APPENDICES

Saieh Hall for Economics | Tom Rossiter

Appendix A: Past and Present Energy Conservation Efforts

FY2010 to FY2017

The University of Chicago implemented more than 155 energy efficiency projects to reduce GHG emissions through facilities energy savings from FY2010 to FY2017. Emissions reduction strategies included, but were not limited to:

- Pursuing United States Green Building Council Leadership in Energy and Environmental Design (LEED) certification of the facilities (new construction, major renovations). Fifteen buildings on the University of Chicago campus achieved LEED certification during this period.
- Retro-commissioning of buildings.
- Piloting continuous commissioning projects.
- Performing infrastructure improvements, including central plant upgrades.
- Completing lighting upgrades, including installation of LED fixtures and lighting controls.
- Leveraging energy project incentives from local utilities.

Main Quadrangle | Robert Kozloff

FY2018 to Present

The University began implementing the plan to reduce carbon intensity by 20% in **2018**. Since 2018, the University has implemented an annual program referred to as Preventative Maintenance + Commissioning (PM+Cx), in which the 38 most energy intensive buildings on campus responsible for 80% of GHG emissions undergo rigorous functional performance testing and extensive energy audits to identify operational issues and energy savings opportunities. This program has been highly effective and has consistently provided both significant energy reductions and positive financial returns. The University completed PM + Cx projects at 26 buildings totaling 3.6 million square feet from 2018 through 2021 that are projected to reduce GHG emissions by over 9,500 MT eCO_2.

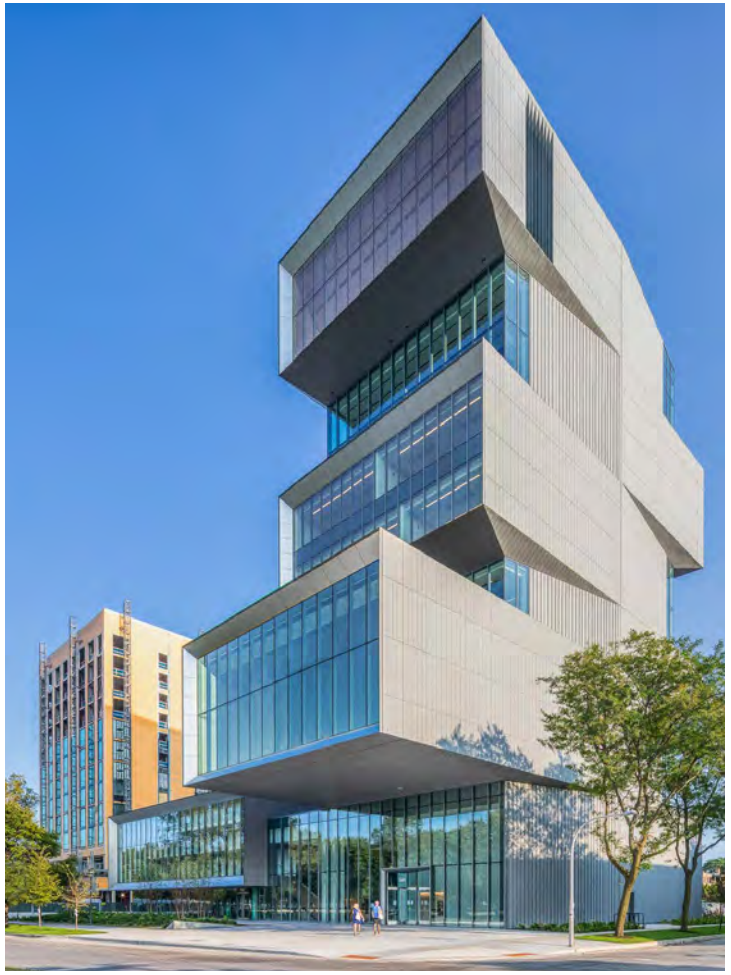
As a result of the PM+Cx program, projects at the Gordon Center for Integrative Science (GCIS) and Searle Chemistry Laboratory won Excellence in Engineering awards from The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

The Regenstein Library and the Joe and Rika Mansueto Library each received Retrofit Chicago Energy Challenge awards for reducing energy use intensity by over 20%.

The University of Chicago also successfully initiated additional projects such as indoor and outdoor LED lighting retrofits in four buildings, demand-based exhaust in three dining facilities, and a campus-wide steam system insulation project.

While improving building energy efficiency was a constant focus of this period, an increased emphasis on campus engagement led to the creation of an **energy webpage**, **social media accounts**, **energy dashboards**, and **articles** highlighting energy achievements. Additionally, UChicago Facilities Services held in-person and **virtual tours** of utility plants, an ENERGY STAR® **Battle of the Buildings** as part of Earth Week 2021, and partnered with the Mansueto Institute for Urban Innovation EF Campus to collaborate on projects that tackle real-world sustainability challenges on campus.

In recognition of its accomplishments in energy management and campus engagement, the University of Chicago was one of two universities to receive the **2021 ENERGY STAR Partner of the Year (ESPOY) Award** from the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE).



David Rubenstein Forum | Brett Beyer

When constructing new facilities, the University has continued its commitment to sustainable design. Since 2018, the University has added five additional LEED buildings, with its most recent major construction project, **David Rubenstein Forum, awarded LEED Gold** with a design that achieved a 40% reduction from ASHRAE 90.1 levels and earned nine points for optimizing energy performance.

Appendix B: Implementation Plan

Scope 1 and 2: Energy Program Opportunities

RCX + CCx

Retro-commissioning (RCx) is a systematic process for testing and tuning buildings using operational changes, maintenance repairs, and controls updates to drive low-cost energy savings. It frequently offers other benefits such as improving thermal comfort and indoor air quality, as well as extending equipment life.

The University has a strong track record of completing RCx projects (referred to as PM+Cx projects) on many of the campus's largest energy-consuming buildings with successful outcomes. However, as the program has moved from the largest buildings into the smaller ones, there are diminishing returns due to the costs associated with performing this type of detailed RCx study, leading to a desire to streamline the process where feasible. In addition, a common challenge that plagues improvements made via RCx projects is the degradation of savings over time as equipment continues to age and components fail, building operation changes, or occupant requests lead to efficient controls being overridden.

The RCx + CCx program improves upon the original PM+Cx program by:

- Simplifying the RCx process to minimize costs while achieving energy savings in smaller buildings
- Installing a CCx software platform to provide automated data analytics to ensure the persistence of savings from RCx projects and further optimize the operating efficiency of the built environment

RCx and CCx efforts are to be targeted at buildings having central building automation systems. This is because automation systems provide the greatest opportunity for low-cost energy efficiency through the optimization of controls and are equipped with digital monitoring capabilities that enable the use of a CCx software platform. **As the most energy-intensive buildings have already undergone the PM+Cx process, the remaining buildings should be tuned using a streamlined approach, as follows:**

- Remote systems review via the building automation system's native data trending capability, or via the CCx platform (once installed)
- Targeted onsite testing to investigate any anomalies observed and confirm proper function of large energy-consuming systems
- Streamlined measurement and verification of savings via existing whole building submeters (IPMVP Option C)

Gordon Parks Arts Hall
Steve Hall © Hedrich Blessing Photographers

Ideally, RCx should be repeated every five to seven years, both to maintain savings and drive new improvements.

