Sustainability at Carnegie Mellon:
A PATH FORWARD

Student Project Report

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Disclaimer and Explanatory Note

This report is the product of a Carnegie Mellon University (CMU) undergraduate research project, in which students from several academic disciplines combine their talents to explore a policy issue involving technology. For one semester, these students conduct research, and then present their results under the direction of CMU faculty and graduate students. This report has not been critically reviewed by experts in the field.

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Project Participants

This is a joint study conducted by students of the Department of Engineering and Public Policy (EPP) and the Department of Social and Decision Sciences (SDS) at Carnegie Mellon University (CMU) for the Fall semester of 2018 under the classes 19-452: EPP Projects and 88-452: Policy Analysis Senior Projects.

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The faculty, project manager, and students would like to thank the members of the Review Panel for their time, effort, and feedback on this report.

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Executive Summary

In discussing sustainability at Carnegie Mellon University, this report expands upon a previous analysis of CMU's carbon footprint (Pittsburgh to Paris, 2017) in three main ways: it 1) provides a more comprehensive analysis of CMU's environmental impacts beyond carbon emissions, 2) incorporates non-environmental aspects of sustainability, and 3) analyzes and recommends a more general set of actions to move CMU forward in sustainability. It begins with a definition of sustainability and defines an evaluation framework for the university's current sustainability actions and proposals. The analysis is divided into several different areas: Campus Buildings, Water and Waste Management, Transportation, Education and Research, Social and Behavioral Dimensions, Economic and Financial Aspects, and Organizational Structure. After separately evaluating these dimensions, overall conclusions and recommendations are presented.

CMU does not have a centralized office of sustainability. Several different entities on campus, such as Facilities Management Services and the Green Practices Committee, independently address certain aspects of sustainability, as do a number of individuals on campus. Overall, however, such activities are highly decentralized, without any high-level organization, structure, coordination or communication. Creating a centralized, high-level office of sustainability would build on these disparate efforts and significantly enhance CMU's sustainability activities, providing a competitive advantage in campus operations, research, and education.

In regard to campus buildings, sustainability includes building standards, certifications, energy use, emissions, and the materials used for construction. There is a need for the university to update its standards to more fully embrace sustainable practices. The lack of adequate and functioning monitoring systems, such as water and steam meters, also makes it difficult to track the use of resources and to develop and prioritize initiatives aimed at reducing the energy consumption and related environmental emissions of campus buildings.

CMU currently engages in a number of activities to reduce its water use intensity and waste production. However, there is again a lack of critical data in these realms, making it difficult to fully assess and target appropriate sustainability policies. CMU's current purchasing system also could be substantially improved to better track key material flows. Waste reduction, reuse, and recycling efforts are further hampered by a general lack of knowledge and the prevailing cultural norms of the campus community, including institutions such as departments as well as individual students, staff and faculty.

In the area of transportation, indirect emissions from CMU-related travel are significant, especially emissions from air travel. Existing carpooling and bicycling options also are underutilized as alternatives to individual vehicle travel. The introduction of some form of carbon offset program for business air travel, plus improved incentives for more sustainable means of commuting, would make CMU's transportation-related activities far more sustainable.

There is significant potential for CMU to also expand its educational and research profiles related to sustainability. Inventories of current CMU activities in these areas developed as part of this project revealed that they are concentrated in specific focus areas and academic departments, mainly related to environmental issues and energy use. Moreover, such activities are quite decentralized. Given the breadth of sustainability issues and related academic interests, there appear to be many opportunities to expand and improve cross-campus programs and collaborations that can enhance CMU's educational mission as well as the pool of available research funding.

CMU has taken a number of actions to promote social sustainability in several domains. However, information in this realm is limited and more data and program evaluations are required. CMU also could apply its existing strengths in behavioral research to key topics in sustainability, improving both the campus environment and the research enterprise in this area.

One general finding is that data on a variety of metrics tied to sustainability at CMU are lacking across key areas. We recommend that the university prioritize the collection and analyses of data to better quantify and characterize the various metrics of sustainability identified in this report, so that it can establish effective goals and initiate, evaluate, and track the progress of programs designed to enhance sustainability across the campus, including activities in education, research and campus operations.

We further recommend that CMU establish a high-level, centralized Office of Sustainability to coordinate, promote, and report on the progress of sustainability efforts. Such offices are common among our peer institutions. In contrast, CMU's current sustainability activities are largely ad hoc and decentralized, mostly involving individuals or groups acting on their own initiative. Providing central coordination and leadership for these activities, and elevating their priority to accord with the stated, core principles of the university, is therefore crucial. Such an office would directly demonstrate CMU's commitment to sustainability, put it on par with our peer institutions, and benefit the campus community by facilitating funding, educational, and research opportunities, as well as improved campus operations. We recommend that this office be jointly sponsored by the Office of the Provost and the Division of Operations, supported by an advisory committee of other relevant campus units. Further details of this recommendation are provided in Chapters 8 and 9 of this report.

Chapter 1: Introduction

The United Nations (UN) began advocating for global sustainability initiatives in a 1987 report entitled, *Our Common Future,* otherwise known as the Brundtland Report. Written to reflect the discussions held by the World Commission on Environment and Development, the text states that the motivator and basis for sustainability is that *"humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland Commission 1987). Since this initial push towards global sustainability, nations, states, institutions, and individuals have worked together to pursue a more sustainable future.

Sustainability has become a growing field of study encompassing many issues, such as ecological protection, environmental health, economic viability, and social well-being. The practice of sustainability has become a way for organizations to move towards the forefront of technological industries and modern values. Educational institutions are particularly regarded as a major source of thought leadership and emerging technological innovation. As Carnegie Mellon University (CMU) continues to demonstrate its prominence in comparable fields, it is imperative that the university also recognize the growing need for concrete measures in sustainability. Past studies have shown that most of CMU's peer institutions already have committed to sustainability practices and programs not yet initiated at CMU. Thus, the present study seeks to identify and characterize the current status of sustainability activities at Carnegie Mellon, and ways in which the university can direct increased attention to sustainability to maintain its prestige and voice of authority within higher education.

1.1 Definitions of Sustainability

In constructing a comprehensive definition of sustainability for CMU, we first examined global definitions of sustainability for a general overview. We then proceeded to analyze definitions in the context of higher education, starting with the definitions used by other institutions. Finally, we established a working definition of what sustainability at Carnegie Mellon means given the university's values and operational infrastructure.

1.2.1 Global Definitions

Modern UN sustainable development goals, published in the *2030 Agenda for Sustainable Development*, are comprehensive and include aspects beyond the typical environmental focus of sustainability, as shown in Figure 1.1. The environmental dimensions are those that are most often regarded in the topic of sustainability, such as "affordable and clean energy" and "climate action". However, the goals also include non-environmental concepts not commonly associated with sustainability, such as "no poverty" and "quality education". The UN definition and goals thus expanded our focus to include not only environmental aspects of sustainability, but also social and economic dimensions ("Social Development for Sustainable Development").

Figure 1.1 Sustainable Development Goals ("Social Development for Sustainable Development")

1.2.2 Triple Bottom Line

The literature details— three aspects or "pillars" of sustainable development—social, environmental, and economic—that are generalizable to any organization (Folke et al. 2016). Sustainability also has been frequently characterized as a "triple bottom line" model, denoted in Figure 1.2, which considers a balance of "people, planet and profit" to be pertinent to the implementation of sustainability. Many modern institutions and businesses have adopted this model in discussing how to generate greater environmental consciousness and business value. The three pillars are recognized and supported by the UN World Commission on Environment and Development and the Organization for Economic Co-operation and Development (OECD).

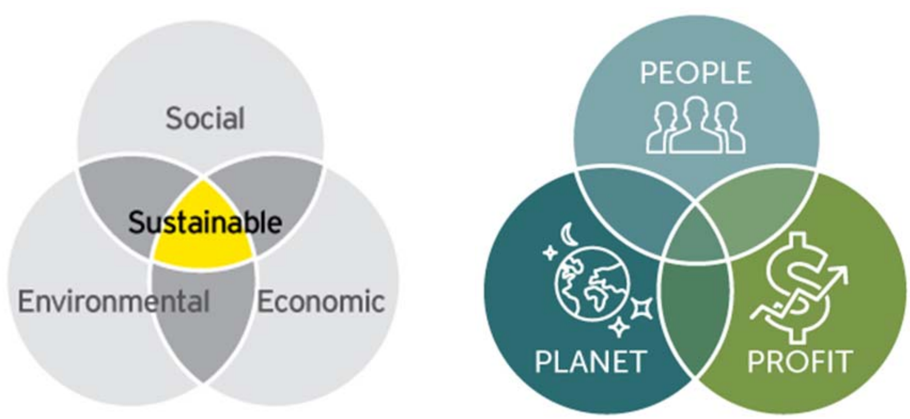

Figure 1.2 Conventional Views of Sustainability in Development through the Triple Bottom Line Model: Sustainable practices involve a focus on People-Planet-Profit, or Social-Environmental-Economic

1.2.3. Definitions in Higher Education

Organizations such as the Association for the Advancement of Sustainability in Higher Education (AASHE) and Higher Education Associations Sustainability Consortium (HEASC) were founded in the early 2000's to make sustainable practices the norm in academia. Based in Philadelphia, PA, AASHE works with institutions in higher education to "enable members to translate information into action by offering essential resources and professional development" in ensuring that "future leaders are motivated and equipped to solve sustainability challenges" ("About AASHE").

