

# Eberly College of Science Greenhouse Gas Inventory for Calendar Year 2019 Report

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## Abstract

The Eberly College of Science (ECoS) produced 28,152 metric tons of CO<sub>2</sub>-equivalent (*MtCO<sub>2</sub>e*) through its various operations during Calendar Year 2019 (CY2019). This greenhouse gas (GHG) inventory presents a breakdown of emissions arising from utility use, air travel, commuting, Fleet leased and rented vehicles, vended supplies, and other sources. This report is the first work of its kind for Eberly College of Science, and only the second unit-level GHG inventory to be performed across The Pennsylvania State University. We recommend that the College repeat this inventory on a regular basis as a metric of success in reducing its emissions of climate-damaging greenhouse gases and urge college leaders to explore the opportunities for action described below. Achieving greater sustainability and resilience will require a combination of systematic and individual and systemic actions across ECoS.

## Supplemental Documentation

This document summarizes the results tabulated in an accompanying spreadsheet ECoS\_GHG\_Inventory\_CY2019.xlsx. The spreadsheet serves as an Appendix to this report.

## Table of Contents

Abstract.....	1
Supplemental Documentation.....	1
Introduction .....	3
Methodology.....	6
0. Conventions .....	6
1. Utility Emissions .....	7
2. Mobile Combustion Emissions .....	10
3. High Performance Computing .....	12
4. Procurement .....	13
Results.....	15
0. Main Results.....	15
1. Utilities .....	18
2. Air Travel .....	20
3. Commuting and Car Travel .....	22
4. High Performance Computing .....	23
5. Vendor Emissions.....	24
Future Work.....	26
0. Procedure.....	26
1. Next Inventory: CY2020 .....	26
2. Collaboration.....	27
3. Evaluation and Action .....	27
Opportunities for Action .....	28
0. Emissions Reductions and Offsets .....	28
1. Green Labs and Sustainable Operations .....	30
2. Sustainable Corporate Engagement .....	31
3. Advocacy at the University Level .....	32
4. Education and Leadership.....	33
Conclusion.....	33

## List of Abbreviations

<b>Abbreviation</b>	<b>Definition</b>
<i>CH<sub>4</sub></i>	Methane, a greenhouse gas
<i>CO<sub>2</sub></i>	Carbon Dioxide, a greenhouse gas
<i>CO<sub>2</sub>e</i>	Carbon Dioxide Equivalent
<i>CY2019</i>	Calendar Year 2019
<i>ECoS</i>	The Eberly College of Science
<i>eGRID</i>	Emissions & Generation Resource Integrated Database
<i>EMS</i>	The College of Earth and Mineral Science
<i>EPA</i>	The Environmental Protection Agency
<i>EUI</i>	Energy Use Intensity
<i>FIS</i>	Facilities Information System
<i>FY18-19</i>	Fiscal Year 2018-2019
<i>GHG</i>	Greenhouse Gas
<i>GWP</i>	Global Warming Potential
<i>HLSB</i>	Huck Life Sciences Building
<i>ICDS</i>	The Institute for Computational and Data Science
<i>LEED</i>	Leadership in Energy and Environmental Design
<i>MRSEC</i>	The Materials Research Science and Engineering Center
<i>MSC</i>	Millennium Science Complex
<i>MtCO<sub>2</sub>e</i>	Metric Tons of Carbon Dioxide Equivalent
<i>N<sub>2</sub>O</i>	Nitrous Oxide, a greenhouse gas
<i>OPP</i>	The Office of Physical Plant
<i>OVPR</i>	The Office of the Vice President for Research
<i>PSU</i>	Pennsylvania State University
<i>PUE</i>	Power Utilization Effectiveness
<i>RFCW</i>	ReliabilityFirst Corporation West, eGRID subregion
<i>SDG</i>	United Nations Sustainable Development Goal
<i>SI</i>	The Sustainability Institute
<i>SSAC</i>	The Student Sustainability Advisory Council
<i>UC</i>	The University of California
<i>UP</i>	University Park

## Introduction

Every year, Penn State's Office of Physical Plant (OPP) produces a [University-wide Greenhouse Gas Inventory](#), summarizing the emissions related to all University operations during the (fiscal) year. For fiscal year 2018-2019 (FY18-19), the College of Earth and Mineral Science at Penn State (EMS) produced the first unit-level inventory at Penn State: 2020 Drawdown Scholar Katherine Gannon analyzed the emissions due to all operations assigned to EMS during FY18-19, including those from utilities, air travel, commuting, EMS-owned vehicles, and Fleet leased and rented vehicles. It is within this context that ECoS decided to perform its own greenhouse gas inventory for CY2019.

The scope of this inventory includes emissions attributable to ECoS during CY2019, mimicking the sources and scopes of both the University-wide and EMS FY18-19 GHG Inventories. We have also expanded on their framework, most notably by exploring Vendor Emissions, a dimension of emissions that pertain to supplies purchased by and produced for ECoS.

A full understanding of an entity's GHG emissions will not capture the full breadth of how "sustainable" they are, nor their environmental impact. Material waste, landscaping, human and biotic impacts, investments, and research are each important aspects of environmental impact that lie beyond the scope of this GHG inventory. Instead, this report attempts to summarize just one important dimension of how ECoS impacts the environment. With respect to the [United Nations Sustainable Development Goals](#) (SDGs), this inventory will provide information mostly pertaining to Goal 13: Climate Action. However, we will take time in the *Opportunities for Action* section below to advocate for actions beyond this goal, and to recognize the intersectionality of Climate Action with all other forms of Sustainable Development.

It is important to distinguish between three categories of emissions, known as Scopes 1, 2, and 3.

- **Scope 1:** Direct emissions, produced onsite;
- **Scope 2:** Indirect emissions, related to purchased utilities; and
- **Scope 3:** Everything else: so the remaining indirect emissions occurring along the value chain. Scope 3 emissions are commonly called "someone else's Scope 1."

Penn State's University-wide Inventory includes all Scope 1 and Scope 2 emissions (as required by the [Greenhouse Gas Protocol](#)). Scope 1 and 2 emissions include those from stationary combustion, utility services, and mobile combustion, as well as those from smaller sources such as refrigerants, fertilizers, and animal management. At University Park (UP), utilities are our main sources of Scope 1 and Scope 2 emissions. Because a portion of Penn State's electricity is produced onsite while the rest is purchased from the grid, some utilities fall under both Scopes 1 and 2. It is worth noting that Scope 3 emissions are challenging to estimate, as they can be nebulous and possibly involve time-intensive investigations into the life cycles of products and investments.

Penn State chooses to follow an "Operational Controlled approach," rather than a "Financial Controlled approach," meaning that it inventories the operations over which it has control, excluding all of the operations within Penn State's financial power yet outside of its direct control. For Penn State, all Scope 1 and Scope 2 emissions would be included in either approach. Therefore, this distinction means that Penn State misses a minor portion of its Scope 3 emissions that might reasonably be assignable to its activities and initiatives. This convention is chosen in alignment with other University GHG inventories, as well as for its ability to capture the activities where Penn State can directly control its reductions efforts. The only Scope 3 emissions inventoried by the University are Commuting, Air Travel, and Non-Fleet Car

Travel, Campus Wastewater (where it counts as Scope 3 for all campuses besides University Park, Wilkes-Barre, and New Kensington), Waste in Landfills, and Electrical Transmission Loss.

This inventory was performed by Raymond Friend, a graduate assistant in Mathematics serving as the Graduate Student Member of the ECoS Sustainability Council, advised by Dr. Charles T. Anderson, Associate Professor of Biology and current ECoS Sustainability Council Chair. This work was made possible by the superior guidance of Shelley McKeague, Compliance Manager within Penn State's Office of Physical Plant.

## Methodology

### 0. Conventions

Throughout the process of performing a unit-level GHG inventory at Penn State, one will be confronted with multiple decision points: How to claim space within mixed-use buildings? What kinds of emissions are feasible to compute? What level of confidence do we need in our data to publish an estimate? Over what time frame should we perform the inventory? Which unit should be held responsible for particular emissions? In this section, we present the conventions adopted by this report.

When deciding on a convention, we considered the following:

- **Replicability:** choose a convention that can be easily reproduced by ECoS or any other unit;
- **Feasibility:** choose a convention that uses the available resources without requiring an unreasonable amount of time or effort to follow;
- **Consistency:** choose a convention that, if adopted by all other units, could produce a consistent and comprehensive inventory of all University emissions at the unit level; and
- **Transparency:** choose a convention that follows a transparent procedure and accurately reflects confidence level.

For instance, there are advantages to performing a GHG inventory during the calendar year:

- The calendar year aligns with annual Environmental Protection Agency (EPA) emissions factors reports;
- CY2019 is the latest choice for a representative year of utility-use and travel prior to the COVID-19 pandemic;
- EnergyCAP, the University's centralized tool for on-campus utility-use, most easily presents data by calendar year; and
- Future University-wide GHG inventories might switch to calendar year.

Moreover, the scope of this inventory was chosen to mimic previous inventories at Penn State for the following reasons:

- Symmetry in structure with EMS aids in comparing results across our units;
- This is the most likely setup to occur in future unit-level inventories at Penn State;
- Symmetry in structure with the University allows ECoS to assess the proportionality of its contribution to the University's emissions footprint;
- The current structure transparently categorizes emissions by Scope and purpose; and
- The University is best equipped to answer questions matching its current procedure.

However, our inventory also presents methodologies and results for non-standard emissions categories, including: Vendor Emissions, Global Program Experiences, and High Performance Computing. Most challenging was Vendor Emissions: relevant entities working on this issue at Penn State include Procurement, the Sustainability Institute (SI), and the Student Sustainability Advisory Council (SSAC).

According to Shelley McKeague, Compliance Manager for OPP and organizer of the annual University-wide GHG Inventory, there are a few reasons why Vendor Emissions are not considered at the University-level:

- Uncertainty when estimating Vendor Emissions would be a limiting factor to the University-wide inventory's accuracy, quality, and completeness.
- Estimating GHG emissions from Procurement opens an arduous task of investigating the lifecycles for various products, posing a challenge for developing a reasonable estimate for all Scope 3 emissions.
- The goal of the University-wide GHG Inventory is not necessarily to numerically quantify all Scope 3 emissions; for Scope 1 and Scope 2 emissions, it is important to set a net-zero emissions goal with a near term date. As a secondary goal, we can develop policy strategies to achieve full decarbonization of value chains without performing the painstaking work of quantifying all Scope 3 emissions.