However, technology solutions like CCx platforms can move this from a periodic to continual improvement process. A CCx platform will be rolled out to the most energy-intensive buildings first to ensure that the saving achieved at these buildings to date are maintained. The platform should then be installed alongside the streamlined RCx process at the campus's smaller facilities. In addition to savings persistence, the CCx platform can be leveraged to further fine-tune building controls for deeper energy savings via its advanced reporting and analytical capabilities.

Lab Optimization

A typical lab's HVAC system must operate 24/7 to ensure safety (even if it is minimally occupied after hours) and uses a "once-through" ventilation system. Fresh outside air is conditioned, supplied to the labs, and then exhausted rather than recirculated due to the possibility of hazardous substances in the airstream. For this reason, laboratory buildings are among the most energy-intensive facilities on campus, but also a source of significant energy saving opportunity.

This plan recommends implementing a Smart Labs program to systematically assess and implement opportunities to optimize lab buildings. The basis of any Smart Labs program will be pulling together a qualified, multi-disciplinary team. The team should be comprised of key stakeholders, such as facilities engineering, office of research safety and environmental health and safety personnel, the specific lab's manager or researchers, operations and maintenance (O&M) staff, sustainability staff, and any others who can provide needed expertise or coordination.

To get started, the University can leverage the existing Smart Labs Toolkit, published by the National Renewable Energy Laboratory (NREL) and the **International Institute for Sustainable Laboratories**.

The program should first rank labs by opportunity level, then assess behavioral, operational, and capital upgrade opportunities at each lab, execute on the projects found to be feasible and financially viable, and maintain the upgraded labs using ongoing benchmarking and feedback.

Typical improvement opportunities may include:

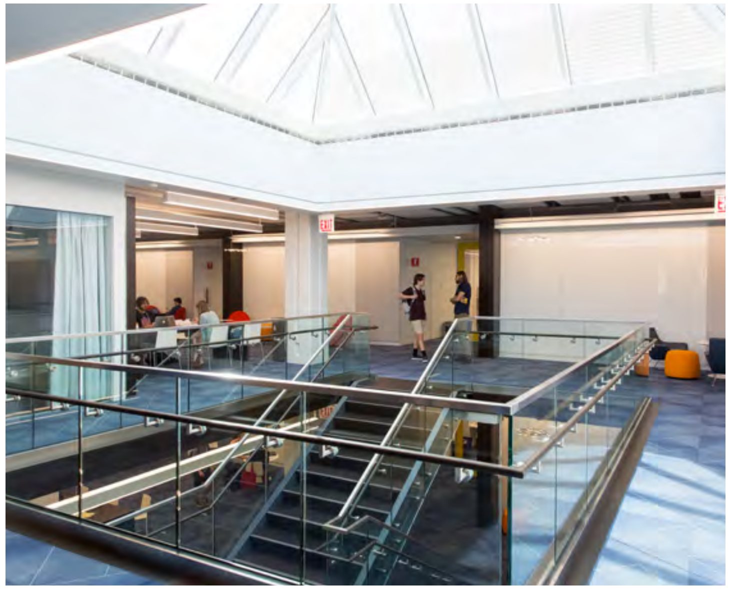
- Improving fume hood sash closure using signage, reminders, and ongoing monitoring to encourage energy efficient behavior by fume hood users.
- Rebalancing minimum air change rates to the University's 8 ACH standard, and currently exceeding.
- Implementing unoccupied temperature setbacks and other HVAC controls optimization opportunities.
- Addressing any unneeded plug loads, wasteful practices, or setups observed.
- Performing laboratory ventilation risk assessments to drive down minimum air changes per hour (ACH) where appropriate.
- Installing presence sensors to setback face velocities on VAV fume hoods.
- Installing variable frequency drives on VAV lab exhaust fans.
- Performing wind tunnel studies for exhaust stack velocity optimization, with possible wind-responsive resets.
- Installing exhaust heat recovery.
- Replacing any constant volume components in the laboratories (such as fume hoods and air control valves) with VAV equivalents and optimizing system controls to take advantage of the increased air turndown capability.
- Installing a critical environment-grade demand-controlled ventilation system, paired with occupancy sensors, to allow for significant air change rate reductions in VAV labs based on real-time monitoring for contaminants.

Searle Chemistry Laboratory | Anton Grassl

Compressed Air Leak Programs, Plug Load Management, and Weatherization

Compressed Air Leak Program

A typical compressed air system loses 20-30% of its total capacity to leaks. Numerous compressed air systems exist across the University campus, serving pneumatic control systems at various buildings and plants. Many of these systems are small and have never been checked for leaks. This plan will establish a compressed air leak survey and repair program to systematically identify and repair compressed air leaks, to be repeated on a periodic basis. This will both reduce energy waste and improve system reliability.



John Crerar Library

Plug Load Management

Plug loads comprise an increasing share of energy consumption in buildings.

While these are often difficult or cost-prohibitive to address directly, this plan includes implementing the following **strategic opportunities to address plug loads that are under the University's direct control:**

- Install smart power strips in computer labs across the campus. Smart power strips automatically shut off parasitic loads (e.g., monitors) when the "control" device (e.g., computer) is shut off.
- Update procurement practices to specify an ENERGY STAR requirement for IT and AV equipment procurement. ENERGY STAR qualified equipment has met specific performance criteria such as:
  - » Efficient operation across various modes
  - » Efficient power management features

Weatherization

Numerous buildings around campus were noted to have envelopes with opportunities for improvement. This plan will address poor envelope conditions by performing inspections and using thermal imaging to identify areas of significant infiltration and poor insulation, and deploying weather stripping, spray foam, caulking, and other methods to seal air gaps and reduce HVAC loads.

Chicago Theological Seminary | Tom Rossiter

Scope 1 and 2: Capital Energy Efficiency Measures

LED Lighting Campus Wide

Most of the lighting installed at the University campus uses older technologies, including fluorescent and high-intensity discharge (HID) fixtures. Modern LED lighting consumes 50-60% less energy than a typical interior T8 fluorescent fixture, and about 70% less energy than a typical exterior metal halide or high-pressure sodium HID fixture. LEDs also have a longer life and slower rate of lumen (light output) depreciation over time compared to older lighting technologies, resulting in operational and maintenance savings alongside energy savings, and often providing a better quality of light output.