AASHE developed the Sustainability Tracking, Assessment & Rating System (STARS) in order to aid institutions in self-reporting sustainability performance. STARS covers the following sustainability categories:

A. Institutional Characteristics
B. Academics
    a. Curriculum
    b. Research
C. Engagement
    a. Campus
    b. Public
D. Operations
    a. Air & Climate
    b. Buildings
    c. Dining Services
    d. Energy
    e. Grounds
    f. Purchasing
    g. Transportation
    h. Waste
    i. Water
E. Planning & Administration
    a. Coordination, Planning & Governance
    b. Diversity & Affordability
    c. Health, Wellbeing & Work
    d. Investment
F. Innovation

STARS judges the ability of institutions to meaningfully impact the community and environment in each of these sustainability categories. CMU submitted STARS reports in 2011, 2013, and 2015, achieving a Silver status recognition in the most recent submission, out of the available status levels of Report, Bronze, Silver, Gold, and Platinum. The rating from 2015 has since expired, and no new reports or ratings are currently available ("STARS Participants and Reports").

1.2.3 Definitions at Peer Institutions

Carnegie Mellon University recognizes twelve peer institutions as listed below, on the left. The institutions on the right were identified by the study group as comparable with Carnegie Mellon, either due to geographic proximity or other similar university characteristics, such as size, organizational structure, and recognition.*

Peer Institutions	Other Related Institutions
1. California Institute of Technology	1. University of Pittsburgh
2. Cornell University	2. University of Michigan
3. Duke University	3. Chatham University
4. Emory University	4. Duquesne University
5. Georgia Institute of Technology	5. Harvard University
6. Massachusetts Institute of Technology	6. Case Western University
7. Northwestern University	7. Oberlin College
8. Princeton University	8. Pennsylvania State University
9. Rice University	9. Purdue University
10. Stanford University	10. Stevens Institute of Technology
11. University of Pennsylvania	11. University of Illinois
12. Washington University in St. Louis	12. University of California Berkeley

A literature review of the 24 above institutions resulted in a distribution of nomenclature, denoted in Figure 1.3. The review involved a detailed examination of institutional definitions, practices, and goals in sustainability – this information was found on websites for sustainability offices, as well as in documents detailing sustainability goals. Faceting the terms within the three pillars of sustainability reveals that a majority of key components fall under environmental sustainability. Social and economic aspects, while considered important, are less often included in university definitions – either because they require fewer administrative resources, there exist departments devoted to similar functions such as financial and health services, or they are less tangible and therefore more complex to define and address.

We concluded that the distribution of keywords would be best represented in five categories; Buildings, Water & Waste, Transportation, Organizational Structure & Social Dimensions, and Education, Research & Behavior. The first three focus on environmental matters, while the latter two focus on economic and social matters.

* In addition, official facilities peers include the University of Chicago, Case Western, Johns Hopkins, University of Rochester and Vanderbilt University.

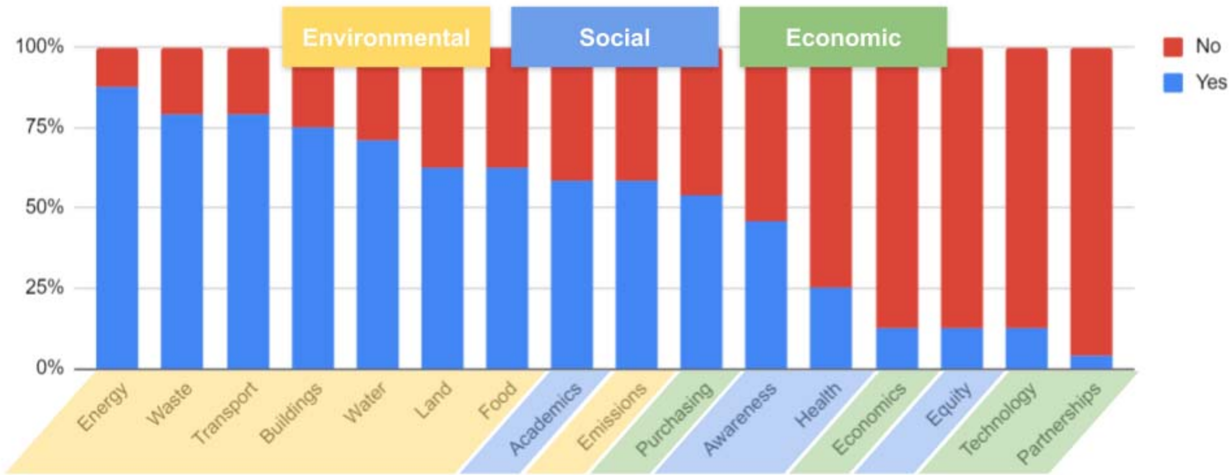

Figure 1.3 Common Sustainability Nomenclature Usage Identified in Literature Review of Peer Institutions

1.2.4 Working Definition of Sustainability at CMU

CMU’s eighth value as defined in its Strategic Plan for the upcoming decade is “Sustainability, reflected in our shared commitment to lead by example in preserving and protecting our natural resources, and in our approach to responsible financial planning” (“Strategic Plan 2025: Our Values”). With consideration of this value, as well as the various sustainability models from our research, the following definition of sustainability was constructed to best describe what sustainability is in the context of Carnegie Mellon:

The environmental component of sustainability includes achieving operations that minimize campus-wide resource use, waste, and emissions. The primary concerns of this component are facility management, construction, procurement, transportation, and water and waste processes. Education and research activities may strengthen knowledge, awareness, and innovation in these domains as well. The economic and societal aspects of sustainability support financial and social longevity through effective financial planning and interpersonal networks. This concerns campus activities, student life, and behavioral functions. Together, these aspects will aid in supporting a university characterized by long-term viability and leadership in sustainability initiatives.

1.2 Study Objectives

Organizations across CMU engage in the discussion and advancement of components of sustainability. However, there is no central body making decisions and advocating for initiatives. An examination of peer institutions and potential internal projects has revealed the need for a unifying body to oversee sustainability projects by articulating university goals, missions, values, funding, and needs with regards to sustainability.

To improve our understanding of where CMU stands in different areas of sustainability, both internally and compared with peer institutions, we contacted campus groups currently involved with sustainability operations, as well as several sustainability leaders at peer institutions. These contacts helped us identify campus needs, define metrics and goals, and ultimately recommend how sustainability should operate and be managed on CMU's Pittsburgh campus.

The objective of this study is to provide direction to CMU by (1) defining sustainability in the context of university operations and (2) establishing sustainability goals and recommendations for these operations at Carnegie Mellon.

1.3 Metrics and Evaluation Framework

The metrics included in this study vary based on the aspect of sustainability under discussion. There is a multidimensional approach to policy evaluation in the domains of environmental, social, and financial impact. Environmental sustainability measures use quota or goal-based figures such as resource use reduction and emission minimization. Economic and social sustainability evaluation use more qualitative approaches, such as value-added models.

Environmental measures of sustainability are usually a measure of resource use reduction. Water usage, electricity usage, materials usage, and food waste are all quantifiable values that we seek to reduce. In addition to reducing resource use, it is important to reduce environmental degradation. Reducing pollution, improper waste disposal, and water contamination are examples of environmental degradation that we aim to limit.

Financial sustainability looks at the cash flows, leadership structures, innovative activities, and professional development networks of an organization. Measures of financial sustainability aim to quantify these categories. Endowment, revenue, expenses, assets, department/office funding, donations, and percent involvement can all be used to benchmark progress. The main goal is to define the value added to the university and its constituents.

Metrics of social sustainability attempt to quantify the impact that an action has on all people involved. One dimension of this is the number of people directly affected by the action. The number of people indirectly affected by the action should also be considered if the action creates significant secondary effects. Another way to evaluate an action is by examining the degree of impact it has on the population. This can be difficult to quantify because negative effects on human life can range from inconveniences to bodily harm; the degree to which an action affects lives is often qualitative. There are ways to use surveys to quantify social sustainability that are explored in Chapter 6 of the report.