To summarize, Scope 3 emissions are all indirect emissions that occur in an entity's value chain. For many corporations, Scope 3 emissions are much greater than Scope 1 and Scope 2. For Penn State to fully address the climate impacts of its entire operations, additional efforts are needed to identify all Scope 3 emissions and develop strategies to address them. The precise quantification of all Scope 3 emissions is not necessarily feasible or appropriate for a University-level or unit-level inventory.

The other significant difference between this ECoS inventory and the inventory performed by EMS is the definition of Scope for a unit within Penn State. There are two approaches one could take:

- Unit as a Separate Entity:** view the unit as entity interacting with the University, treating many Scope 1 emissions for the University as Scope 2 emissions for the unit.
- Unit as a Part of the Whole:** view the unit as a subset of the University, which acts as a collective and shares emissions by Scope regardless of which unit actually directly produces the emissions.

The convention followed by EMS was the former, treating EMS as a partner to the University that procures the University's utilities for its purposes. As the first unit-level inventory, it was not totally clear which convention to follow, but with guidance from OPP, we have determined that the latter approach: treating ECoS as a part of the whole University, is more appropriate. The University is purposefully organized to have OPP perform most direct fossil-fuel burning for the benefit of other units, a convenience for units like ECoS. As such, we will always adopt the Scopes as they are defined at the University level and not treat internal demand for utilities as a separate procurement process. This will help ECoS more directly compare its inventory to that of the University, and we predict that future inventories will follow this convention as well.

The following subsections will highlight other specific conventions adopted for this inventory.

## 1. Utility Emissions

By utility usage, we refer to the resources consumed in order to operate the buildings in which ECoS resides. At University Park, utility usage is measured at the building level, meaning there is no more specific way to estimate the utility usage of ECoS beyond estimating the College's proportional use of each building on campus. Luckily, thanks to Lan Wei and Shelley McKeague of OPP, as well as the Penn State Facilities Information System (*FIS*), we were able to obtain a spreadsheet detailing how every room in each building in which ECoS resides is assigned, as well as the floor area of each such space. In order to produce an estimate for the utility usage by ECoS in each of those buildings, we wished to sum the floor area of each room assigned to ECoS in a building and assign a proportional amount of that building's utilities to ECoS. However, one feature of how space is assigned within buildings at UP is that general purpose rooms like closets, hallways, bathrooms, etc. are assigned to "Office of Physical Plant" despite

these spaces primarily serving the other units present in the building. Instead of leaving those spaces assigned to OPP, we decided to also proportionally split all OPP-assigned space to the remaining units. For example, in Thomas Building, ECoS is assigned 28,400 square feet of space, OPP is assigned 72,800 sq. ft., and the remaining units total 7,100 sq. ft., approximately. Of the total non-OPP space, ECoS comprises nearly 80%, so 80% of OPP's space in Thomas Building was also assigned to ECoS for this inventory. Therefore, 80% of all utilities measured at Thomas Building were assigned to ECoS. [If repeated by every unit, this convention would avoid double counting and cover most assignable space.]

Utilities are summarized on EnergyCAP, the University's centralized tool for reporting utility usage at the building level. EnergyCAP reports measurements for Steam, Electric, Chilled Water, Water, Sewer, and Natural Gas. We sought measurements for each of these utilities during CY2019 for each of the 21 buildings in which ECoS was identified as having assigned space (in actuality, this number is 19, plus 2, as explained below in *Complication 1*).

The emissions factors (or numerical factors by which to multiply utility amounts to estimate emissions) for each utility were obtained from a few different sources. Each utility has a unique emissions factor, some depending on standard factors released by the EPA for 2019 [see the [EPA's Code of Federal Regulations for Greenhouse Gas Emissions](#), and the [EPA's 2019 eGRID Emissions Rates \(RFCW\)](#)], and others depending on OPP estimates for onsite utilities [OPP GHG Calculator, Shelley McKeague]. Moreover, emissions factors must be normalized to Metric tons of CO<sub>2</sub>-equivalent (*MtCO<sub>2</sub>e*) because there are multiple kinds of GHGs emitted besides CO<sub>2</sub>. Each GHG has a corresponding Global Warming Potential (*GWP*). The GWP for CO<sub>2</sub> is 1; the GWP for CH<sub>4</sub> is 25; and that for N<sub>2</sub>O is 298. With these normalization factors, we combined the emissions factors for the three most common GHG and calculated a normalized emissions factor for each utility.

*Complication 1:* In the course of compiling the rooms and buildings in which ECoS resides, we noticed that some key office and lab spaces were missing on our FIS report from OPP; namely, those residing within the buildings controlled by the Huck Institutes of the Life Sciences. Upon investigation on FIS, we realized that all such spaces were actually assigned to a different unit: the Office of the Vice President for Research (OVPR). While we could have left these spaces for that unit to inventory, we agreed that those spaces were more specifically serving ECoS, and so we wished to include those spaces into our inventory. Huck Associate Director of Operations James Marden was able to connect us with the Huck Facilities Director Michael Uchneat, who identified all of the rooms serving ECoS within Huck Institutes buildings, as well as their floor areas. This narrowed down our search to the following three buildings: the Huck Life Sciences Building (*HLSB*), the Millennium Science Complex (*MSC*), and Wartik Laboratory. We then requested another FIS report from OPP listing all of the rooms in each of those buildings (in fact we already had Wartik because Wartik contains some ECoS controlled rooms). Using a similar process to what we used to estimate utilities in the other 18 buildings, we summed the total space assigned to ECoS, OPP, and the remaining units in each building. We had to manually add the floor areas reported to us by Michael Uchneat to the ECoS category, and accordingly subtract the same from a column labeled "Office of the Vice President for Research."

*Complication 2:* The Botany Greenhouse is not metered separately: its utilities are part of Buckhout Laboratory, a building in which ECoS does not otherwise reside. After speaking with the Botany Greenhouse manager and other relevant personnel, we were unable to estimate its utility usage directly. Instead, we relied on metered data from the Entomology Greenhouse, another greenhouse on campus



that is metered separately and heated with natural gas, to estimate utility use in the Botany Greenhouse. However, the Botany Greenhouse is heated using steam, which means the utilities do not match between these two buildings. Instead, we used the Electricity, Chilled Water, Water, and Sewer information from the Entomology Greenhouse to estimate those values for the Botany Greenhouse; we eliminated Natural Gas from Botany's utilities; and we set the Steam for Botany as an average of the Steam used in other buildings heated by Steam (normalized by floor area). The average amount of Steam used per unit area in the remaining buildings in which ECoS resides was about 0.107 klb / sq-ft. Applying this to the Botany Greenhouse, which has floor area 6,664 sq-ft., we estimated that the Botany Greenhouse used about 715 klb of Steam during 2019. For the other utilities, we divided each by the floor area of the Entomology Greenhouse and multiplied by the floor area of the Botany Greenhouse assignable to ECoS (100% of the floor area).

**Scope(s):**

- **Steam:** Scope 1. Produced onsite using Natural Gas.
- **Electricity:** Scope 2. Purchased from the grid.
- **Chilled Water:** Scope 2. Derived from Electricity.
- **Water:** Both Scope 1 and Scope 2. That arising from Gas, Oil, or Propane is assigned Scope 1, while the rest is due to Electricity, so Scope 2. About 89% of energy devoted towards Water is due to Electricity.
- **Sewer:** Scope 1.
- **Natural Gas:** Scope 1. Used onsite.

**Caveats:**

- This procedure treats all assignable square-feet as equal in utility intensity, a poor assumption in light of work performed by OPP during 2016-2017 quantifying the differences in Energy Use Intensity (*EUI*) between buildings of various functions [1617 EUI, OPP]. That report concluded that buildings coded as laboratories were between 1.62 and 1.91 times as energy intensive as buildings coded as mostly office spaces per unit area. This EUI study would not have helped us perform a more granular comparison of labs and office/classroom spaces since the EUI study was also only able to compare across buildings, not rooms.
- This procedure also treated general purpose classrooms and spaces as used proportionally by the present units. While this is a massive simplification of the true operations at Penn State, this convention is the most feasible option at the moment.
- This procedure ignores the emissions related to upkeep of these spaces such as energy use related to maintenance vehicles or renovations.

**Confidence:** Medium to High. Without more granular of data, it is difficult to more accurately assess ECoS's utility usage in full. Most of the uncertainty comes from differences in the utility-intensities between spaces with distinct functions.

**See Tabs:** Buildings Raw, Building vs Unit, Utility Emissions Factors, and Building Utilities.

## 2. Mobile Combustion Emissions

According to the Greenhouse Gas Protocol, mobile combustion includes “combustion of fuels in transportation devices such as automobiles, trucks, buses, etc.” For our purposes, we considered emissions due to Air Travel, Global Programs, Car Travel, Commuting, and College-owned Vehicles all within mobile combustion. Multiple assumptions were made in order to produce emissions totals within each of these categories.

*Air Travel:* The EPA released [updated emissions factors](#) depending on a flight’s Haul type. A flight is defined as Short Haul if it is less than 300 miles; Medium Haul if 301-2300 miles; and Long Haul otherwise. We computed normalized emissions factors per passenger-mile using the GWP for each of the three most common GHGs and their associated emissions factors according to the EPA. All data for air travel were received internally within ECoS, and using distances for each flight, we categorized flights into their Haul type and used the appropriate emissions factors. This Air Travel excludes student experiences through Global Programs, and only includes faculty/postdoc/graduate student trips for ECoS business-purposes.

*Global Programs:* Penn State’s Office of Global Programs offers experiences for students/faculty to travel abroad for educational purposes. There are many ways in which students participate in experiences offered by Global Programs. Sometimes students choose to study abroad independently (those emissions are not considered to be a part of this inventory). Other times, students participate in faculty-led programs, of which there are two types: (1) free-standing programs, and (2) embedded programs. Free-standing programs are owned and operated by Global Programs (paid for using Global Programs’ funds), whereas embedded programs serve as small portions of larger courses. Through discussions with Matt Lockaby from Global Programs, we believe the most reasonable way to distribute emissions related to faculty-led experiences is to assign all programs of type (1) to Global Programs, and assign all programs of type (2) to the responsible unit. Matt Lockaby provided us a summary of the few courses offering embedded experiences during 2019 (of which only one was attributable to ECoS), the number of individuals traveling in each trip, and the itineraries for each (from which we extracted flights taken). Moreover, while the itinerary for an embedded experience may include multiple air and ground trips, we assume the majority of emissions come from the back-and-forth air travel required for the trip. Therefore, we only consider emissions related to Air Travel in this estimate. Note that Global Programs could be grouped with Air Travel above, but we separate it in our inventory to have a clearer picture of our College’s various behaviors. You will notice in the spreadsheet that we follow the same process of categorizing by Haul to compute emissions. Flight distances were computed by converting each location to its appropriate global coordinates, and then [applying the Haversine formula to obtain distance](#).