> **This plan calls for a campus-wide lighting audit, retrofitting all interior and exterior lighting to LED and installing lighting controls for occupancy and daylight-based turndowns where justified by a lifecycle cost analysis (LCA).**

To realize the best efficiency and lifetime for LED lamps and minimize unnecessary waste, disruption, and costs from full fixture replacements where they are not needed, the University will undertake full fixture retrofits (removing ballasts and installing LED drivers and type C LED bulbs) wherever the existing fixtures are in good condition and can be re-used. Fixtures that are not a good fit for a retrofit kit due to age, condition, or configuration, should be upgraded entirely to new LED fixtures. Occupancy and daylighting controls will be installed wherever justified by an LCA. This will likely consist of a blend of fixture-mounted occupancy and daylight harvesting dimming controls, and wall or ceiling mounted occupancy sensors, depending on space use, configuration, vicinity to windows, etc.

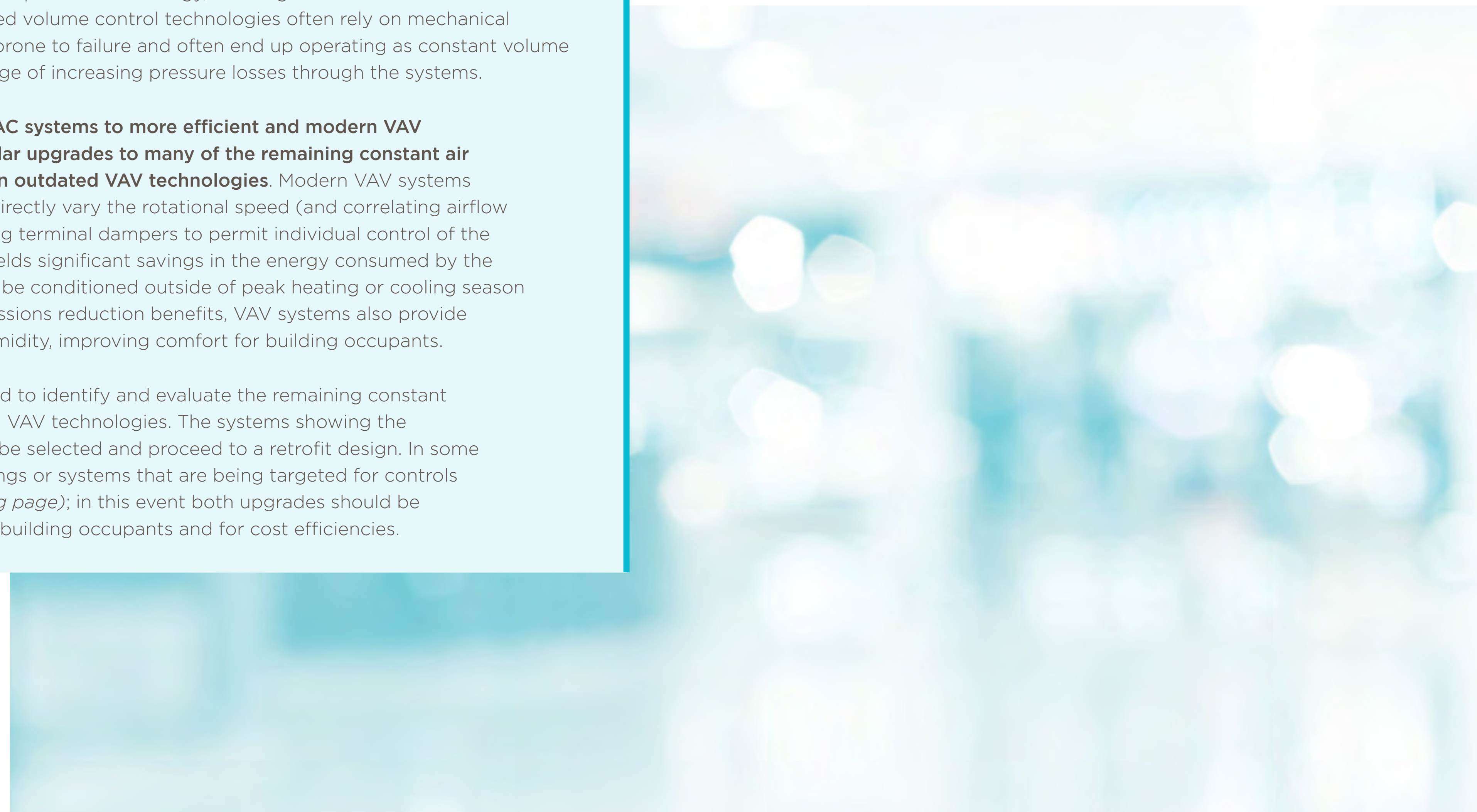
> Modern LED lighting consumes 50-60% less energy than a typical interior T8 fluorescent fixture, and about 70% less energy than a typical exterior metal halide or high-pressure sodium HID fixture.

HVAC Variable Air Volume Conversions

Older HVAC systems were often designed to deliver a constant air volume or use outdated technology to vary the amount of airflow delivered. Delivering a constant volume of air regardless of the actual heating, cooling, and ventilation loads within a space wastes energy, as a larger volume of air must be conditioned and circulated with fans. Outdated volume control technologies often rely on mechanical devices such as inlet guide vanes, which are prone to failure and often end up operating as constant volume systems over time, with an added disadvantage of increasing pressure losses through the systems.

The University has upgraded most of its HVAC systems to more efficient and modern VAV technologies; this plan would complete similar upgrades to many of the remaining constant air volume systems and those still dependent on outdated VAV technologies. Modern VAV systems typically utilize variable frequency drives to directly vary the rotational speed (and correlating airflow rate) of fans, with larger systems also installing terminal dampers to permit individual control of the amount of air delivered to each room. This yields significant savings in the energy consumed by the fans and reduces the volume of air that must be conditioned outside of peak heating or cooling season conditions. In addition to the energy and emissions reduction benefits, VAV systems also provide better control of space temperatures and humidity, improving comfort for building occupants.

Initial conceptual studies should be conducted to identify and evaluate the remaining constant air volume systems and those using outdated VAV technologies. The systems showing the greatest potential for improvement can then be selected and proceed to a retrofit design. In some cases, these systems may overlap with buildings or systems that are being targeted for controls upgrades *(described in detail on the following page)*; in this event both upgrades should be pursued in tandem to minimize disruption to building occupants and for cost efficiencies.