1.4 Organization of Report

This report provides an overview of research, metrics, findings, and a set of recommendations and goals for each of the identified dimensions of sustainability. These dimensions are further divided into the following chapters to address sustainability related to: Campus Buildings (Ch. 2), Water & Waste Management (Ch. 3), Transportation (Ch. 4), Education & Research (Ch. 5), Social & Behavioral

Dimensions (Ch. 6), Economic & Financial Aspects (Ch. 7), and Organizational Structure (Ch. 8). Each of these chapters also addresses comparable practices at peer universities, metrics and methods, and potential initiatives that CMU could undertake in promoting sustainability in each respective domain. Lastly, Chapter 9 presents a summary of overall conclusions and recommendations for next steps in promoting sustainability at Carnegie Mellon University.

1.5 Chapter 1 References

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Chapter 2 Sustainability in Campus Buildings

2.1 Introduction

This chapter focuses on the status of buildings at Carnegie Mellon University relevant to sustainability criteria. It is divided into seven sections, which include Building Construction Standards, Building Certifications, Electricity Use in Buildings, Steam and Natural Gas Use in Buildings, Environmental Emissions from Energy Use in Buildings, Cogeneration for Campus, and Conclusions for Campus Buildings.

2.1.1 Current Inventory of Buildings at Carnegie Mellon

There are seventy-nine principal buildings on the Carnegie Mellon University (CMU) campus that operate at all hours of the day (Altschul 2018). Academic and administrative services account for fifty of the buildings, and housing accounts for the remaining twenty-nine (Property Accounting Services 2018). In addition, there are thirty-six other minor structures included in the official building count.

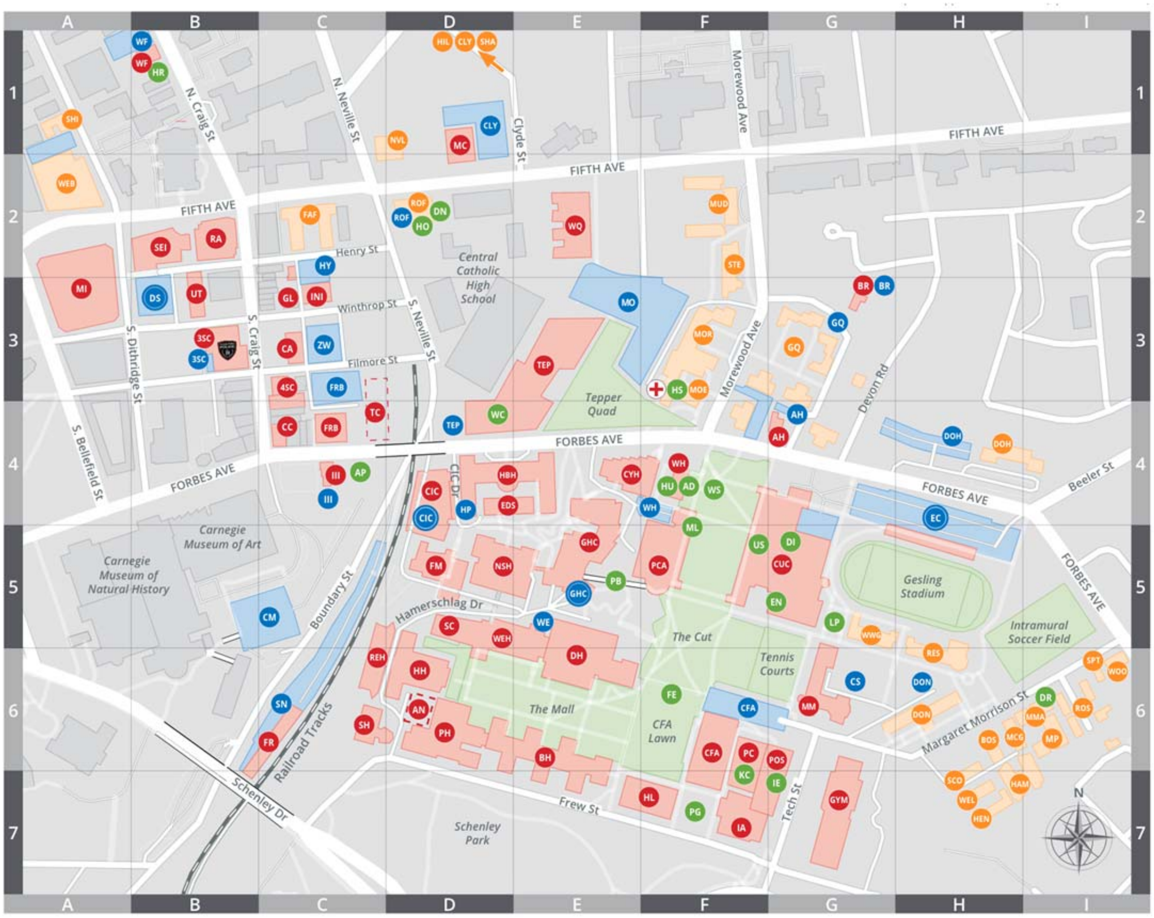

Figure 2.1 Map of Buildings on CMU Campus (Carnegie Mellon University 2018)

To determine the usage of academic buildings, the buildings on campus are first divided into areas. The divided areas are then designated as a certain type of facility and under a certain group of ownership (Property Accounting Services 2018). Figure 2.2 shows the breakdown of the different types of facilities and the square footage area of different building types.

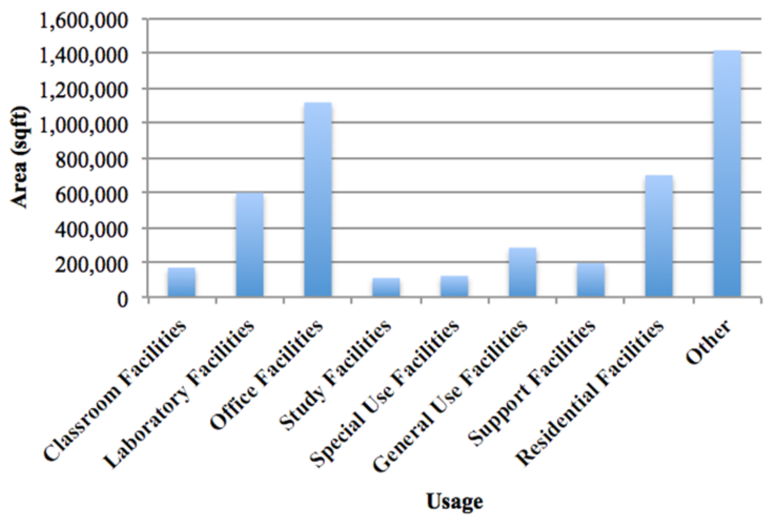

Figure 2.2 Area of Building Usage by Facility (Carnegie Mellon University 2018)

Figure 2.3 reveals the breakdown of buildings based on principal occupant and shows the area of building usage by each occupant.

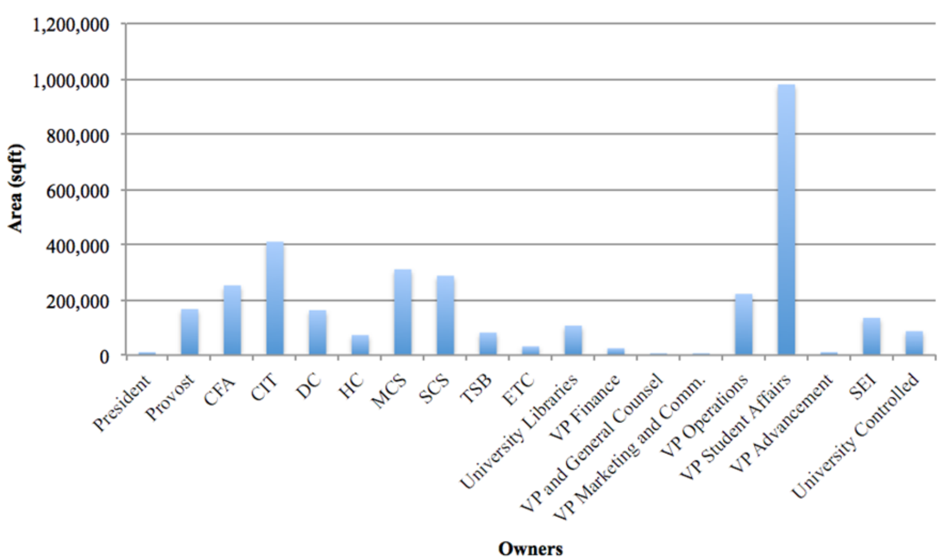

Figure 2.3 Area of Buildings Usage by Ownership (Carnegie Mellon University 2018)

As of the 2017-2018 academic year, there were 4,077 people housed in campus residential buildings (Carnegie Mellon University 2018). The breakdown of the population for each campus housing building can be seen in Figure 2.4.