*Road Travel:* For all road travel, we make use of the [EPA’s estimate for the emissions due to a typical passenger vehicle](#), estimating emissions due to mileage driven.

- *Commuting:* Commuting data were obtained from the Transportation Services T2 Parking System, with zip code data from WorkLion. We estimated the daily commute from a resident of a certain zip code by computing the Google Maps shortest route from that zip code to University Park, and assumed the same number of days driven into work as EMS: 244 days per year. We implicitly assumed that each parking pass corresponded with someone driving and utilizing that spot for each of these 244 days, which is an overestimate. More specific spatial or alternative transportation data was impractical to obtain for our inventory.

- *Car Travel:* ECoS records all reimbursed driving trips, mostly due to personal vehicle and University Fleet rentals. Within the records, most trips have only a reimbursement price listed without mileage information. Based on the remaining rows that did contain distance data, it became evident that ECoS uses a standard factor of \$1.72 per mile, so we estimated distance for the price-only rows using that factor. The total mileage driven over all reimbursed ECoS trips was totaled to obtain a final emissions figure.
- *College-Owned Vehicles:* ECoS owns four vehicles: one shared by the ECoS Shop & Chemistry Maintenance Shop, one owned by Biochemistry and Molecular Biology, one owned by Astronomy and Astrophysics, and another used by the college. Most of these vehicles are relatively inactive, and are collectively driven less than 1,000 miles per year. Rough estimates were made for the total 2019 mileage of each vehicle, and we used the same emissions factor to estimate total GHG emissions due to their use. For each vehicle for which we had more specific information on the make, model, and fuel type, we used the specific fuel economy for that vehicle.

I would like to acknowledge Teresa Diehl, Associate Dean of Administration, and Timmy Huynh, Data Analyst at ECoS, as excellent sources of data for much of this sector of emissions.

#### **Scope(s):**

- **Air Travel:** Scope 3.
- **Global Programs:** Scope 3.
- **Commuting:** Scope 3.
- **Car Travel:** Scope 1.
- **ECoS-owned Vehicles:** Scope 1.

#### **Caveats:**

- Categorizing Air Travel by Haul Type (i.e., Short, Medium, and Long) may be crude.
- Without more granular knowledge of the addresses at which employees travel to and from work, it is difficult to more accurately estimate commuter emissions. We also have little knowledge of the makes and models of cars used to commute. In the University-wide Inventory, estimated miles are split between passenger car, light, duty truck and SUV based on the PA registration data published by the Federal Highway Administration.
- There is currently no way to more accurately recover distance data from reimbursed driving without estimating from cost.

**Confidence:** Medium to High. Air Travel was well-documented and the emissions factors for air travel are trustworthy. A vast majority of ECoS employees fly economy class, the default case for emissions factors. Emissions factors for driving depend on the types of the vehicles rented and used for commuting, as well as how members of our college get to work. Most of the uncertainty comes from assumptions for commuting.

**See Tabs:** Air Travel Raw, Air Travel vs Dept, Air Travel Emissions Factors, Air Travel, Global Programs Raw, Global Programs, Commuting Raw, Car Travel Raw, Car Travel, Commuting, ECoS Vehicles.

### 3. High Performance Computing

Individuals and labs within ECoS have access to computational services offered by the University through the Institute for Computational and Data Sciences (ICDS). Computation is performed using the supercomputer known as Roar (formerly known as the ICDS-ACI), which requires electricity to run. To investigate the emissions related to ECoS's Roar requests throughout CY2019, we contacted Lindsay Wells, i-ASK Team Lead, as well as Carrie Brown, Advanced Cyberinfrastructure Research and Education Facilitator, within ICDS. They were able to provide us with charts summarizing ECoS's high performance computation requests each month in units of CPU Hours, as well as statistics on ECoS's use compared to the total workload of Roar throughout CY2019. From this, we were able to identify the percentage of all Roar computational hours related to ECoS (call it  $p$ ). According to Carrie Brown, the proportion of computational hours related to ECoS out of the total was around  $p = 21\%$ .

To estimate electricity use from this percentage, we contacted Andrew Arvin, Project and Program Manager for Penn State IT & Infrastructure. Andrew provided the following estimates on energy consumption related to the equipment in the Tower Road facility.

Category	Avg. Power Utilization CY2019 (kW)
ICDS TRDC Tier I – Non-ACI/Roar	100.29
ICDS TRDC Tier I – ACI/Roar	330.33
ICDS TRDC Tier III	75.24

Table 1: Average Power Utilization by Category for Tower Road facility, CY2019. Provided by Andrew Arvin.

According to the [Uptime Institute](#), the data center Tier classification system categorizes the infrastructure required for operations within a data center. For instance, Tier I includes the data centers offering a basic capacity level, with an uninterruptible power supply, an area for IT systems, cooling equipment, and a backup generator. A data center is instead labeled Tier III if it offers a certain level of redundancy that allows normal IT operation to continue even when some equipment requires maintenance. While Tier I includes most computations related to ECoS, Tier III includes administrative and storage operations. ICDS offers both Tier I and Tier III data centers, yet only Tier I exhibits a strong positive correlation between computational time and power utilization. Conversely, Tier III has a more complicated picture: there is only a weak positive correlation, at best, for equipment in Tier III; some overhead (primarily) in Tier III could be attributed to the ICDS as a unit, and some of Tier III use/utilization is also related to dev. and other dedicated clusters that should not be attributed to the units leveraging ACI/Roar services. Therefore, we chose to exclude the row on Tier III from our calculation.

The “Non-ACI/Roar” equipment was excluded from our calculation, as we operated under the assumption that all computations by ECoS used ACI/Roar equipment in 2019.

Using only the average power utilization due to ICDS TRDC Tier I – ACI/Roar (330 kW), we estimated the emissions related to ECoS's use of ACI/Roar services. First, we compute ECoS's IT Power as  $P_{IT} = p \cdot 330.33$  kW. Next, we note that for each of the utilization values listed above, there exists facility overhead such as cooling, facility devices and losses, lighting, and more. This overhead is usually accounted for by a ratio called the Power Utilization Effectiveness ( $PUE$ ). The value of this multiplier is generally assumed to be  $PUE = 1.6$  for the Tower Road facility. This ratio means that for every 1 kW of power needed for IT load (whether equipment for ICDS, Penn State IT, or another group) the facility will require 1.6 kW to

operate. Therefore, we compute ECoS's Hosting Power by  $P_{Hosting} = P_{IT} \cdot PUE$ . Finally, we compute ECoS's IT total Energy spent on computing throughout the entire year as

$$E_{IT} = P_{Hosting} \cdot 24 \frac{hours}{day} \cdot 365 days.$$

Finally, we multiply  $E_{IT}$  by the corresponding electricity emissions factor computed in the sheet `Utility Emissions Factors`, obtaining the emissions related to High Performance Computation.

**Scope(s):** Scope 2. Derived from Electricity.

**Caveats:**

- At the moment, the procedure for fairly distributing utilization related to Tier III data center(s) across the units leveraging ACI/Roar has not been decided.
- There may be other sources of High Performance Computing offered to staff with ECoS (e.g., many labs have access to their own clusters). Including these data centers was infeasible for this inventory.

**Confidence:** High. We do not make too many assumptions or simplifications in this estimate.

**See Tabs:** High Performance Computing.

#### 4. Procurement

Vendor emissions are those related to the supply chain for ECoS equipment and supplies. Vendor emissions are purely Scope 3, but including them acknowledges that we generate demand for the items that are created, distributed, and used for our work and operations. While ECoS has detailed accounts of each of its tens of thousands of purchases (totaling over \$11 million) in 2019, the data is mostly unusable for the purposes of identifying what types of products are being purchased at what quantities. Instead, we turn to a previous initiative to establish a rough estimate of ECoS's emissions due to procurement.

In her [UC Berkeley 2009 Procurement Carbon Footprint](#), author Kelley Doyle estimated vendor emissions for the University of California Berkeley. This analysis was one of the most thorough we could find and describes a useful process known as a hybrid top-down approach to calculate vendor emissions. Their results are unlikely to precisely mirror the vendor emissions due to procurement at Penn State during 2019, but they help establish an order of magnitude estimate. In particular, Doyle found that the average carbon intensity of scientific equipment was around 0.66 kilograms of CO<sub>2</sub>e per dollar, whereas that for office product supplies was around 0.47 kilograms of CO<sub>2</sub>e per dollar. Most surprisingly, she found that the carbon intensity for food was around 0.83 kilograms of CO<sub>2</sub>e per dollar, greater than all other categories. The overall intensity of UC Berkeley's operations, including emissions related to scientific equipment, office supplies, construction, IT & telecommunication, and food equated to 0.000257 MtCO<sub>2</sub>e/\$.

From data provided by ECoS for its CY2019 expenses, we were able to recover information about our largest vendors (i.e., the vendors with whom we spend the most money). However, there will need to be much greater organization and inventorying at the purchasing level for labs and offices in order to be able to generate of more specific information. The current format is infeasible for performing an accurate inventory.

Because of our inability to move forward with an accurate assessment of our Vendor Emissions, we decided not to include Vendor Emissions in the final tally of ECoS's GHG footprint. However, we believe it is still very useful to understand our emissions in Procurement, since these emissions are fully within our control to affect, unlike much of the emissions due to utilities.

**Scope(s):** Scope 3.

**Caveats:**

- We assume that the vendor emissions related to procurement at UC Berkeley in 2009 provide a ballpark estimate of those related to procurement within ECoS during 2019.
- The composition of activities and equipment required at UC Berkeley as a whole may differ greatly from that of ECoS.
- UC Berkeley may have a very different set of suppliers, energy grid emissions, and procurement practices than Penn State.
- Estimating emissions from dollars is inherently flawed. The supplier, specific product, and more variables can all affect the true emissions related to that product.

**Confidence:** Low. The numbers used by Doyle are from a power grid on the West Coast in 2009, and the composition of supplies, construction, and equipment for the entirety of UC Berkeley may be very different from that of ECoS. Most likely, our vendor emissions will be larger, especially as we learn more about the emissions that go into gathering raw materials, manufacturing, and shipping supplies to Penn State.

**See Tab:** Vendor.

## Results

### 0. Main Results

First, we present the full CY2019 ECoS GHG Emissions by Source in the following Table 2.