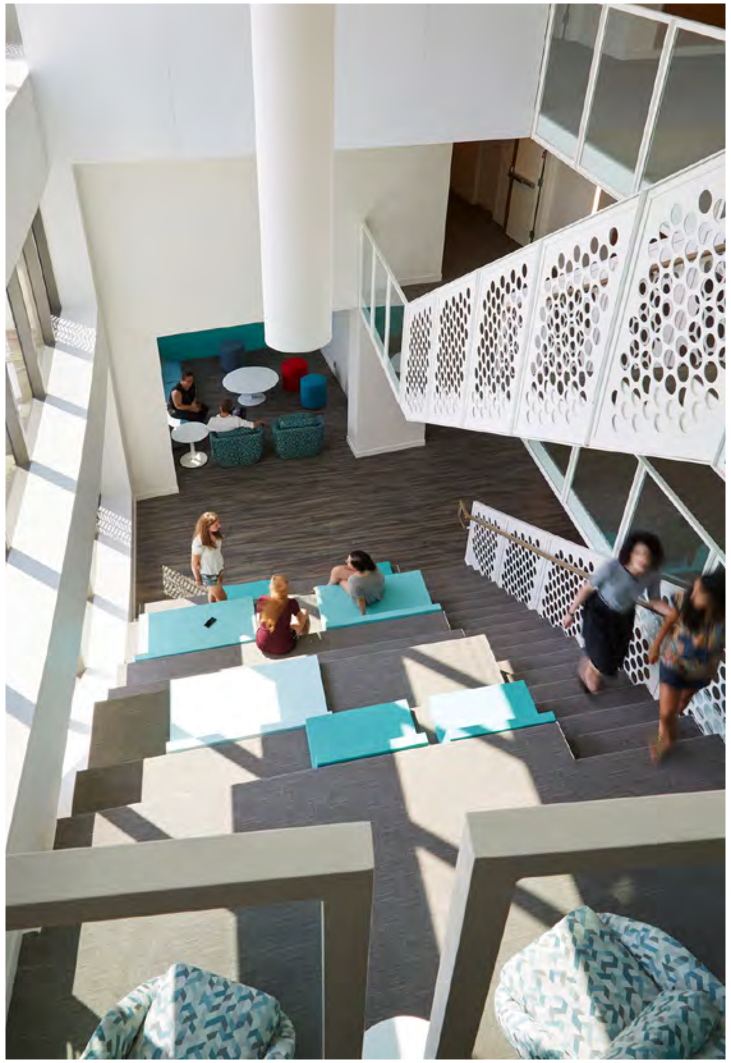
HVAC Controls Upgrades

Control systems for HVAC play a key role in their energy consumption, enabling automation of temperature control, pressure control, scheduling, and more. Most installed HVAC systems are equipped with some variety of control; however, controls technology has evolved significantly over the years as new digital technologies have become more available, cost effective, and reliable. Older centralized HVAC controls often rely on pneumatic systems, which use compressed air powered devices to measure conditions such as temperature or pressure, relay a corresponding air pressure signal, and vary the position of controlled components such as dampers or valves in response. While functional and robust when well maintained, these pneumatic systems provide little data to building operators, which makes it difficult to detect when a malfunction occurs and leads to degrading performance over time. Furthermore, this lack of data visibility limits the control capabilities of the systems and prevents remote monitoring.

The University uses central building automation systems (BAS) to monitor and control HVAC systems across the campus's numerous facilities. Systems and subsystems that rely on pneumatics, or for which only localized controls (such as simple thermostats) were provided, are not visible from the BAS and are far more likely to be operating inefficiently and have undetected component failures that impact occupant comfort. This plan would upgrade these systems to modern direct digital controls (DDC) connected to the campus's central BAS to permit remote monitoring, optimized control strategies, and early detection of issues. DDC systems have an ever-expanding array of control and monitoring device options, use flexible computer programming to dictate how each system responds to its sensed inputs, and allow data to be viewed, recorded, and analyzed to detect anomalies and inefficiencies.

> **All of these factors lead to a more energy-efficient operation of systems, improved control of environmental conditions, and a better occupant experience.**

Initial conceptual studies should be conducted to identify and evaluate the buildings where pneumatic controls are still used, in whole or in part, and systems for which only localized control exists. The systems showing the greatest potential for improvement can then be selected and proceed to a retrofit design. In some cases, these systems may overlap with buildings or systems that are being targeted for VAVs upgrades (described in detail on the above page); in this event both upgrades should be pursued in tandem to minimize disruption to building occupants and for cost efficiencies.



Campus North Residential Commons
Steve Hall © Hedrich Blessing Photographers, Courtesy Studio Gang

Central Utility System Improvements

The University has already invested significantly in improving the operating efficiency of its central utility plants, which generate steam and chilled water (CHW) to heat and cool the campus facilities. UChicago will continue the fine-tuning of efforts that are currently in progress, as well as strategically investing in equipment upgrades and new technology pilots to drive continuous improvement.

For the central chilled water system, the following optimization opportunities will be pursued:

- Fine-tuning of central plant and building-level tertiary CHW pumping controls (continue existing in-progress efforts)

- Continue work to identify and address the root cause of buildings exhibiting low CHW temperature differentials

- Pilot and evaluate the installation of Smart Energy Valves that combine thermal energy meters with smart valve controls to optimize coil flow rates, increasing temperature differentials and reducing CHW flow

At the South Steam Plant, the existing continuous blowdown heat recovery system is degraded and not performing well. Replacement of this system is in progress; this will improve heat recovery and increase plant efficiency.