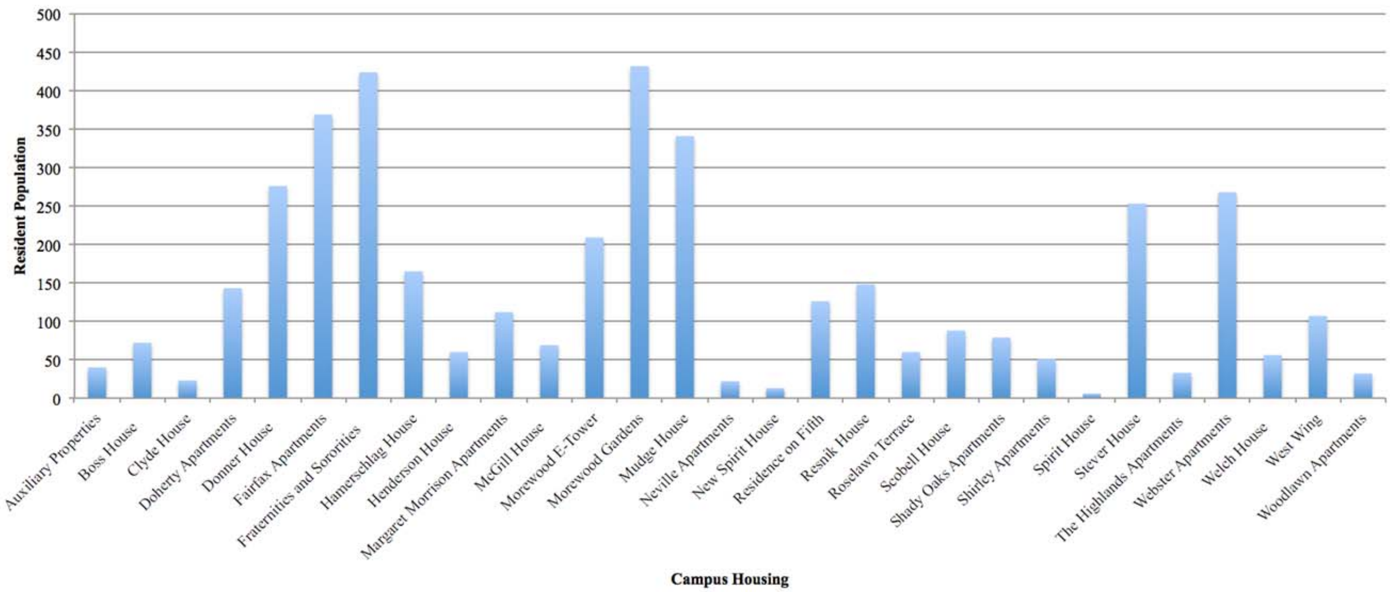

Figure 2.4 Residential Population by Campus Housing Unit (Carnegie Mellon University 2018)

2.1.2 Dimensions of Sustainability for Buildings

Campus buildings can be evaluated in terms of several dimensions of sustainability. Each dimension gives a different perspective of how a building should be considered when defining whether it is sustainable. These dimensions include certifications and standards, energy use, and emissions. Peer universities were assessed to see what dimensions they considered to be important for sustainable buildings, and it was determined that they have converged on a set of similar dimensions.

2.1.3 Metrics of Sustainability

Each dimension covers different issues that arise when determining the sustainability of a building. A method of measurement has been determined for evaluating each of these dimensions. Certifications includes an analysis of the variation of green building space of every campus building, the implications for a certain designation, and a cost analysis of a green certified building. Energy use includes measurements of annual electric and steam usage per area and per population. Emissions include measurements of CO_2 and other air pollutant emissions created (directly or indirectly) by campus buildings, typically via energy use.

Table 2.1 Dimensions and Metrics of Sustainability in Campus Buildings

Dimensions	Metrics
Certifications & Standards	Building Design Standards, LEED, ENERGY STAR, Pittsburgh 2030 District Goals, Simmonds Commission
Energy Use	Annual Electricity and Steam Usage (total, per unit area, per capita))
Emissions	GHGs (equivalent CO_2), and other air pollutants

2.2 Building Construction Standards

Most universities have an office or department responsible for construction on campus. CMU is no different and has an office that manages new construction and renovations on campus.

2.2.1 Standards at Carnegie Mellon

At CMU, there is an office called Campus Design and Facilities Development (CDFD). Based on their website, the office is responsible for "the planning, acquisition, design, construction, and renovation of university facilities. CDFD is part of the University's Operations Division and reports directly to the Vice President for Operations" (Carnegie Mellon University 2018). This office, along with the office of Facilities Management Services (FMS), develops and oversees construction on campus (Altschul 2018). Both offices report to the same vice president at the university; however, the division of responsibilities between the two offices is that CDFD handles capital or large-scale projects on campus while FMS handles projects related to maintenance and repair, such as roof replacements (Altschul 2018).

Responsibility for the maintenance and supervision of CMU's Design and Construction Standards is shared between CDFD and FMS. These standards act as guidelines for contracted engineers and architects, and as such they reflect the university's priorities. The guidelines cover a range of topics. Some of the topics include furnishings, contract requirements, landscaping, concrete, metalwork, and woodwork. Generally, the guidelines help inform contractors what is expected of them when on a university sponsored project.

Despite the intention for the Design and Construction Standards to serve as a resource for the outside parties that work on university projects, the standards document as a whole has not been updated since December 1998. When a 2015 version of the "Instructions to Design Consultants" document was compared to the most recent (October 2018) version, it appears that there have not been any changes except for a modification to the date appearing in the document footer. Other sections of the document that have been updated since December 1998 include doors and window, equipment, and electrical systems. Additionally, there are still ten sections that have not been updated since 1998.

The Board of Trustees created the Simonds Commission in 2012 to draft and refine the design principles for CMU. The resulting product of this commission was the Simonds Principles. It consists of ten principles ranging from architecture, public art on campus, to sustainability. The sustainability principle takes on a broad goal for sustainability on campus. This is the higher level guideline that is expected from designers when they are brought on to a new campus project, and is thought to be a better guide for sustainable campus building design than the building standards currently in place (Altschul 2018). The principles do not explicitly state what is needed, but gives designers the freedom and opportunity to meet the guidelines through different means.

The sustainability principle sets a goal, stating the “highest-level environmental sensibilities should be integral to the design, construction, and management of all built and open spaces, consistent with the university’s international standing in sustainable and green practices and cutting-edge systems and technologies, with particular emphasis on energy and water efficiency, the life cycle of materials, biodiversity, stormwater management, and transportation management” (Carnegie Mellon University 2018).

CMU also has a master plan for the university that lays out a plan for campus growth. The current master plan was last updated in 2015. There is a strategy for sustainability outlined. The strategy states the following: “The university will continue to strive to innovate and be a leader in sustainable building and operating practices and the development of emerging sustainable technologies.” (“Master Plan” 2015). Like the Simonds Principles, this strategy is not a clear plan for contracted work to follow. Later in the master plan it is mentioned that university policy is that all new construction should achieve LEED Silver. However, the master plan does not serve as a guideline for outside architects and engineers. Instead the document is used for guidance in future planning for CMU and shows the university following Pittsburgh’s zoning laws (“Master Plan” 2015). For this reason, we do not consider this document as a construction standard and it will not be included in the analysis mentioned in the next section.

2.2.2 Standards at Peer Universities

Design and construction standards are common among universities. In order to gauge where CMU stands in comparison to other universities, the standards documents of peer institutions also were assessed. Ten peer institutions were chosen including: California Institute of Technology, Duke University, Emory University, Georgia Institute of Technology, and Massachusetts Institute of Technology, Northwestern University, University of Pennsylvania, Rice University, Stanford University, Washington University in St. Louis. In order to have the best representation of building standards and guidelines at every institution, all building standards that could be found on each university’s campus design page were downloaded for assessment.

Table 2.2 displays the total word count of the eleven university building standards documents, shown in ascending order. Based on the table, CMU has the second lowest word count in its building standards document. However, there is a large range among the eleven institutions, with the lowest at 100,000 words and the largest at 1,770,000 words.

Table 2.2 Total Word Count for University Building Standards Document

University	Total Word Count
Rice University	100,158
Carnegie Mellon University	138,629
Washington University in St. Louis	212,800
California Institute of Technology	309,306
Emory University	333,201
Georgia Institute of Technology	341,828
Northwestern University	429,820
Duke University	481,281
University of Pennsylvania	696,180
Massachusetts Institute of Technology	841,737
Stanford University	1,769,789

To analyze and assess how Carnegie Mellon compares to its peers, an "R" script was written to gather and read all the documents relating to building standards at each institution. Once the documents were read, the frequency of each word appearing in the documents was collected. Because we did not want to assess the frequencies of every word, keywords that relate to sustainability were chosen. Words such as "sustainable," "green," "efficient," and "LEED" were chosen. We also filtered out other unrelated words to generate frequencies of only words we were interested in.