CY2019 ECoS GHG Emissions by Source			
Source	Emissions	Units	Percentage
Steam	12257	MtCO <sub>2</sub> e	43.5%
Electric	11652		41.4%
Chilled Water	1637		5.8%
Water	134		0.5%
Sewer	129		0.5%
Natural Gas	38		0.1%
Air Travel	748		2.7%
Global Programs	33		0.1%
Car Travel	197		0.7%
Commuting	853		3.0%
ECoS Vehicles	1		0.0%
Computing	474		1.7%
<b>Total</b>	<b>28152</b>	<b>MtCO<sub>2</sub>e</b>	<b>100.0%</b>

Table 2: Emissions for ECoS during CY2019, categorized by Source.

If we categorize by Scope instead of Source (following the Scope breakdown discussed in the section *Methodology*), we obtain the following Table 3.

CY2019 ECoS GHG Emissions by Scope			
Scope	Emissions	Units	Percentage
Scope 1	12636	MtCO <sub>2</sub> e	44.9%
Scope 2	13882		49.3%
Scope 3	1601		5.7%

Table 3: Emissions for ECoS during CY2019, categorized by Scope.

Alternatively, we can present these tables as pie charts.

## CY2019 ECoS GHG Emissions by Source

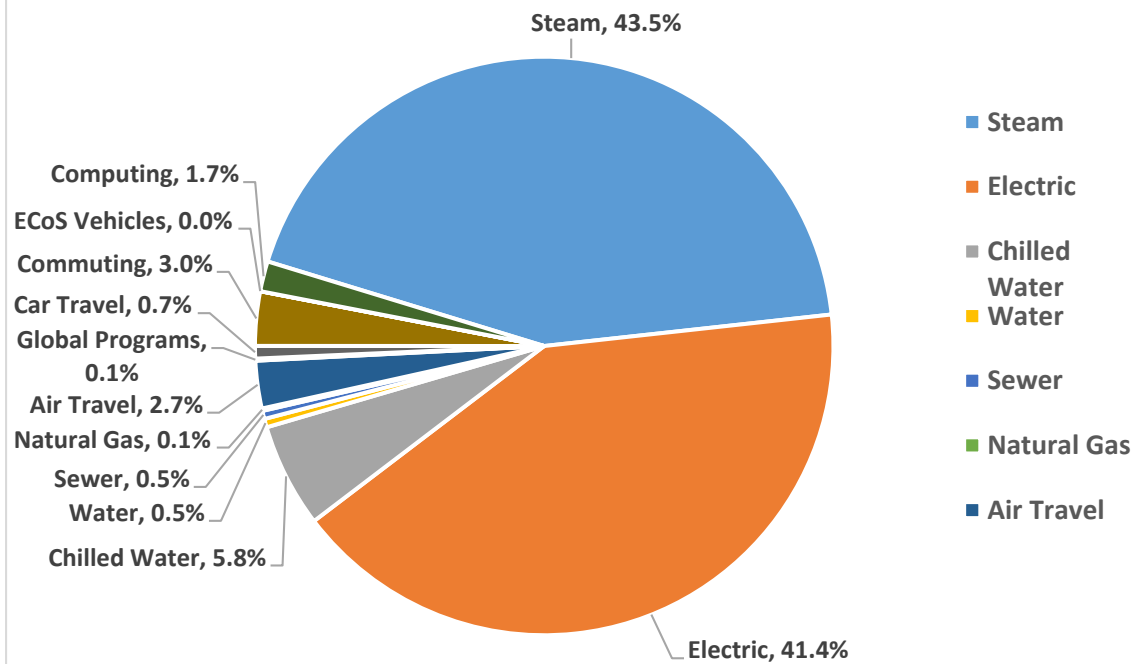


Figure 1: Emissions for ECoS during CY2019, categorized by Source. Corresponds to Table 2.

## CY2019 ECoS GHG Emissions by Scope

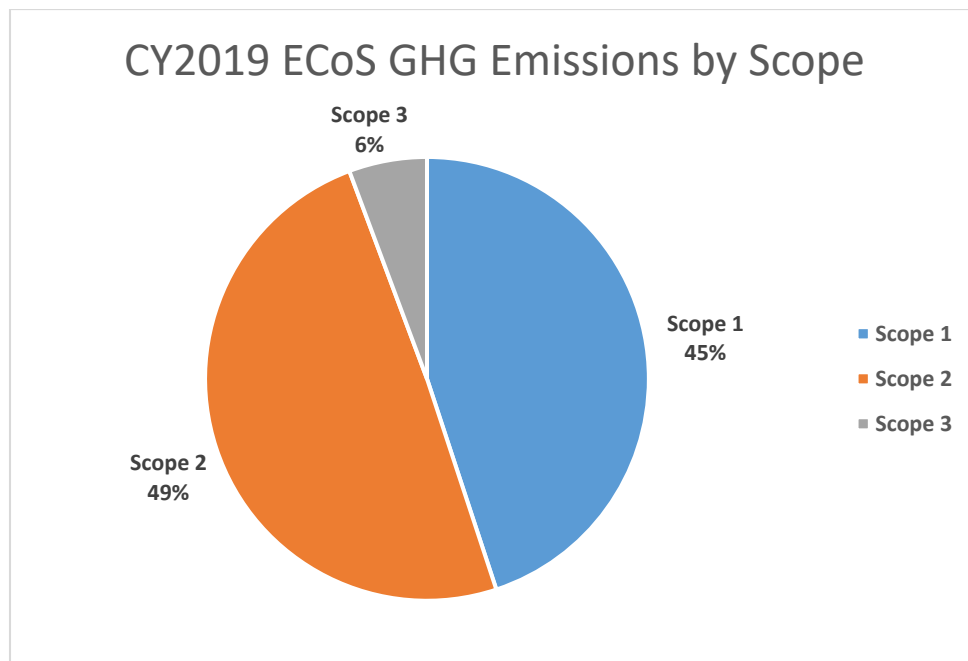


Figure 2: Emissions for ECoS during CY2019, categorized by Scope. Corresponds with Table 3.



We may compare our results to those of both the University's and EMS's FY18-19 inventories, as seen in Table 4.

Comparison of ECoS to University Emissions				
Source	University Emissions	ECoS Emissions	Units	ECoS Percentage
Steam Plant	107143	12257	MtCO <sub>2</sub> e	11.4%
Purchased Electricity	184199	13882		7.5%
Stationary Sources	28797	379		1.3%
Campus Vehicles	7220	1		0.0%
Commuting	70716	853		1.2%
Air Travel	19220	781		4.1%
Waste	2558	N/A		N/A
Synthetic Chemicals	7640	N/A		N/A
Animal Management	2467	N/A		N/A
Other	12665	N/A		N/A

<b>Total</b>	<b>442625</b>	<b>28152</b>	<b>6.36%</b>
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Table 4: A comparison of ECoS's CY2019 emissions to those of the University (FY18-19; chosen because FY19-20 was significantly impacted by the SARS-CoV-2 pandemic). The right column shows how much of each source category ECoS composes of the entire University's emissions (including all Commonwealth campuses besides Hershey Medical).

From Table 4, we see that ECoS comprised roughly 11.4% of all Steam use across the University, 7.5% of all Purchased Electricity, and 4.1% of all Air Travel. In total, ECoS made up about 6.36% of the University's total emissions [caveat: we currently have no way of quantifying ECoS's Synthetic Chemicals, Animal Management, Waste, or Other categories yet, and we certainly contribute to those source categories]. To clarify the table: 6.36% is equal to ECoS's 28,152 MtCO<sub>2</sub>e out of the University's 442,625 MtCO<sub>2</sub>e throughout the year. If we were to eliminate the rows corresponding to sources for which we are missing data for ECoS, then we would estimate that ECoS more likely makes up 28,152 MtCO<sub>2</sub>e out of the University's 417,295 MtCO<sub>2</sub>e, or about **6.74%**.

We can also compare our results to those of EMS: see Table 5.

Simplified Comparison of ECoS & EMS to University		
Source	ECoS Percentage of University (CY2019)	EMS Percentage of University (FY18-19)
Stationary Sources/Purchased Electricity/Steam Plant	8.28%	4.40%
Campus Vehicles	0.01%	1.10%
Commuters	1.21%	1.70%
Air Travel	4.06%	5.10%
<b>Total</b>	<b>6.36%</b>	<b>4.10%</b>

Table 5: The first unit-level comparison at Penn State: ECoS CY2019 vs. EMS FY18-19 GHG emissions. We were unable to make a more specific comparison due to differences in data details between this and EMS's report.

We notice that ECoS, as a larger college, makes up more of the University's total GHG footprint than EMS, but the two units differ substantially in their activities. ECoS seems to require significantly more utilities for its activities on campus, but much less for any College-owned Vehicles or Air Travel.

Does ECoS's footprint "make sense?" That is, how far is ECoS from the "average" unit? Using some rough numbers: Penn State employs roughly 17,000 full time faculty and staff at University Park, and welcomes about 14,000 graduate students at UP. Considering only faculty, staff, and graduate students as comprising ECoS, we estimate that ECoS houses about 1,600 people. If everyone at UP contributed equally to the University's emissions, we would expect ECoS to compose roughly  $1,600 / 31,000$ , or about 5.16% of Penn State's emissions. This is below our actual footprint (both the 6.36% and the adjusted 6.74% figure), meaning we contribute more than average to the University's GHG emissions.