South Campus Chiller Plant | Murphy/Jahn Architects

Scope 1 and 2: Distributed Energy Resources

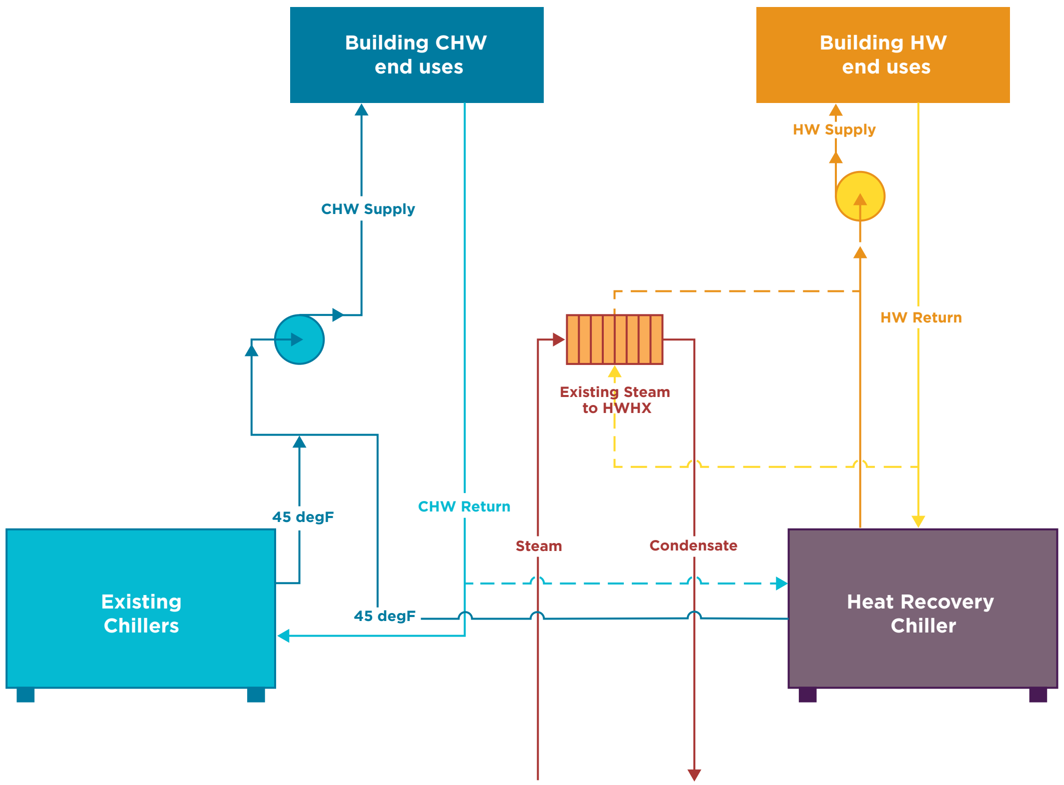
Heat Recovery Chillers

Heat recovery chillers (HRCs) are a form of water-to-water heat pump that are gaining popularity for their energy performance, electrification potential, and compact modular design. These chillers provide excellent energy performance by taking advantage of both the heat rejection and heat absorption sides of the refrigeration cycle to simultaneously generate hot and chilled water. A traditional chiller rejects the heat it absorbs when producing chilled water to the atmosphere, whereas HRCs recover this waste heat to generate useful hot water. Traditional water-cooled chillers, while more energy efficient than their air-cooled counterparts, have the additional disadvantage of consuming significant volumes of water via evaporation, drift, and blowdown in cooling towers; this water consumption is also avoided in HRCs as the heat is rejected to a closed hydronic loop for which little to no make-up water is needed.

> **Because the superior energy performance of HRCs is based on their ability to provide both heating and cooling at the same time, they are best suited to applications where these loads are coincident.**

This plan proposes to pilot this technology in two locations where significant simultaneous heating and cooling loads exist—at Regenstein Library, to provide chilled water and heating hot water, and at the William Eckhardt Research Center, to serve the process cooling system and to provide preheat at the air handlers' outside air intakes. Currently, the campus uses traditional chillers to provide cooling for these facilities and natural gas combustion boilers to provide heating. Piloting HRCs for these applications will not only result in energy savings but will also allow the University to test the viability of this technology for reducing its dependency on onsite combustion for heating.

FIGURE 15. HEAT RECOVERY CHILLER



Example piping and instrumentation diagram of heat recovery chiller at a University building

Creating electricity with solar PV cells is a renewable energy solution that can be implemented both on campus and off campus.

Onsite Solar Photovoltaic Panels

Creating electricity with solar PV cells is a renewable energy solution that can be implemented both on campus and off campus. This section focuses on the on-campus opportunities. Due to the geography of the urban campus, these opportunities are most likely rooftop-mounted solar panels as opposed to ground-mounted, or more expensive carport installation, typically in a parking lot.

Chicago and, more broadly, the Midwest, is not an ideal market for solar PV. This is one reason that off-campus renewable opportunities are being explored by the University, with another reason being that off-campus land can host a much larger solar array. However, Illinois, through the Illinois Power Agency, has a solar renewable energy credit (SREC) program that incentivizes onsite solar in Illinois. This SREC program has a significant impact on financial returns for on-site solar PV, making it as attractive financially as off-site investment.

To serve as an ideal candidate for rooftop solar PV, a building should meet three criteria:

1. A large, flat roof capable of installing 75 kW DC or more
2. A new roofing membrane or a roofing membrane that is due for replacement and can be replaced as part of the project
3. An annual electric load greater than the output of the solar array

The reason for these criteria is that there are quantities of scale to larger rooftop installations—once solar panels are installed, it becomes much more expensive to remove and replace the roof membrane and then reinstall all the solar equipment. Roof membranes are typically warrantied for 10-15 years and replaced around that same timeframe. Finally, ComEd has net metering rules that require onsite solar electricity produced be less than annual metered load so that the electricity is used “behind the meter” and not exported to the larger electrical grid.

As part of this larger study, nine buildings were identified that potentially meet these criteria that could support up to 2 MW DC. The list of buildings is a moving target based on the roofing membrane criteria, but we modeled the impact of this 2 MW DC. The impact of this installation is small in terms of overall GHG reduction—1,400 MT CO_2e/year, or about 1% emissions reduction.

Scope 1 and 2: Vehicle Planning and Fleet Measures

Institute a Procurement Hierarchy—Choose Electric Vehicles First

> **When selecting a new vehicle, choose an EV first. If an EV is not available, select a plug-in hybrid or hybrid.**

Only when no other green choice is available should a standard internal combustion engine vehicle be chosen, with the most emissions-friendly model selected. EV technology and charging options are evolving in real time. Each year, more vehicle types will become available.

Plan for and Install More EV Chargers

The University has already begun installation of level 2 chargers in its parking garages and has plans for more. The University will conduct an engineering study to determine the best locations for the chargers in relation to where vehicles are parked, staged, and used. In addition to level 2 chargers, The University will consider direct current (DC) fast chargers at selected spots on campus.

Campus Security—Hybrids Vehicles and Anti-Idling Software

Campus Security is the primary consumer of gasoline on campus. Security vehicles work around the clock and are often idling in order to maintain computers, lights, and cabin comfort for heating and cooling. It has already replaced older vehicles with optimized police special-duty hybrids designed to meet these equipment needs with an electric motor. The Ford Interceptor hybrid became available in 2021 and is rated to save at least 30% on fuel use.

With newer standard internal combustion engine police vehicles expected to remain in the fleet for some years (model years 2017–2020), fuel use may be reduced via installation of anti-idling software. This software is accepted by vehicle manufacturers and gears down the engine's rpms during operation of the vehicle. It also allows the lights, computers, and climate controls to operate using less gasoline.

Electric Vehicle (EV) and charging station at university garage

Parking & Transportation EV GEM

University of Chicago vehicle

Photos source: University of Chicago

Planning for Greening of Shuttle Buses

The UGo shuttle service is outsourced via a contract with First Transit, a large pupil transportation service provider. There are 19 diesel shuttle buses and 2 gasoline transport vans. At present, changes to the shuttle fleet are limited, but **options for decarbonizing the shuttles include future electrification or use of a super low-carbon fuel such as renewable natural gas derived from biodigester agricultural or landfill projects**. These options should be reviewed ahead of contract renewal. Technology for the shuttle bus platforms should be considerably advanced by the time of the next contract, affording enhanced options.

Collaborate and Leverage Relationships

There are simple, no-cost components to decarbonization of the University fleet. The U.S. Department of Energy's (DOE) Chicago Area Clean Cities Coalition is housed at the City of Chicago and offers an opportunity for the University of Chicago to become a stakeholder and benefit from participation. This group offers free consulting services on alternative fuel vehicle and infrastructure options and can provide guidance on available fleet-related tools and resources developed by the Department of Energy, as well as grant funding programs. Large EV grant funding programs are expected at the state and federal levels starting in mid-2022.

The University has routes that are run by the Chicago Transportation Authority (CTA), and the University's Parking and Transportation Department frequently interacts with CTA. CTA is currently running a pilot project for EV transit buses which, if successful, is expected to expand to more buses and routes. The University should continue to work with CTA to have a future EV transit bus assigned to its route.