In order for a comparison to be completed that was not skewed by the length of the documents, because each university's building documents varied greatly in length, the frequency of keywords was normalized per ten thousand words in the overall document. Figure 2.5 displays the usage of different words associated with sustainability at CMU compared to the mean of the ten peer institutions. Although this method of comparison has its limitations, it is nonetheless instructive.

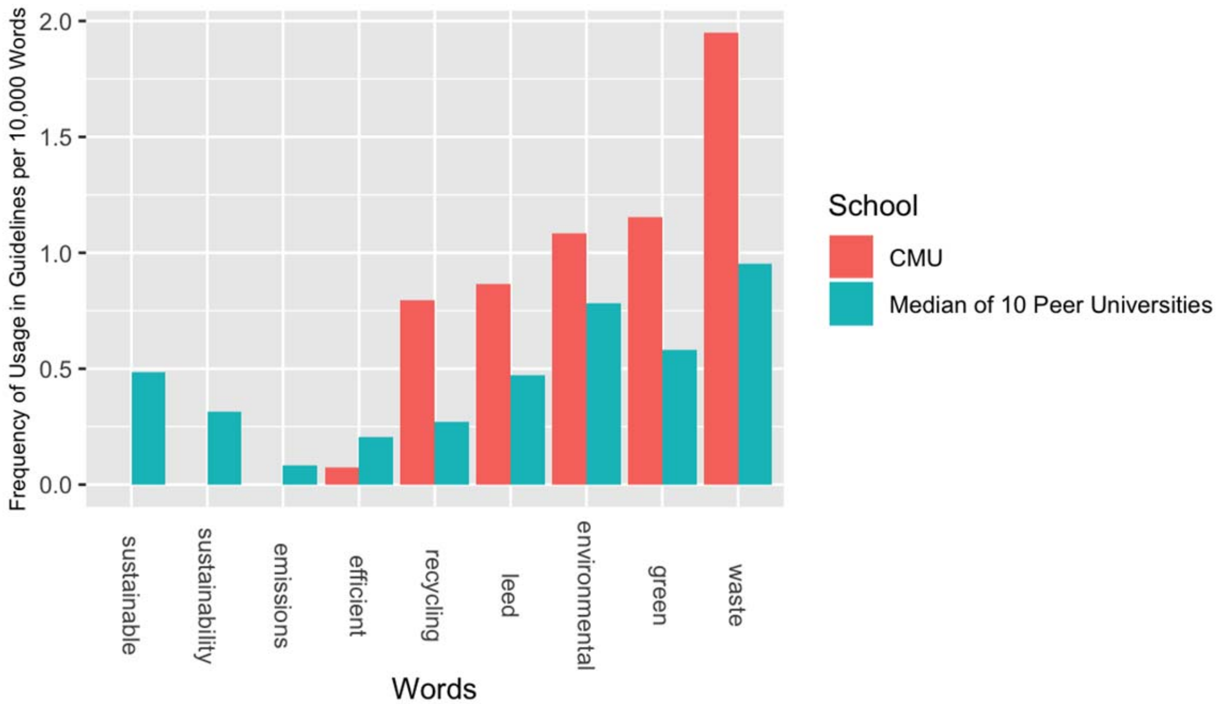

Figure 2.5 Sustainability Language in University Building Guidelines

Based on Figure 2.5, Carnegie Mellon is mixed in its use of sustainability language compared to its peers. While the words “sustainable,” “sustainability,” and “emissions” do not appear at all in CMU’s documents, the words “green,” “recycling” and “waste” appear more than the mean of peer institutions.

One word that serves as a fair indicator of a university’s views on sustainability when it comes to buildings is “LEED.” LEED, discussed in section 2.3, is an important standard for evaluating sustainable buildings. It appears that LEED and environmental are words that have similar frequency to the mean of peer institutions. The similarity in frequency leads to a conclusion that Carnegie Mellon, along with peer institutions, have set building requirements that include a minimum level of LEED certification for construction on campus and have an additional focus on the environment when it comes to buildings and construction.

When looking at the documents for each university’s building requirements, it was noticed that some universities choose to have separate documents pertaining to sustainability in their buildings. Thus, Stanford has a separate set of guidelines for sustainable construction advertised on its sustainability website. The document clearly outlines their goals for sustainable buildings and what sustainability looks like through different phases of design and construction. While this approach was not seen in every university, this approach could help CMU set clear expectations and serve as a supplement to the Simonds Principles.

2.2.3 Findings

Through the analysis and comparison of CMU's building standards with those of peer institutions, it was determined that Carnegie Mellon is lacking in some areas of sustainability language. Peer institutions' building guidelines are generally longer than CMU's building guidelines. Paired with the old date of publication, there is a need for the design and construction standards to be updated.

2.3 Building Certifications

Building certifications are another way of assessing sustainability of buildings at Carnegie Mellon relative to peers. In order to be competitive among its peers when it comes to sustainability, CMU has to find common benchmarks that are used by other universities and achieve those benchmarks in order to be considered a sustainable campus.

2.3.1 Current Certifications

CMU is committed to designing all new buildings to be, at the minimum, Certified LEED Silver (Carnegie Mellon University 2016). According to the United States Green Building Council, LEED stands for Leadership in Energy and Environmental Design, and "provides a framework to create healthy, highly efficient and cost-saving green buildings" (USGBC, 2018). LEED is the most ubiquitous name **when it comes to green building rating systems. LEED has a standard score system for several different** types of projects, which include building design and construction, interior design and construction, buildings operation and maintenance, neighborhood development, homes, and cities and communities. For the newest version, each score system has its own scorecard and is given a score out of 110 points. Table 2.3 gives a breakdown of the level of certification a LEED rated building can receive.

Table 2.3 LEED Rating Point Breakdown (USGBC, 2018)

Certified	Silver	Gold	Platinum
40-49 Points	50-59 Points	60-79 Points	80+ Points

According to the Carnegie Mellon Factbook, around 26% of the total (gross) square footage of the university is at least LEED Certified with the majority of this area being at least LEED Silver. Gross area refers to the total area of the entire building including unusable space, which is different from the net area which only considers the usable space. However, 74.3% of the square footage on campus is not certified because the buildings were built before LEED was created or before it was a requirement for buildings on campus. Since 2004, however, 100% of new space created has been LEED certified.

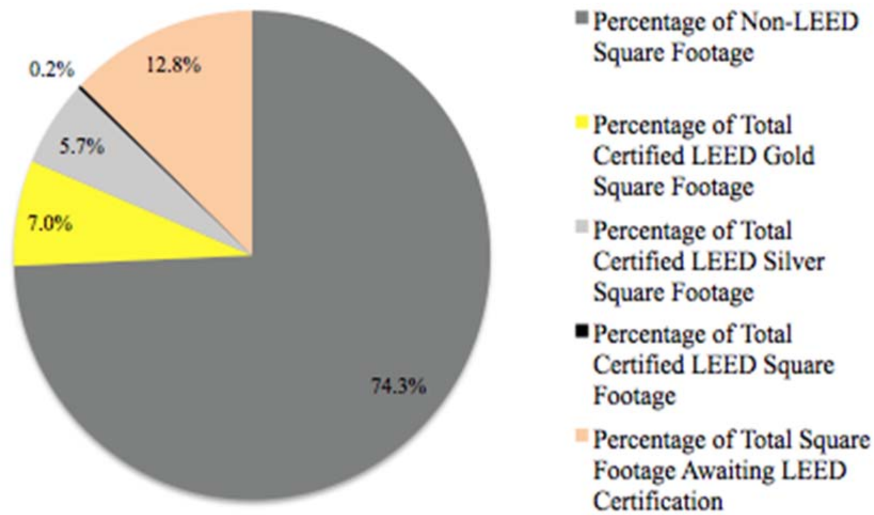

Figure 2.6 LEED Certifications for Administrative, Residential, and Academic Buildings at Carnegie Mellon University by Gross Square Footage (Property Accounting Services 2018)

The LEED scorecard points that are made available online for renovations and buildings at CMU are broken down in Table 2.4. CMU buildings or renovations that have a public scorecard the LEED website include the Resnik Café, the Graduate School of Industrial Administration (GSIA) West Entry Addition and First Floor Renovation, the Gates Hillman Centers, Scott Hall, Porter Hall 100 Renovation, Doherty Hall Phase II, the Mellon Institute, the Doherty Hall Renovation for Material Science Engineers, and the Hamburg Hall Auditorium. U.S. Green Building Council (USGBC) publicly provides the score of certain CMU buildings and renovations, but does not include the score breakdowns. These LEED certifications include Stever House, Henderson House, 300 South Craig Street, Mellon Institute Renovations, and the Posner Center (USGBC 2018). The total points available by each LEED certification and the total points that were awarded for each LEED certification were calculated and used to find the total percentage of points Carnegie Mellon received in every LEED scorecard category. As seen in Table 2.4, the university scored significantly lower in the categories of “Water Efficiency” and “Energy & Atmosphere” relative to the other categories. However, we note that architects may sometimes optimize the total number of LEED points by avoiding points in certain categories in order to increase the points in another category. Thus, these percentages alone may not tell the whole story.