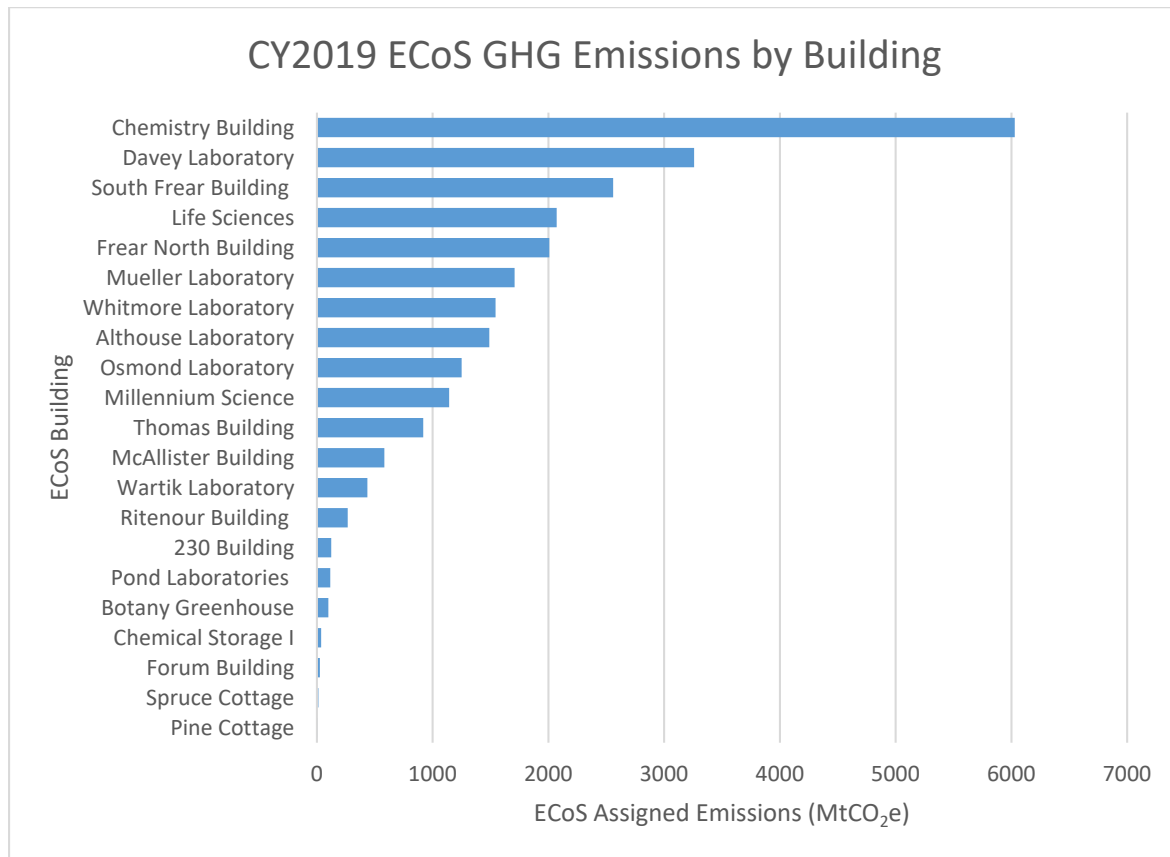
### 1. Utilities

Most of the data found for utilities was found on EnergyCAP, and it is summarized in the *Building vs Unit* tab of the accompanying spreadsheet. Part of our calculations for utilities involved computing an ECoS Assigned Proportional Presence, i.e., the proportion of floor area assignable to ECoS within each of the buildings in which ECoS resides. As described in the *Methodology* section, a portion of OPP space was also assigned to the ECoS space, producing the following Table 6 of ECoS Assigned Proportional Presences within the 21 buildings identified to contain ECoS-assigned space:

<b>BUILDING_NAME</b>	<b>ECoS's Assigned Presence (sq. ft)</b>	<b>ECoS Assigned Proportion</b>
McAllister (Hugh N)	59582	1.00
Spruce Cottage	4997	1.00
Joab L Thomas Building	86568	0.80
Chemistry Building	169046	1.00
Ritenour Building	22720	0.56
Botany Greenhouse	6664	1.00
Frear North Building	61010	1.00
Osmond Laboratory	120023	1.00
Pond Laboratories	7501	0.20
Whitmore Laboratory	82364	1.00
Mueller Laboratory	70981	0.95
South Frear Building (Life Science II)	71990	0.89
Althouse Laboratory	43539	0.92
Davey Laboratory	105281	0.79
Chemical Storage I (Farm No 13)	1848	0.24
Pine Cottage	4510	1.00
Forum Building	4214	0.16
Guion S. Bluford Building (230 Building)	3358	0.06
Huck Life Sciences Building	54792	0.39
Millennium Science Complex	32138	0.12
Wartik Laboratory	34133	0.53

*Table 6: Assigned Presence of ECoS within each of the 19 buildings in which ECoS has any assigned space according to FIS. Assigned Presence, according to this inventory, depends not only the space assigned to ECoS by FIS, but other present units.*

We were also able to estimate the emissions related to the operations of ECoS within each of the buildings in which it resides. See results in Figure 3.



*Figure 3: Assigned ECoS Emissions categorized by building. For instance, ECoS produces over 6,000 MtCO<sub>2</sub>e through its utility-usage in the Chemistry Building over the course of a year.*

A more useful plot might be that showing emissions by building but further normalized by floor area, quantifying the utility-intensity for each unit of space in each ECoS building (considering only the portion of utilities and space assigned to ECoS). Compare Figure 3 above to Figure 4 below.

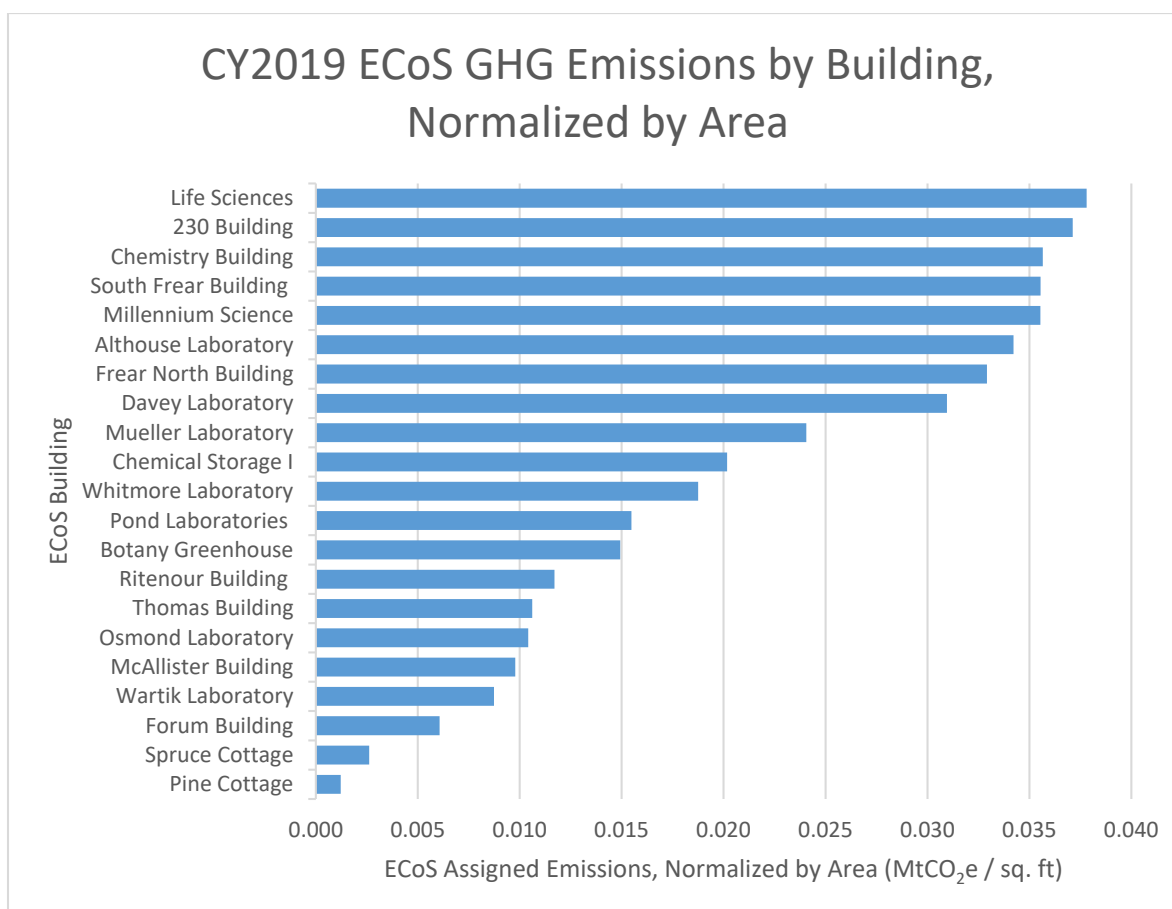


Figure 4: Assigned ECoS Emissions categorized by building and normalized by floor area. For instance, ECoS produces over 0.035 MtCO<sub>2</sub>e per square foot through its utility-usage in the Chemistry Building over the course of a year. That is equivalent to 77.2 lbs. of CO<sub>2</sub>-equivalent emissions per square foot per year.

In total, Utilities comprised the lion's share of ECoS's 2019 GHG emissions, totaling about 25,800 MtCO<sub>2</sub>e. The results are summarized in Table 7 below.

Computed Total ECoS Utility Use and Emissions CY2019							
Utility	Steam	Electric	Chilled Water	Water	Sewer	Natural Gas	TOTAL
<b>Total</b>	122370	23910890	6719785	42642	42696	710	
<b>Units</b>	klb	kWh	Ton Hr	Kgal	Kgal	MMBtu	
<b>Emissions</b>	12257	11652	1637	134	129	38	<b>25846</b>
<b>Units</b>	MtCO <sub>2</sub> e						MtCO <sub>2</sub> e

Table 7: Summary of utility use across all ECoS spaces, CY2019, and related emissions.

## 2. Air Travel

Because the flight data provided by ECoS came with department names attached, we were able to learn more about department behaviors for Air Travel. Below, Table 8 summarizes Air Travel by department.

Department	Trips	Total Air Miles (mi.)	Emissions (MtCO <sub>2</sub> e)	Dept. Size	Trips per capita	Miles per capita	Average Flight Distance (mi)
Physics	816	1128770	181.38	231	3.53	4886	1383
Biology	903	1079086	169.80	239	3.78	4515	1195
BMB	530	575402	91.80	260	2.04	2213	1086
Astronomy & Astrophysics	486	575309	88.38	120	4.05	4794	1184
Chemistry	628	558772	83.80	289	2.17	1933	890
Mathematics	319	448855	71.00	231	1.38	1943	1407
Statistics	241	304077	48.36	144	1.67	2112	1262
Dean's Office	108	87259	13.24	87	1.24	1003	808

<b>Total</b>	4031	4757530	<b>747.7</b>	1601.0	2.5	2972	1180.2
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Table 8: Air Travel vs. Department. Dean's Office includes all non-departmental staff. MRSEC is part of Physics, and Forensics is part of BMB.

We were also able to compare the distribution of Air Travel by Haul Type by the entire College with the 2006-2007 estimate performed by Travel Services, as seen in Table 9.

UP FLIGHT HAUL BREAKDOWN		ECOS DISTRIBUTION 2019
AIR DISTANCE	Empirical Proportion of Trips, UP '06-'07	Proportion of Trips
Short Haul (<= 300 miles)	18%	6%
Medium Haul (> 300 miles)	39%	38%
Long Haul (> 2300 miles)	43%	57%

Table 9: Distribution of Haul Types for each flight taken by a typical PSU employee during 2006-2007 versus that for the typical ECoS employee during 2019. EMS used the Empirical Proportion because their data lacked a field for mileage.