Monitor Electric Vehicle and Charging Infrastructure Grant Funding Opportunities

The State of Illinois has potentially large amounts of grant funding available for EVs and EV charging equipment going forward. Funding will be available from remaining funds of the Illinois Volkswagen Settlement, as well as from provisions of the Climate and Equitable Jobs Act. The City of Chicago has a Congestion Mitigation and Air Quality (CMAQ) program for clean vehicles called Drive Clean Chicago, which at some point will have renewed funds for clean trucks and buses. The federal government also has large allocations to transition vehicles from internal combustion engines to EVs contained in its bipartisan Infrastructure and Investment Jobs Act. **The University should monitor developing programs to take advantage of grant opportunities.**

Scope 3: Direct Air Travel

The first recommendation from the travel team was a pilot project in an attempt to reduce the large scope 3 GHG emissions contributions from direct air travel. A pilot project is the best way to provide an example of the benefits of being "travel aware" and making the best choices when it comes to planning and booking a trip. Metrics from a pilot can inform other departments of potential cost savings from use of the University's preferred booking system and also substantiate GHG emissions reductions.

The pilot project has several important subcomponents for overall awareness raising:

Individual Choices

- Hold a workshop with executive assistants who book travel to raise awareness
- Foster development of "internal champions" who can drive awareness and adoption of program goals
- Identify "super travelers" and mentor on how to reduce GHG emissions

Technology Assists

- Add a GHG emissions calculator to the Travel Toolkit web page
- Issue departmental level travel scorecards to bring attention to travel metrics

University Booking System

- Engage with preferred travel agency to identify airlines using sustainable aviation fuel and enacting other sustainable practices
- Determine what resources preferred travel agency may have for offering emissions related information to consumers at point of sale via on-line booking, or via a travel counselor

> **Communicating the message that individual travel choices can have a significant impact on GHG emissions will be the primary path to effecting change going forward.**

Therefore, **creating an overall sustainability-led awareness campaign around the University's air travel contribution to overall GHG emissions** will be the core effort to drive change.

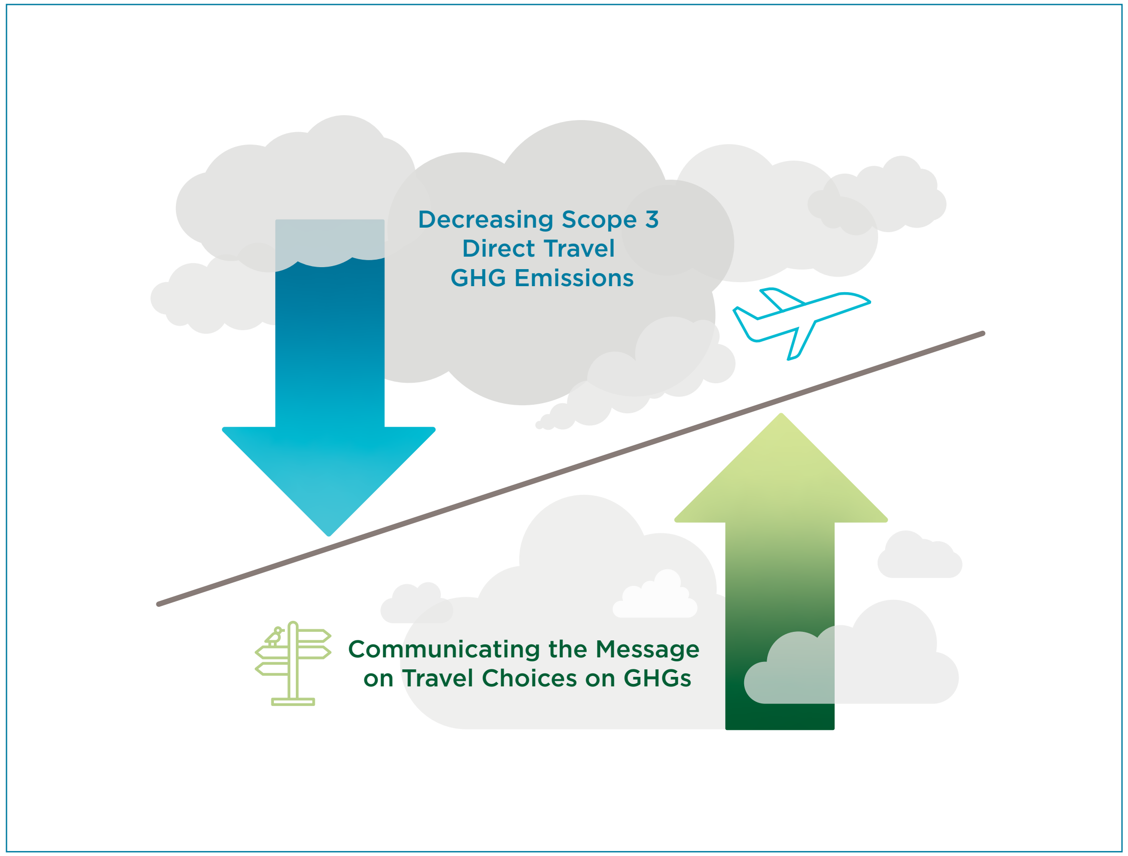
Fostering awareness of the benefits of booking trips through the University system is another essential component for examining and addressing travel. These benefits include:

- Capturing the total GHG emissions of the trip (air, vehicles, hotels).
- Providing preferred pricing on the trip's components.
- Enabling a critical risk management factor with the University system, the traveler can be located anywhere in the world.
- Placing the trip's costs and GHG emissions in one easily trackable system.

Fostering tele-conferencing modalities to defer travel will also be an essential part of decreasing travel GHG emissions. The development of better technologies to connect and communicate, without traveling, is one positive takeaway from the pandemic. Resources should be concentrated on seamless modalities to virtually connect and collaborate.

A portion of the University's travel GHG emissions is related to meetings and conferences.

Creating a University-wide initiative for group travel related to conferences and other large meetings, along with plans to incorporate a GHG emissions awareness component, will help make planners aware of the environmental impact of their events. Tools previously specified, including the University booking system, the Travel Toolkit GHG emissions calculator, and the awareness campaign on GHG travel emissions, will drive this effort.



Scope 3: Campus and Community Engagement

Engaging stakeholders through information transparency provides an opportunity to increase engagement in sustainability on campus.

Saieh Halll for Economics | Tom Rossiter

Those interested in sustainability are eager to know more about current conditions and future plans. The University of Chicago's Office of Sustainability website is an excellent location to house data and key information. Marketing the website and the public dashboards it contains is important. This site also presents an opportunity to encourage the exchange of ideas.

Leveraging existing University of Chicago work such as UChicago Eco (University of Chicago's Environmental Community), which serves as a center for communication, academics, and research on sustainability around campus, will help advance the mission. EPIC's (Energy Policy Institute at the University of Chicago) research in GHG emissions and environmental economics can be leveraged to drive sustainability policies at the University. The University of Chicago, as a world-class research university, has an opportunity to connect with faculty and researchers, explore their work, and apply it to help meet sustainability goals.