Table 2.4 Comprehensive LEED Scorecard Breakdown (USGBC 2018)

	LEED Categories						
	Sustainability Sites	Water Efficiency	Energy & Atmosphere	Materials and Resources	Indoor Environmental Quality	Innovation	Regional Priority
Points Available for CMU Buildings	122	46	184	125	171	48	12
Points Awarded for CMU Buildings	90	16	59	59	100	40	7
Percentage of Points Obtained in Each Category	73.8%	34.8%	32.1%	47.2%	58.5%	83.3%	58.3%

2.3.2 Pittsburgh 2030 District Goals

The 2030 District is a non-profit organization that strives to establish a network of cities around the world dedicated to sustainable practices. Pittsburgh is one of those cities (see Fig. 2.7).

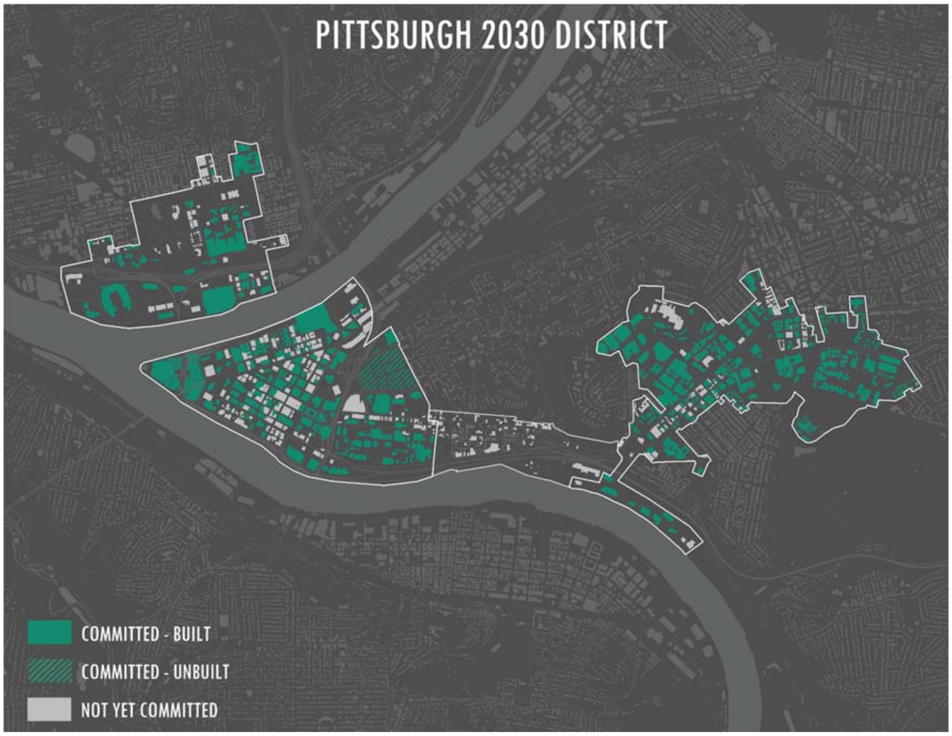

Figure 2.7 Pittsburgh 2030 District (2030 Districts)

Pittsburgh has set a number of goals for 2030. For existing buildings in Pittsburgh, technology must be implemented that reduces energy consumption, water usage, and transportation emissions by 20% by 2020 and 50% by 2030. For new buildings, there has to be a 70% reduction below the national average in energy consumption and 50% reduction below the district average in water usage and transportation emissions. Additionally, by the year 2030, the buildings should be carbon neutral (2030 Districts). The Pittsburgh 2030 district goals used the Commercial Building Energy Consumption Survey (CBECs) data to find the median energy use by building in the United States in order to create benchmarks for all buildings to follow in the committed area of Pittsburgh.

According to FMS personnel, CMU has informally decided to buy into these 2030 District Goals. This requires CMU to publish building data from now until 2030 to see if the university met the district goals. Based on the evidence in the subsequent sections, while CMU has made progress on some energy use metrics, it does not seem to be making the rate of progress needed to meet the District goals for reducing energy consumption and water usage.

2.3.3 ENERGY STAR

ENERGY STAR is a government approved tool to monitor energy usage for a defined system. Created in a joint effort between the Environmental Protection Agency and the Department of Energy, the tool allows organizations to make well-informed decisions about how they can increase their energy efficiency. ENERGY STAR scores a building or system from one to 100, which is based on how efficient a building or system is based on a comparison to the energy efficiency of buildings or systems already registered in ENERGY STAR. With ENERGY STAR, families and businesses have been able to save

$450 billion and 3.5 trillion kilowatt hours of electricity (Environmental Protection Agency, and Department of Energy).

According to Martin Altschul, Assistant Vice President of Facilities Management Services (FMS) and University Engineer, CMU has an ENERGY STAR Portfolio Manager that records and analyzes data regarding energy usage on campus. Although the Portfolio Manager can analyze university energy usage as a whole, the current meters installed on the Pittsburgh campus provide insufficient data. For CMU to receive a score from ENERGY STAR, the school will need more meters to provide ENERGY STAR with accurate data (Altschul, et. al. 2018).

2.4 Electricity Use in Buildings

CMU tracks electricity use using a metering system. Meters are spread out around campus and are able to determine the amount of electricity use in each building. The following section analyzes the electricity use in all buildings and reveals projections for future electricity use. This section also states the current findings from peer universities regarding electricity usage and what CMU needs in order to start to reduce campus-wide usage.

2.4.1 Electricity Usage Trends and Projections

In order to estimate future electricity use, it is important to know the past and current usage to find trends. Data on electricity usage was collected by CMU's FMS dating back to 2002. The electricity use has been analyzed as the total usage, the usage per capita, the usage per area, the usage per month, and the usage per building. These different metrics help to identify different trends in CMU's electricity use. Figure 2.8 shows the total electricity usage in million kWh for CMU's Pittsburgh campus. Based on a linear trend estimation, CMU's electric use is increasing by about 2 million kWh every year. This increase in electricity consumption could be due to an ever increasing campus population, new construction, or the addition of electricity intensive applications.

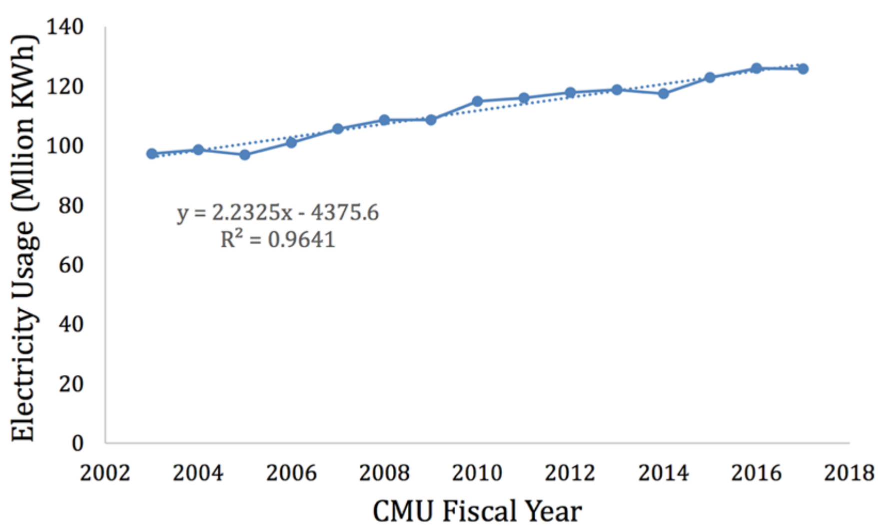

Figure 2.8 CMU Total Electricity Use 2003-2017 ("Pittsburgh to Paris" 2017)

CMU's campus population has been increasing every year. Figure 2.9 shows that electricity usage per person has been decreasing by about 55 kWh/person every year. Insofar as electricity use is tied to campus population, CMU is becoming more efficient per person, but population is growing so rapidly that total electric use is increasing.