Table 10 below summarizes the Air Travel emissions and Haul breakdowns for ECoS during CY2019 in full.

Computed Total ECoS Air Travel Use and Emissions CY2019				
Haul	Short Haul	Medium Haul	Long Haul	Total
Count	1384	1992	654	4030
Total Mileage	2.67E+05	1.80E+06	2.69E+06	4.76E+06
Units	miles			
Average Mileage	193	905	4111	1181
Units	miles / trip			
Emissions	57.99	241.98	447.78	<b>747.75</b>
Units	MtCO <sub>2</sub> e			
Emissions per Trip	0.04	0.12	0.68	0.19
Units	MtCO <sub>2</sub> e / trip			

Table 10: Air Travel emissions and mileage by Haul Type for ECoS during CY2019.

Global Programs also participated in a significant amount of Air Travel, and we summarize our results below in Table 11. Because there was only one experience assigned to ECoS, the total emissions are relatively low: only 33 MtCO<sub>2</sub>e.

Computed Total ECoS Embedded Global Programs Emissions CY2019				
Haul	Short Haul	Medium Haul	Long Haul	Total
Count	0	0	23	23
Total Mileage	0.00E+00	0.00E+00	2.00E+05	2.00E+05
Units	miles			
Average Mileage	---	---	8701	8701
Units	miles / trip			
Emissions	0.00	0.00	33.33	<b>33.33</b>
Units	MtCO <sub>2</sub> e			
Emissions per Trip	---	---	1.45	1.45
Units	MtCO <sub>2</sub> e / trip			

Table 11: Emissions related to travel during an embedded Global Programs experience during CY2019.

Based on the EPA guidance on Haul type, we can plot the emissions due to flying against flight distance of Table 10:

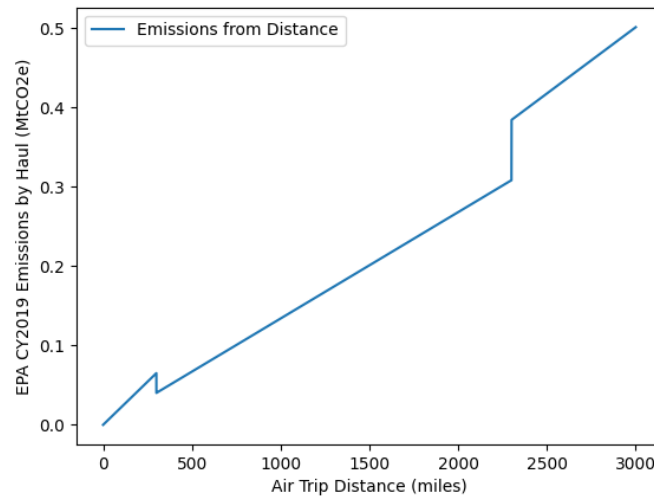


Figure 5: EPA rule for emissions due to flying versus distance of the flight. This plot is piecewise defined over Short Haul, Medium Haul, and Long Haul.

This plot suggests that there exists an interval of distances (between 300 and 500 miles) over which certain “Medium Haul” trips can actually produce fewer emissions than “Short Haul” trips, despite being longer. The EPA’s oversimplification of emissions factors likely explains the presence of this feature, so we suggest not to assign too much meaning to this special interval of distances. The purpose of this plot is mostly to illustrate how emissions grow essentially linearly with distance.

### 3. Commuting and Car Travel

We analyzed data received about Commuting and Car Travel to produce a few summary statistics for ECoS during 2019. The median one-way commute was only 2.50 miles for any commuter at ECoS. But the average distance was greater: 9.14 miles. This may seem short (to a driver), but 9.14 miles is a long distance over which to expect an employee to consider alternate means of commuting such as bicycling or public transit, especially given the lack of infrastructure for these types of transit in areas outside State

College. The reality for ECoS is that we mostly rely on personal vehicles to get to work. Commuters outside a 15-mile radius of campus produce half of the commuting emissions, whereas the commuters living within 15 miles make up the other half. Table 12 below summarizes these statistics:

STATISTICS		
PARAMETERS	VALUES	Units
Median 1-way Commute	2.50	miles
Mean 1-way Commute	9.14	
OPP FY16-17 Median 1-way	8	
OPP FY16-17 Mean 1-way	13	
50-th Percentile for Emissions	15	

Table 12: Summary statistics of ECoS commuters. OPP performed a study in 2016-2017 to analyze commuters at UP, so we compare ECoS to the sampled UP commuters.

The average distance of a trip taken by an individual from ECoS renting a vehicle (or using a personal vehicle and receiving a reimbursement) during 2019 was 276 miles total. ECoS employees took a total of 1768 ECoS-related trips, or just over one trip per person in the College on average. The emissions due to a typical trip was 0.11 MtCO<sub>2</sub>e. Table 13 below summarizes these results.

ECoS Car Travel (Non-Commuting) Use and Emissions CY2019	
	Total
Trips	1768
Average Cost per Trip	\$160.25
Cost	\$283,321.87
Total Distance	488535
Units	miles
Average Distance	276
Units	miles / trip
Total Emissions	197.37
Units	MtCO <sub>2</sub> e
Emissions per Trip	0.11
Units	MtCO <sub>2</sub> e / trip

Table 13: Computed Car Travel for ECoS during CY2019, and related summary statistics. This includes all reimbursed/rental trips by car, either University Fleet or personal.

#### 4. High Performance Computing

Staff at the ICDS were able to summarize the CPU Usage according to the department of the PI requesting the services by month (see Figure 6). Summing across all months in 2019, we learn that ECoS requested a total of just over 20,800,000 CPU Hours. Compare this to the total of over 99,100,000 CPU Hours

requested across the University. Therefore, the percentage of the energy utilization at the Tower Road facility that can be attributed to ECoS should be about  $p = 21\%$ .

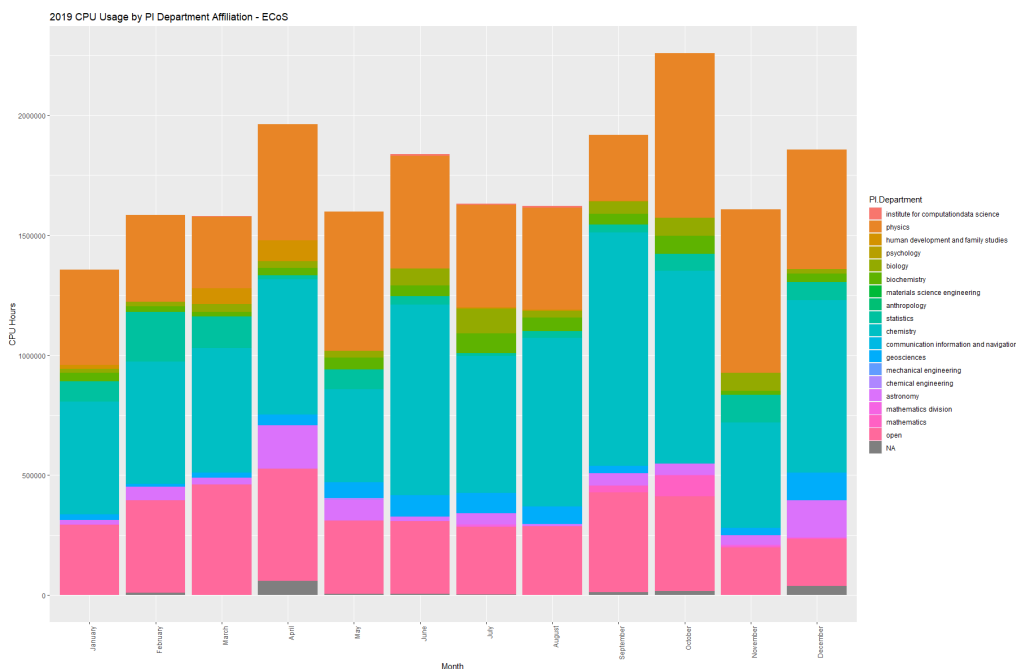


Figure 6: CY2019 CPU Usage by PI Department Affiliation in ECoS. Produced by ICDS, Carrie Brown.

We summarize the results of the computation described in the *Methodology* section in Table 14 below, concluding that ECoS produced roughly 470 MtCO<sub>2</sub>e due to its High Performance Computation throughout CY2019.

Computational Emissions for ECoS CY2019		
Total ECoS Time	2.08E+07	CPU Hours
Total Roar Time	9.91E+07	CPU Hours
ECoS's Percentage	21.00%	
ECoS's IT Power	69.36	kW IT
ECoS's Hosting Power	111.0	kW Hosting
ECoS's Hosting Energy	972163.8	kWh
ECoS's Hosting Emissions	473.8	MtCO <sub>2</sub> e

Table 14: Power and Energy utilization by ECoS for the High Performance Computation services provided at the Tower Road facility, as well as the resulting emissions, CY2019.

## 5. Vendor Emissions

ECoS spent \$11,381,758.42 on supplies and equipment during CY2019. Using Doyle's factor of 0.000257 MtCO<sub>2</sub>e/\$, we produced an estimate for ECoS's Vendor Emissions at 2900 MtCO<sub>2</sub>e. We do not include Vendor Emissions in our inventory for 2019 because of the low confidence in this figure, as discussed in the *Methodology* section. We were able to produce Table 15 detailing ECoS's top vendors during CY2019.



Top ECoS Vendors CY2019	
Vendor	Subtotal
FISHER	\$ 1,835,195.51
VWR	\$ 1,503,160.20
AGILENT TECHNOLOGIES	\$ 404,755.56
SIGMA	\$ 343,305.88
ILLUMINA INC	\$ 302,067.10
GE HEALTHCARE BIO SC	\$ 272,835.12
PRAXAIR DISTRIBUTION	\$ 265,480.79
BRUKER BIOSPIN CORP	\$ 207,996.00
JANIS RESEARCH COM	\$ 203,985.92
General Stores (OPP)	\$ 158,687.44
SHIMADZU S	\$ 151,062.35

Table 15: Top vendors for ECoS during CY2019. For instance, ECoS spent a collective \$1,835,000 on supplies and equipment from Fisher Technology.

## Future Work

This section makes recommendations for future ECoS GHG inventories and outcomes related to the results of those inventories.

### 0. Procedure

Future inventories should greatly improve on the procedure for estimating Vendor Emissions. Future inventories should also consider many other types of Scope 3 emissions, including those related to construction (such as with the upcoming Physics building), building upkeep, telecommunication & IT services, and computing services. Adopting a [hybrid top-down approach](#) to computing most Scope 3 emissions is a reasonable first approach.