Enhancing communications within the current range of channels including the Maroon, social media, list-serve system, student government, and Registered Student Organizations (RSOs), allows people who want to get involved to get information, to ask questions, and ultimately to get involved.

Staffing Investment and Additions

Undertaking a project of this size on campus requires capital and human resources. For example, some of the energy program opportunities require staff to monitor and complete preventive maintenance items as well as participate in and implement targeted energy programs. Capital energy efficiency measures and distributed energy resource projects require project developers and project managers.

The University will need to hire or subcontract building engineers, building automation system engineers, and project development support.

Scope 3 recommendations require significant staffing resources to focus on waste and travel reduction, sustainability communications, and marketing.

All these positions can be internal to the University or subcontracted. For example, some funding mechanisms, such as performance contracting, include project development and construction management as part of the project.

It is anticipated that scope 3 recommendations will be carefully considered and implemented as the necessary staffing resources are made available over the next eight years.

Appendix C: Additional Considerations

Numerous options were considered during the development of this plan, some of which were ultimately not included due to questionable near-term feasibility, poor financial performance, or lack of alignment with the University's long-term vision for sustainability. Options that were considered but not included in the plan are summarized below:

Combined Heat and Power (CHP) Plant: CHP plants generate electricity via fossil fuel combustion and recover the heat produced as a byproduct to generate steam or hot water. Installing a CHP plant to replace one or more of the campus's central steam plants would offset the grid electric consumption and allow steam to be produced using waste heat. However, CHP increases the campus's dependency on fossil fuels, with unknowns around utility interconnection and electrical infrastructure upgrades, potentially limiting its feasibility and adding significant costs.

Centralized Ground Source Heat Recovery Chiller (HRC) Plant: A centralized version of the HRC electrification discussed under the Pathways to Electrification section of this document was considered, using geothermal wells as the heat source in winter and a heat sink in summer. However, this option was determined to be infeasible due to the extreme disruption on campus that would result from replacing miles of existing steam piping with hot water distribution end-use modifications required in some buildings to convert from steam to hot water, and insufficient land availability to provide the needed heat source in winter.

Geothermal Heat Pumps: Discrete opportunities to install geothermal heat pumps to replace select buildings' existing steam-based heating systems were assessed based on nearby land availability to meet the required heating load. This option was found to have limited applicability due to campus space constraints, while the cost per ton of emissions reduction prevented from scaling.

Biogas: Biogas is a renewable fuel source produced via anaerobic digestion in which bacteria breaks down organic waste and outputs methane, which can then be processed and burned like natural gas. Biogas can be procured from nearby landfills or wastewater plants, as it is a natural byproduct of their operation, while purpose-built anaerobic digesters can be built to generate biogas from organic waste streams. Neither approach was found to be feasible for the University, as nearby facilities were already using their biogas in-house. In addition, onsite anaerobic digestion requires a consistent waste stream of organic material that must be separated from other types of waste, which the University does not currently produce via its normal operations. Furthermore, fuel quality can be a major issue for biogas, as impurities can impact equipment performance and reliability.

Renewable Natural Gas (RNG) via Plasma Gasification: RNG and a variety of other beneficial fuels and byproducts can be derived from municipal solid waste using a plasma enhanced gasification system (PEGS). Gasification takes place at extremely high temperatures, which breaks down the waste stream into its elemental constituents, converting all organic materials into hydrogen and carbon monoxide and residual inorganic materials into vitrified slag. The gaseous output, referred to as syngas, is then conditioned into RNG, which can be used in place of traditional natural gas in boilers or other applications. This technology is being piloted at a few locations in the U.S. and would require a larger waste stream than the University currently produces to be financially feasible; however, it may be worth exploring in the future as both a possible source of RNG and as a landfill diversion tactic.

Hydrogen: Hydrogen has recently re-emerged as a renewable fuel of interest, as the combustion byproduct of water and hydrogen is not a greenhouse gas. When considering its applicability for the University, two significant feasibility barriers were found: First, the generation of renewable, or "green," hydrogen is typically via electrolysis, which requires more electricity than other electrification options. Second, hydrogen storage is challenging, as its lower heating value corresponds to higher volume requirements and the hydrogen molecule is too small to be stored at high pressure in traditional materials like steel without causing embrittlement.

Packaged Heat Pumps: Discrete electrification opportunities were explored to replace existing packaged HVAC equipment, which uses natural gas furnaces for heat with packaged heat pump systems that require only electricity. While this option should be kept in mind when the existing equipment is at its end of life, the financial savings and GHG emissions reductions did not justify early retirement of the equipment as part of this plan.

Condensing Boiler Stack Economizers: The existing steam plants at the University use boiler stack economizers to recover waste heat that is traditionally lost in the boiler exhaust. Replacing these with condensing stack economizers would allow a larger portion of that waste heat to be recovered, improving system efficiency. However, the marginal efficiency gains from upgrading the stack economizers were not enough to economically justify the upgrades, as under current operations neither of the existing steam plants are operated year-round.

Roof Insulation and Window Replacements: Investing in envelope upgrades, such as increased roof insulation and new energy efficient windows, was explored. These were not found to be justifiable based solely on energy savings but should be pursued where their age and condition require upgrades or as part of a major building renovation project.

Reva and David Logan Center for the Arts | Tom Rossiter

Appendix D: Assumptions

Key assumptions used to generate savings and cost estimates for the energy program, capital energy efficiency, and distributed energy resources opportunities are outlined below:

Onsite Energy Optimization Measures

> **All energy savings estimates were based on the metered building energy consumption data for electricity, steam, chilled water, and natural gas.**

- **End use consumption for each building's energy consuming systems** was broken out based on the building type and the Commercial Building Energy Consumption Survey (CBECS) 2012 data tables, with adjustments made as required based on the building's actual energy consumption profile and engineering judgement.
- A 0.9 to 0.95 **interactive effects multiplier** was applied to all HVAC-related savings estimates.
- **Steam and chilled water savings** at the building level used overall efficiency values (inclusive of distribution losses) of 64% and 0.737 kW/ton, respectively, to convert to utility natural gas and electricity savings.
- **Utility cost savings** were calculated using FY2021 utility rates and a 2.6% annual escalation.
- **Labor cost annual escalation rate** was assumed to be 1.5%.
- A **discount rate of 6.5%** was used for financial modeling
- **Onsite solar PV PPA costs** assume that the University will leverage the Illinois SREC incentive program.
- **LED lighting upgrade savings** were based on ASHRAE 90.1 lighting power density tables by building type to estimate baseline watts per square foot (interior) and watts per linear foot (exterior), with scaling factors applied based on the existing lighting technology in the building. Costs were based on retrofitting most existing interior fixtures with new remote drivers and type C LED lamps, with full fixture replacements only where necessary based on fixture type or condition, and for exterior fixtures.
- **RCx + CCx and laboratory optimization savings opportunities** were based on the energy usage intensity (EUI) at each building compared to the benchmark EUI for similar building types reported by CBECS; savings opportunity was then scaled based on the EUI as a percentage of the existing HVAC and lighting energy consumption.
- **Weatherization savings and cost estimates** were based on the 2012 Case Study of Envelope Sealing in Existing Multiunit Structures prepared for NREL, using the average energy savings percentage reported in the comparable Ohio and Indiana test site locations, and escalating the average cost by 3% per year. Note that the cost and savings are based on reducing unintended air leakage through the building envelope through means such as spray foam, caulking, and weatherstripping, and do not include capital upgrades such as new windows or insulation.
- **HVAC variable air volume conversion savings potential** was based on the estimated percentage of constant volume air handling units observed via the building automation systems and from prior reports.
- **HVAC controls upgrades saving potential** was based on the observed existing controls at each building, assessed by reviewing the existing building automation systems.