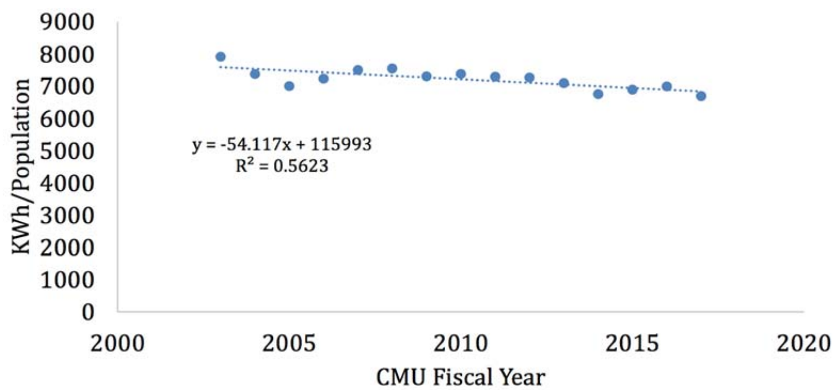

Figure 2.9 Electricity Use per Person 2003-2017 ("Pittsburgh to Paris" 2017)

Another possibility for the increase of overall electricity use on campus is new construction. Carnegie Mellon has added approximately 769,000 sq feet of new buildings over the last decade, and given its master plan, new buildings will continue to be added over time (Carnegie Mellon University 2018; Carnegie Mellon University 2008). Figure 2.10 reveals that there has been an increasing amount of electricity used per square meter of building area over the past fifteen years. To the extent that electricity use is related to building area, CMU's buildings are becoming more energy-intensive.

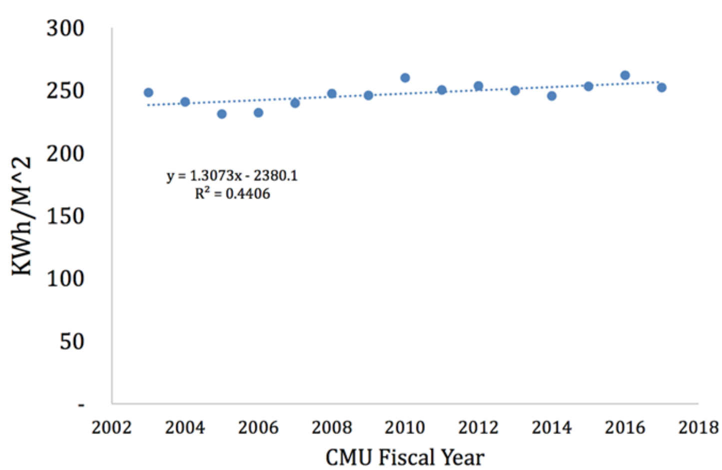

Figure 2.10 Electricity Use per Area 2003-2017 ("Pittsburgh to Paris" 2017)

Electricity use is also dependent upon the time of year. Figure 2.11 shows that electricity use is higher in warmer months than in colder months. This increased demand in electricity in warmer months is likely tied to air conditioning loads. Note that many of these warmer months are during CMU's summer session, a time when the student population is greatly reduced. This could be evidence that the base load of electricity is only loosely tied to the student population.

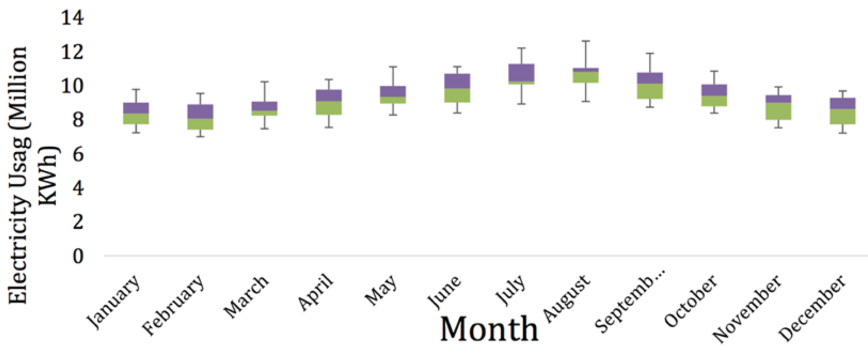

Figure 2.11 Electricity Use per Month 2003-2016 ("Pittsburgh to Paris," 2017)

Electricity use per building was analyzed in a similar manner to the total electricity use. Figure 2.9 shows the overall electricity use for academic and residential buildings. Academic buildings are highlighted in blue while residential buildings are highlighted in red. Based on the figure, academic buildings use approximately ten times more electricity than residential buildings.

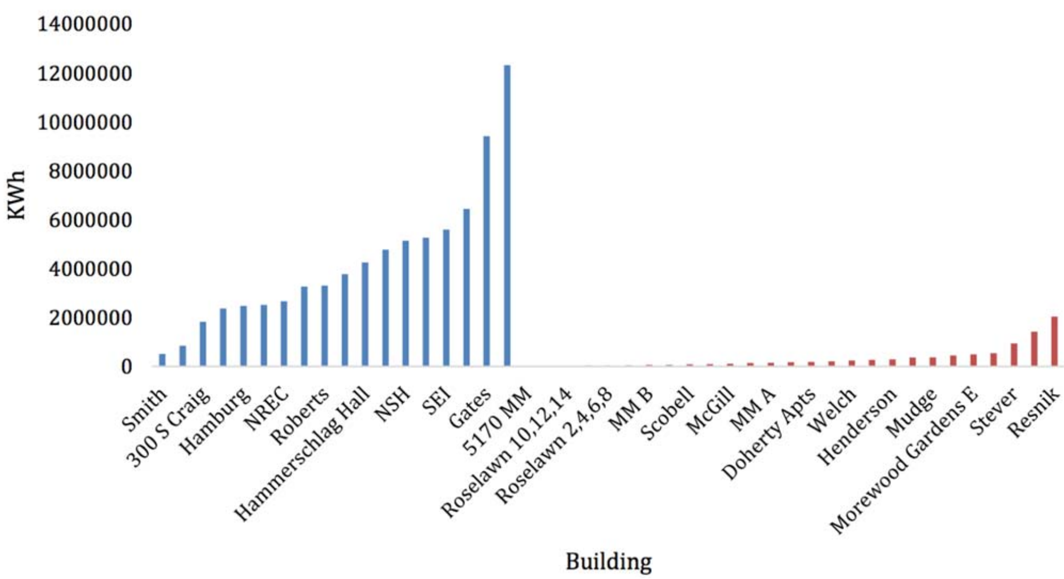

Figure 2.12 Total Building Electricity Use 2014 ("Pittsburgh to Paris" 2017)

Figure 2.13 normalizes the electricity use in these buildings by their size. Academic buildings still appear to use two or more times electricity on a per meter squared basis than residential buildings.

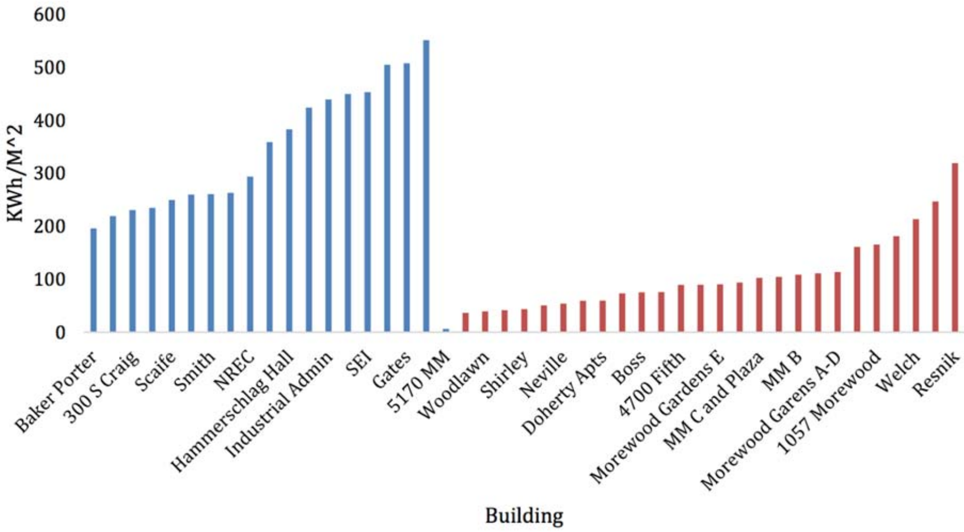

Figure 2.13 Building Electricity Use per Area 2014 ("Pittsburgh to Paris" 2017)

Figure 2.14 organizes all academic and residential buildings in terms of when they were built. The buildings are compared by the amount of electricity used per meter squared of building area. The hypothesis was that older buildings would use more electricity than the newer, LEED certified buildings, however this is not seen in the figure below.