If ECoS decides to invest in carbon offsets (as explained in the following section), any future GHG inventory must separate emissions from offsets, transparently computing a net footprint. Such a structure will allow us to see how well we are reducing our GHG output regardless of our purchased offsets.

Inventories for years beyond the installation of the solar array from Penn State's 2020 Power Purchase Agreement with Lightsource BP will need to consider the emissions factors and Scope of Electricity. It is important to note that even with this Power Purchase Agreement and with other onsite steam generation (based on natural gas), a significant portion of Penn State's electricity is still purchased from the grid, which comes with the standard EPA eGRID emissions factors. Therefore, any marginal reductions in electricity use will only be reducing our purchased, not generated, electricity. Shelley McKeague and other personnel at OPP will be able to produce more accurate emissions factors for this utility depending on the year.

Another important aspect of Electricity not considered in this inventory is transmission loss, or the amount of power lost as electricity makes its way from where it is generated to where it is used. The 2019 eGRID factor for transmission loss in our region was 5.1%. That means our metered data in electricity is likely 5.1% lower than the amount generated at the plant, meaning our emissions from electricity are actually larger than calculated. Deciding how best to correct for transmission loss should be a topic considered in future inventories, and ECoS should work with OPP to develop a reasonable approach to accounting for transmission loss.

### 1. Next Inventory: CY2020

Beyond the procedural differences, we believe the next inventory will serve a distinct purpose compared to this one: in early CY2020 commenced a global pandemic lasting the rest of the year (and still into 2021). Remote courses, conferences, and work collectively reduced our University's GHG emissions. While our footprint is not likely to have dropped by even 25% between CY2019 and CY2020, we believe the next year's inventory might reveal operational advantages of many of the telework practices adopted during the pandemic. Such an inventory would help to identify and quantify these advantages, as well as provide an impetus to develop modified/hybrid approaches to our typical workflows that value sustainability, wellbeing, productivity, time savings, quality education, quality work, and flexibility. We should also look to the University-wide inventory for a broader perspective on the effects of the pandemic on GHG emissions across Penn State.

## 2. Collaboration

ECoS must collaborate with the Sustainable Operations Council through the Sustainability Institute to stay up to date on the best GHG inventorying practices, as well as to encourage other units to perform their own inventories.

We further recommend that ECoS learn from the work of Drawdown Scholars under the supervision of Meghan Hoskins of the Sustainability Institute, who will be investigating University Scope 3 emissions in the coming months.

We also encourage ECoS to collaborate with relevant offices to ensure that our means of collecting data like procurement expenses, air travel, car rentals, and more can each be more useful and readable. In particular, there is room to improve procurement documentation so we can more easily extract information about the items purchased within each order.

## 3. Evaluation and Action

For ECoS to assess its progress in GHG drawdown, the college should make performing a GHG inventory a regular occurrence. EMS is already performing a second inventory for their next fiscal year. More specifically, a regular inventory will show that ECoS is committed to sustainability, will provide accurate numbers from which to plan and make decisions, will provide an educational opportunity to the inventorying faculty/staff/student(s), and raise the bar for other units to do the same. Furthermore, an ensemble of inventories happening across every unit at Penn State will positively influence the University to hasten its pursuit of GHG drawdown.

ECoS should assign specific actions tied to the outcome of its future inventories: for instance, ECoS could preemptively agree to meet a certain rate of drawdown each year; and if it does not, it would make itself liable to offset the excess emissions. We recommend that ECoS consult with its Sustainability Council for guidance in setting up such a series of actions tied to its inventories.

## Opportunities for Action

### 0. Emissions Reductions and Offsets

With the totals from their first GHG Inventory, EMS intended to invest in carbon offsets to attempt to counterbalance a large portion of their carbon footprint. Carbon offsets are carbon mitigation projects that allow investors to claim emissions reductions without having to actually reduce their own GHG output and demand. They rely on a provable “net effect.”

It has yet to be seen what types or costs of offsets, or in lieu of which emissions EMS will choose to pursue this strategy. Carbon offsets can be a relatively cheap option for reducing a unit’s carbon footprint, but as scientists, we need to be circumspect about their efficacy. Richard Kim and Benjamin Pierce of the University of Pennsylvania produced [a comprehensive overview](#) that explains why carbon offsets are a viable temporary solution for reducing one’s GHG emissions, as well as how to properly evaluate carbon offsets. For the purposes of this report, we offer the following recommendations in parallel with those of Kim and Pierce:

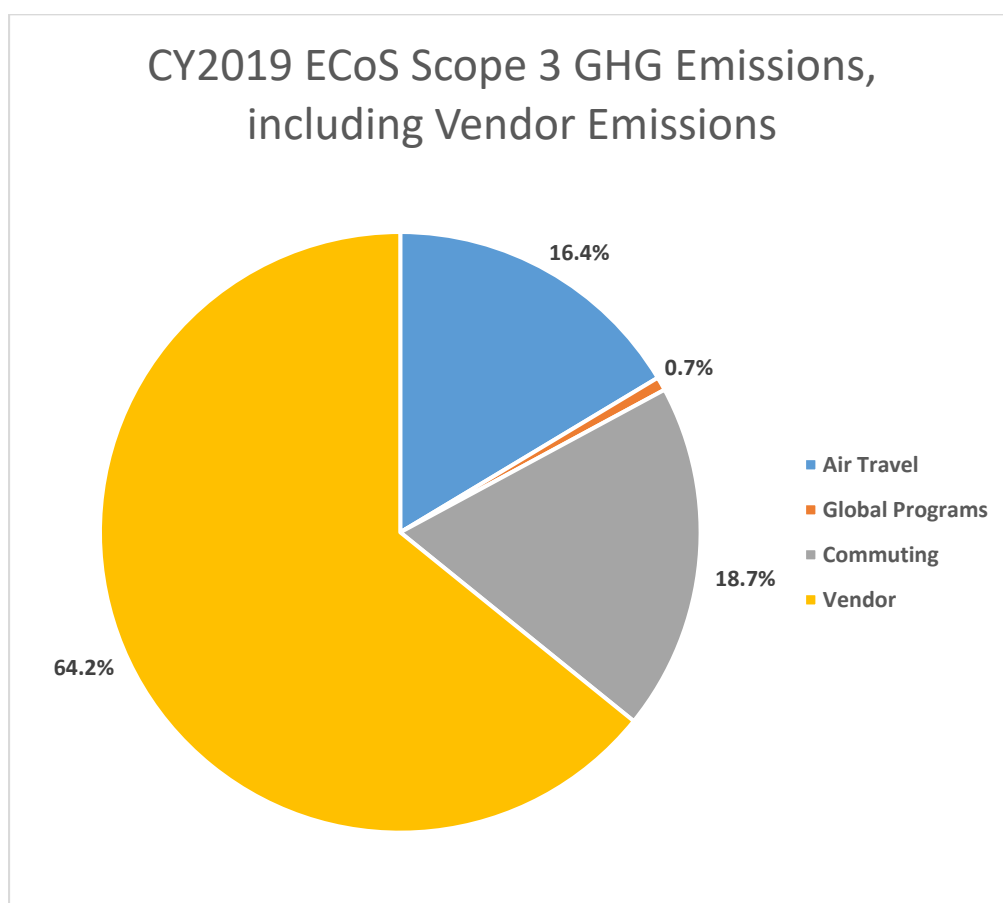
- ECoS should consider purchasing carbon offsets as a short-term or partial carbon strategy while simultaneously pursuing overall carbon emissions reductions. ECoS should especially consider offsetting the emissions due to its use of Utilities, Air Travel, and Car Travel, which are less directly under its operational purview.
- ECoS should develop and adopt an official set of criteria for high-quality carbon offsets (including criteria on Additionality, Permanence, Absence of Leakage, and Verification). The [Gold Standard](#) is an existing, relatively strict set of criteria that additionally emphasizes the Sustainable Development Goals in its evaluation of offset projects.
- ECoS should collaborate with EMS, the Sustainability Institute, and other partners across the University to ensure that its intended offset purchases align with the ECoS and University Strategic Plans and UN SDGs. Carbon offsets should confer positive co-benefits as described by the [Duke Carbon Offsets Initiative](#).
- ECoS should seek financial support from the University and external grants/funds to help afford these carbon offsets.

Carbon offsets can be an effective short-term solution, or a jumpstart to real change, but they are not a replacement for true carbon reductions. In the following list, we provide an interpretation of the results of this inventory on a macro scale:

- Based on our inventory, we see that utilities comprise the large majority (91.8%) of our college’s emissions. This means that, at the moment, reductions efforts for utilities are likely to have the largest impact on our college’s emissions. We recommend that ECoS aggressively reduce its utility use as soon as possible for this reason. Because the University has recently pursued alternative forms of energy production, we should expect our true emissions due to utilities to fall over the coming years “for free,” i.e., with no intentional participation by ECoS. As discussed in the subsection on *Advocacy at the University Level*, the emissions factors related to our utilities are not within our direct control, so if the University continues to pursue alternatives to fossil fuels, we will be left to address emissions from Scope 3.
- We recognize that ECoS’s Scope 3 emissions, as they have been computed and reported in this inventory, seem small. However, these emissions will not go away if the University achieves even

100% renewable energy: we will still depend on cars, planes, and procurement for our usual operations. For that reason, we propose that ECoS specially consider its Scope 3 emissions separately from its Scope 1 and Scope 2. If ECoS wants to set meaningful goals related to this inventory, we suggest that it uses Scope 3 emissions—rather than utilities emissions—as its gauge for progress. Scope 3 emissions are much more indicative of our college’s habits and common practices. This is not to take away from the fact that our Scope 1 and Scope 2 comprise the majority of our emissions, and should be addressed as soon as possible through our own actions as part of the University.

- Within Scope 3 emissions, Vendor Emissions may be the largest category considered in an “Operational Controlled Approach.” We recommend that ECoS invest in developing a more thorough understanding of its procurement practices and pursuing meaningful corporate partnerships, as will be discussed in the subsection *Sustainable Corporate Engagement*.



*Figure 7: Scope 3 emissions for ECoS during CY2019, including Vendor Emissions. This chart is meant to visualize how our various Scope 3 emissions compare to one another. The number for Vendor Emissions is not official nor accurate, just an order of magnitude estimate.*

In an effort to meaningfully reduce ECoS’s carbon footprint, ECoS should consider the following drawdown strategies:

- ECoS should perform a space evaluation to identify excess utility use. Surveys of space and energy used by staff, faculty, and researchers could extract useful information from individuals who notice excessive space/utility waste in close proximity to them.