- **Compressed air leak savings opportunity** was based on the compressor horsepower for each applicable building provided by the University, with audit and repair costs based on prior completed projects.

- **Plug load management savings** are based on the difference between using Energy Star rated equipment and standard equipment, assuming that 100% of laptops and desktop computers and 60% of other typical plug loads (such as servers/data center equipment) are already Energy Star rated.

- **Heat recovery chiller sizing, application, savings potential, and cost estimates** for Regenstein Library and the William Eckhardt Research Center were based on prior PM+Cx reports provided to the University in 2020.

- **Chiller plant optimization savings potential** was based on optimizing the buildings' tertiary chilled water pump operations, assuming these pumps operate for 20% of the year on average, and on the verified costs and savings reported from a pilot installation of smart control valves equipped with thermal energy meters to address low chilled water temperature differentials.

- **The South Steam Plant's continuous blowdown heat exchanger upgrade costs and savings** were taken directly from an investment-grade report provided in 2021 by PRVN Consultants, for Option 3A—Flash Separator with HX (2) 60% Units.

Greening of the Grid

> **The 'greening of the grid' constitutes the passive emission reductions over time on the purchased electricity load from the grid.**

As electrical grids transition to lower or zero carbon emission sources over time, there will be less carbon emitted for the same purchased electricity load, even with the University taking no action. A relatively conservative base case derived from the 2021 EIA Annual Energy Outlook report was used to estimate emission factors for 2030 and extrapolated for intermediate years 2021-2029. Assuming no change in University of Chicago's load from 2020 (most recent data provided), possible emissions were estimated by applying electricity load to the scenario emission factors. While the greening of the grid exercise does not represent projected emissions, it is intended to serve as a reference for how future scope 2 emissions may look within the goal period.

Fleet Optimization

Based on most representative year of recent fuel use—2019, fuel use for pandemic year of 2020 not representative

- Assumes **gasoline cost** of $3.50/gallon
- Standard Chevrolet Bolt used for **example sedan vehicle replacement** at 2,600 miles/year
- **Electricity used** determined via "Vehicle Cost Calculator" tool of the USDOE Alternative Fuel Data Center based on domicile location address
- Conversion factor from **gasoline gallon equivalents to kWh used** is average of USDOE EPACT table (31) and US EPA Green Vehicle mpg guidance (33.705)
- **Level 2 charging costs reference source**: USDOE Office of Energy Efficiency and Renewable Energy (EERE), Report "Costs Associated with Non-Residential Electric Vehicle Supply Equipment" Appendix C: Electricity Consumption for 30 amp, 240-volt units
- **DC Fast charging costs reference source**: USDOE EERE Report "Costs Associated with Non-Residential Electric Vehicle Supply Equipment" Appendix C: Electricity Consumption Examples with EVSE Type: DCFC 480 VDC and Power Level: 48kW (100A). Expected utility costs also based on EERE report with commensurate utility kWh costs

Landfill Waste Diversion

- **FY2019 campus waste diversion and subsequent waste diversion measures** are based on the assumption that food waste digestate expelled wastewater is a qualified waste diversion practice. US EPA and AASHE do not consider this a waste diversion practice.

Landfill bound waste reduction estimates and associated greenhouse gas emission reduction estimates are based on multiple assumptions:

» **Monthly landfill and recycling tonnage reporting estimates** provided by Lakeshore Recycling, and annual tonnage reporting for specialty streams (i.e., electronics) provided by UChicago staff

» **Peer university campus and building-type material composition** assumptions and US EPA's 2018 estimation that 21.6% of total MSW generation consists of food waste (**source**)

» US EPA's **Volume-to-Weight Conversion Factors for Solid Waste** (**source**)

» **Hiring a Recycling Coordinator recommended** to implement many of the recommendations

» US EPA **Waste Reduction Model (WARM)** which calculates greenhouse gas emissions reduction estimates (**source**)

» **Estimates and pathways based on pre-pandemic conditions, developed using 2019 data**, do not consider impacts on waste generation or management strategies that may have resulted/will result from COVID-19 response

Appendix E: Additional Resources

Helpful Resources

- Smart Labs Toolkit: **Smart Labs Toolkit (i2sl.org)**
- Commercial Building End Use Survey Results & Datasets: **Energy Information Administration (EIA) — Commercial Buildings Energy Consumption Survey (CBECS)**
- ENERGY STAR IT Equipment: **Choose ENERGY STAR IT Equipment | Products | ENERGY STAR**
- Overview and sample contract language for ENERGY STAR product requirement: **Energy-Efficient Products | ENERGY STAR Buildings and Plants | ENERGY STAR**
- Sample **ENERGY STAR Equipment Procurement Policy**
- Implementation Guide & information on the benefits of Energy Efficient Product Procurement: **Energy-Efficient Product Procurement: A Guide to Developing and Implementing Greenhouse Gas Reduction Programs (epa.gov)**

Supporting Case Studies

- Smart Mode Control Valve Retrofit at CSU Dominguez Hills: **Best Practices 2017 Smart Mode Control Valve Retrofit at CSU Dominguez Hills (berkeley.edu)**
- **Case Study of Envelope Sealing in Existing Multiunit Structures (NREL, 2012)**
- Outlook on Sustainable Aviation Fuels taken from various sources including: Chokshi, Niraj and Krauss, Clifford, "**A Climate Problem with no Easy Fix**," New York Times, June 2, 2021; attendance at Aviation Industry News, Sustainability in Aviation Workshop, Tarrytown, NY, September 18, 2021.
- Information on the status of rideshare in the Chicagoland area, regarding the ten largest metro areas in the U.S., with Chicago being the only one without a transportation demand organization, taken from **information provided by the Metropolitan Planning Council, "Commute Options"**
- Information on the status of electric buses in use by the Chicago Transit Authority taken from CTA website and available news sources. CTA's "**CTA Unveils New Electric Buses as Part of City's Green Initiatives**," April 21, 2021, accessed various times. Also, "**Electric Buses**". Available news sources include WTTW's "**CTA's New Bright Blue Electric Buses Are a Down Payment on a Green Future**," April 2, 2021

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