- ECoS should encourage remote work and event participation. Air Travel, Car Travel, and Commuting can all be reduced with better incentives and infrastructure to host or attend events remotely. ECoS should ensure that there are adequate resources, technologies, and troubleshooting measures to promote virtual or hybrid meetings and conferences.
- ECoS should consider funding Penn State-specific or local drawdown projects that meet our College's Strategic Plan.
- ECoS should seek support and counseling from external drawdown strategists who specialize in decarbonizing research institutions in order to develop an even stronger decarbonization plan.
- ECoS should continue to incentivize energy-efficient, minimal-waste vending practices. However, this should occur in a way that does not encourage replacing perfectly good supplies/equipment for marginally better versions.

Beyond these operational changes, ECoS has many other opportunities to take action to reduce its environmental impact. Additional strategies are outlined below.

### 1. Green Labs and Sustainable Operations

Kristin Dreyer, Program Director for Education & Outreach at the Penn State Materials Research Science & Engineering Centers (*MRSEC*), has assembled a group called the Green Labs Network to develop a program to encourage sustainability literacy and operations across the many labs at Penn State. The Green Labs program originated at UC Davis, with the intent to challenge researchers and classes to choose sustainable practices. At Penn State, the Green Labs Network imagines a system that connects labs with expert solutions to pursue operational or academic improvements in regard to UN Sustainable Development Goals, evaluates those improvements, and awards labs with corresponding certifications and incentives (see below).

ECoS has the opportunity to pilot such a program when it forms, as well as reevaluate its lab spaces to prioritize utility and space efficiency. For instance, ECoS should develop an incentive for using physical space efficiently: at Penn State, labs do not pay for the space they use. There should exist an incentive process to award higher overhead return to labs that generate more research output and employment per unit of space or energy than their peers. It is important to note that HVAC systems, lighting, and occupancy control are generally outside of the control of the college/laboratory; instead, we need to be creative in developing solutions for utilizing ECoS spaces more efficiently, for example providing flex spaces for undergraduate researchers and others who do not use lab/office spaces full time.

A comprehensive analysis of the environmental impacts of labs within ECoS was beyond the scope of this inventory. However, labs have the ability to pursue sustainability literacy and drawdown themselves. For example, the Green Labs program will have the ability to help labs perform GHG inventories of their own. To reiterate a point made previously: OPP performed an analysis of its data during 2016-2017 that quantified the differences in energy intensity between buildings of various functions. It was found that laboratory buildings were between 1.62 and 1.91 times as energy intensive as buildings primarily characterized as general purpose office/classroom spaces per unit area. Because ECoS is comprised of a significant number of researchers and labs, the onus is on us to learn and adopt responsible practices related to sustainability.

ECoS has a further opportunity to demonstrate its commitment to encouraging sustainable, livable spaces with the upcoming construction of a new Physics building. ECoS should take this chance to advocate for,

and invest in, more sustainable options, including requirements that extend beyond OPP D&C standards and LEED certification.

## 2. Sustainable Corporate Engagement

Vendor Emissions are a singular component of sustainability within our corporate engagements. Suppliers, corporations, and other institutions are collectively making progress in evaluating and improving their environmental and social impacts, including the emissions occurring throughout the lifecycles of their products. As a unit with millions of dollars spent annually on suppliers of lab equipment, office supplies, and other vended items, and a unit that is equipped to perform inventories of our own, we should develop relationships with corporations to start the conversation about sustainable practices and evaluations. Currently, guidelines on seeking sustainable suppliers are far from developed, especially at Penn State. Individuals from the Sustainability Institute working with Penn State's Procurement Services will certainly work to improve such guidance, but we must form relationships with our current suppliers in order to even start an evaluation process.

In 2010, the EPA produced a [guide for Managing Supply Chain GHG Emissions](#); we recommend that ECoS works to adopt the EPA's strategies for engaging suppliers in sustainability:

- a) **Strategically choose which suppliers to engage:** focus on our largest suppliers, or smaller suppliers that provide critical or energy-intensive equipment.
- b) **Keep the questions simple:** pursue broad, possibly qualitative questions to emphasize sustainability as a whole; do not get caught up in the numbers.
- c) **Build trust with suppliers:** demonstrate cost savings, willingness to improve together, and respect for business-sensitive information.
- d) **Provide training and capacity-building:** offer guidance to suppliers to estimate their GHG emissions and other sustainability metrics.
- e) **Leverage third-party programs to strengthen internal supplier engagement efforts:** collaborate with other units and institutions to study shared suppliers or industries.
- f) **Conduct pilot initiatives before scaling up:** The Carbon Disclosure Project's Supply Chain initiative has developed [questionnaires](#) for various kinds of suppliers to investigate their sustainable metrics.

ECoS can begin by requesting sustainability snapshots from its top vendors and their relevant competitors to determine standards by which equipment and supplies are purchased and advocate for the university to partner with vendors that meet our sustainability requirements. These snapshots can help guide departments and individual laboratories in deciding from whom to order supplies. Procurement Services will play a critical role in helping the College obtain snapshots from specific vendors. However, departments and laboratories must be conscientious to inquire with sales representatives when ordering supplies.

Computing emissions related to Procurement can be complicated, as explained in the [UC Berkeley 2009 Procurement Carbon Footprint](#) document. The main ingredients required to perform a GHG inventory for a particular vendor would include an open channel for communication, as well as estimates on the footprints of the materials going into producing the product, the process using those materials to make the product, and the means by which the product is transported to ECoS. We believe that the Corporate

Engagement Center, Office for Innovation, and Office for Student Engagement will serve as potential resources for establishing industry contacts and performing this extended inventory task.

We also have the opportunity to collaborate with corporations in order to research and perform decarbonizing projects. Much like how Lightsource BP sponsored Penn State's latest solar farm in Franklin County, ECoS may find further opportunities to decarbonize with the help of the private sector.

### 3. Advocacy at the University Level

Highlighting a large caveat of this inventory: not all emissions assigned to ECoS are within the control of the College to eliminate directly. Because ECoS, like all other units at University Park, relies on centralized utilities, we cannot control the emissions factors related to our utility use. Nor can essential academic, research, or operational procedures be canceled. Much of our future drawdown success could instead be achieved by changes made at the University level. At this level, OPP can pursue renewable energy projects such as the [Franklin County Power Purchase Agreement](#) completed in mid-2020 (projects like these work to reduce our reliance on the energy grid, but they do not solve our thermal energy requirements. Thermal is a more difficult and expensive issue for the University).

This also begs the question: what portion of operational ECoS emissions should ECoS be responsible for eliminating? Should the University leverage its corporate partnerships and massive operational forces to pursue emissions reductions across all of its units? Moreover, if neutrality cannot be achieved without dedicating significant additional funding, will the University dedicate the necessary funding? We note that Penn State could become "carbon neutral" within days if it would purchase Renewable Energy Credits to cover its Purchased Electricity and purchase carbon offsets to cover everything else. This is the strategy employed by multiple universities like [Arizona State University](#), as well as most other schools that are "carbon neutral." The reality of our situation is that actual operational reductions are hard and more expensive than the current cost of offsets.

ECoS will benefit from pursuing drawdown now for multiple reasons:

- ECoS is comprised of a prolific spectrum of faculty, staff, and students. As highlighted by the ECoS Sustainability Town Hall in March 2021, ECoS takes a unique approach to sustainability compared to other units at Penn State. Tapping into the creativity and skills of our personnel will evoke drawdown strategies suited to our College, and possibly lead to University drawdown even sooner.
- The University has not committed any additional funds that specifically target carbon reduction independent of financial savings. So far, the University has required any project approved for funding through the Energy Savings Program to be budget-neutral and have a relatively short Return on Investment. If our College wishes to see progress between this inventory and the next, we need to show individual agency now.
- While many administrators and individuals are excited for the work of the Carbon Emissions Reduction Task Force, which will guide the University towards its best options for drawdown over the next six months, it would be pragmatic not to expect the report and recommendations arising from this Task Force to solve all of our college's problems. Unfortunately, outcomes related to the [Waste Stream Task Force](#) (a Task Force charged in 2018 to create "fiscally, environmentally, and socially responsible goals and principles to guide the University's procurement, operational, and solid waste management decisions while also providing opportunity for academic engagement") have received little attention despite being accepted by the University. In a conversation between Executive Vice



President and Provost Nick Jones and SSAC in April 2021, he apologized for the slow progress of those outcomes, and promised to look into the issue. Because of the momentum and surrounding climate action, we do not anticipate the University being as slow with implementing emissions reduction projects, but we have to recognize the possibility of a slow rollout. Moreover, these projects will take several years to implement.

- ECoS has the chance to champion emissions reductions in its various forms, with the special talent to develop scientific approaches to pursue this ambitious goal. We have the opportunity to share our progress and expertise with other units across the University and beyond, and we should take that opportunity.

We cannot control our entire footprint; much of it is determined by the University. Thus, it behooves us to advocate for appropriate actions to be taken at the University level. ECoS should establish what sources of emissions are beyond its control and subsequently submit formal requests to the University to pursue drawdown solutions addressing them.

#### 4. Education and Leadership

ECoS has opportunities beyond operational activities to improve sustainability in all its forms, especially through its education and outreach. Youth-led initiatives, such as Penn State Climate Action, Sunrise State College, Eco Action, and the Student Sustainability Advisory Council have collected to demand the advancement of sustainability in education across Penn State. ECoS Sustainability Council Undergraduate Member: Divya Jain, has especially spearheaded this effort through her multiple roles. The ECoS Sustainability Council has done the work of mapping current syllabi across the entire College to the UN SDGs, and held a Town Hall in March 2021 to showcase notable sustainability-focused courses in ECoS.

All educators in ECoS should consider how they can incorporate sustainability into their courses; it might in fact be easier than we think. ECoS should establish a set of resources to guide instructors and course planners on how to get started in the process of deciding how sustainability may fit into their curriculum. Moreover, we should collaborate with other colleges, labs, Universities, students, staff, and community members to seek creative ways to accomplish this.

Much as ECoS is a piece of the whole University, Penn State lies within central Pennsylvania, and as a land grant institution is uniquely responsible for stewarding the local environment. ECoS should formally consider its responsibility to the greater Pennsylvania community, as well as to other units across the University. We should continue to assist other units, universities, and corporate partners with performing their own sustainability snapshots.

## Conclusion

ECoS has the opportunity to advance sustainability on a multitude of fronts. This Greenhouse Gas Emissions Inventory serves as a platform to guide ECoS to a more sustainable, resilient future. We challenge ECoS to consider emissions reductions and offsets, sustainability-focused education and corporate engagement, and advocacy for sustainability at the University-level.