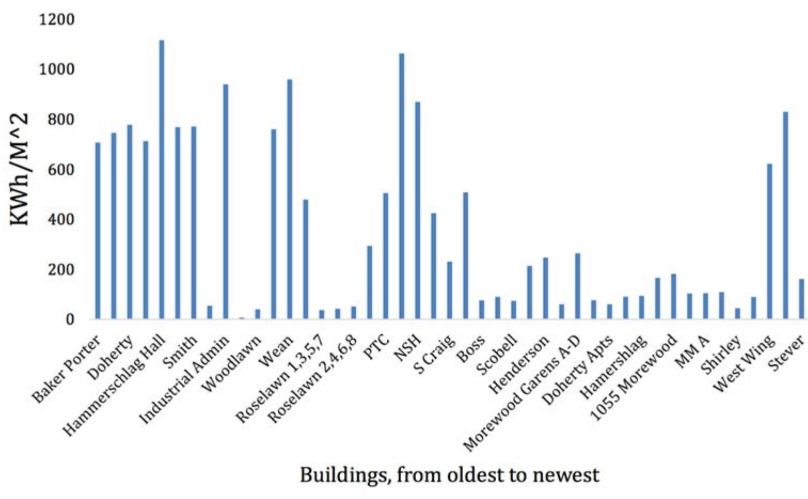

Figure 2.14 Building Electricity Use per Area Ordered by Build Date ("Pittsburgh to Paris" 2017)

The overall projected electricity use can be seen in Figure 2.15. According to a recent analysis of CMU's energy use and carbon footprint , electricity is expected to increase by 7% with the addition of the

Tepper Quadrangle (recently opened in 2018) and then continue to increase by about 2 million kWh for each year after, based on the trend from 2003-2017 ("Pittsburgh to Paris" 2017).

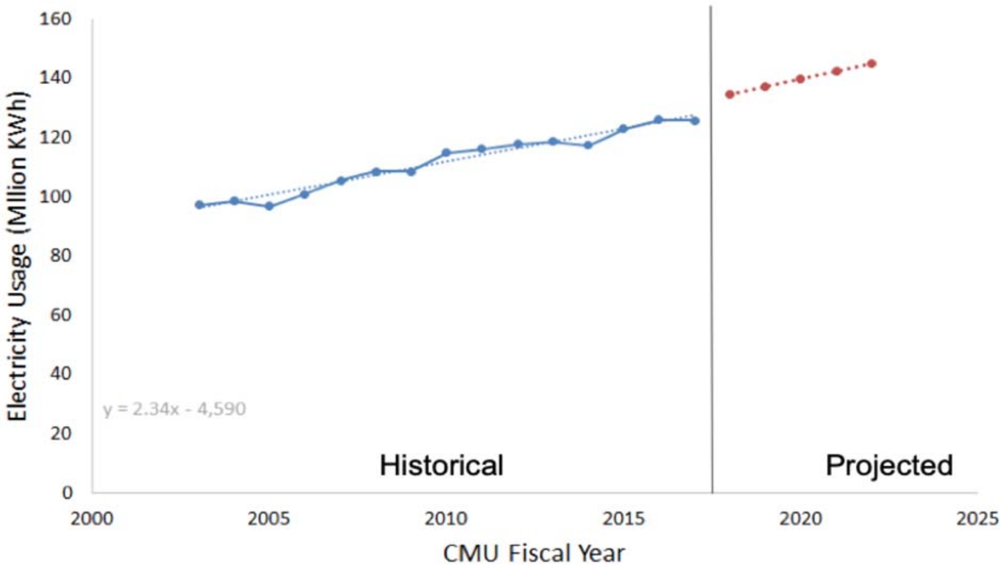

Figure 2.15 Projected Total Electricity Use 2017-2022 ("Pittsburgh to Paris" 2017)

The electricity when normalized to the population growth is seen in Figure 2.16 and is expected to continue along the same trend as 2003-2017 and decrease on average per person. This trend is expected to continue because there are no major increases or decreases in population that can be expected in the coming years.

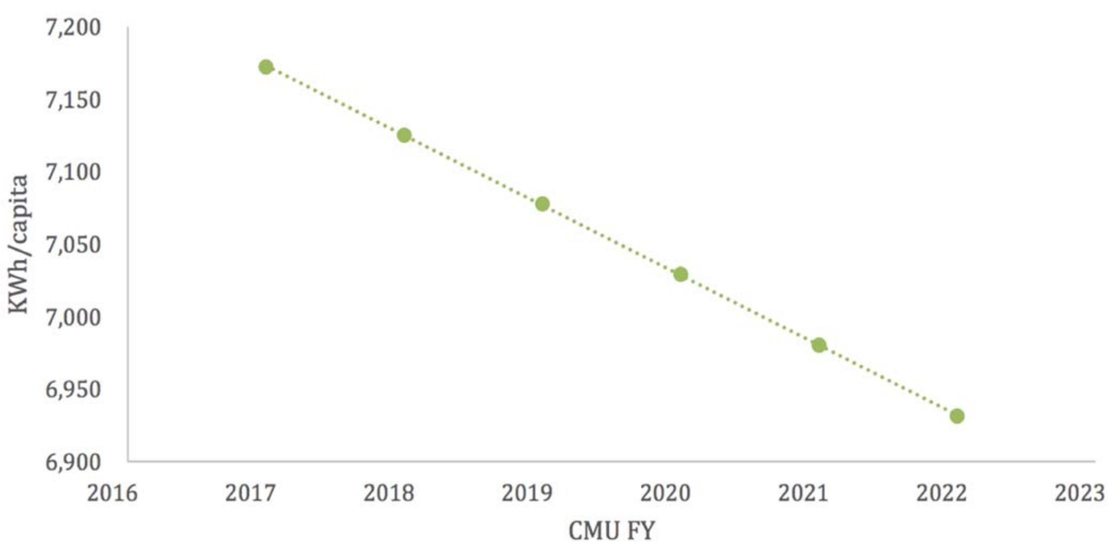

Figure 2.16 Projected Electricity Use per Capita 2017-2022 ("Pittsburgh to Paris" 2017)

The electricity usage was also projected in terms of area and can be seen in Figure 2.17. As in the past, the electricity use per area will not change much from year to year.

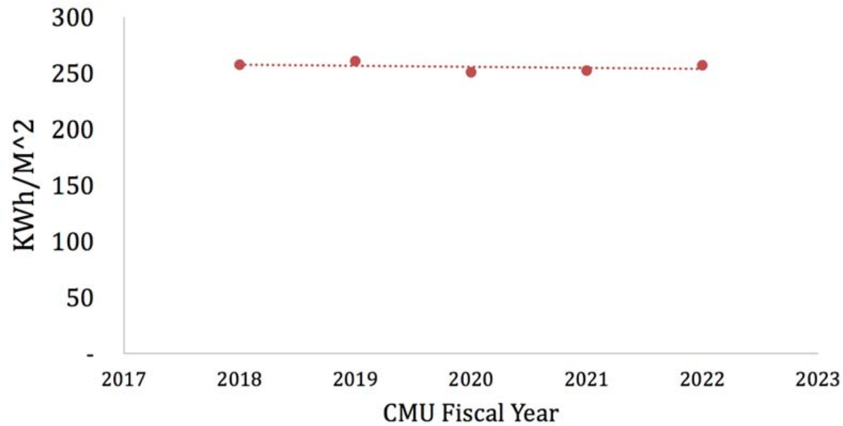

Figure 2.17 Projected Electricity Use per Area 2018-2022 ("Pittsburgh to Paris" 2017)

2.4.2 Potential for Energy Savings

Based on past and projected electricity use, the biggest concern is that total electricity use on Carnegie Mellon's Pittsburgh campus is increasing every year. The number of buildings and the population of the campus have been growing every year, so electricity also has increased. Many of our peer institutions, however, have successfully decreased electricity usage while increasing population and new construction.

Findings from Past Studies

The most widely used electricity reduction strategy among our peer universities is upgrading or retrofitting what is already in place. Stanford, Princeton, Duke, and Washington University focus on upgrades to their lighting and HVAC systems. An upgrade to the lighting system in these cases means changing the traditional lights to high efficiency light emitting diodes (LED). The type of light bulb can either drastically increase or decrease the energy use and emissions in a building. Studies show that switching from traditional incandescent light bulbs to LED can reduce electricity use by 70-80% (Energy.Gov). Boston University (BU) participated in a retrofitting project in 2012 and saw large reductions in electricity use and emissions. BU converted all of the lights in twelve buildings from standard incandescent light bulbs to LED or compact fluorescent (CFL) bulbs, which are slightly less efficient light bulbs than LED but still more efficient than halogen light bulbs. The university found that just by changing the lights in those twelve buildings it had saved 5,796,000 kWh of electricity that year and 2,710 metric tons of CO_2e (Alzate 2012). According to FMS Associate Vice President, Don Coffelt, CMU is on its way to converting all lights to LED. There is a certain stock of traditional lights that are still being used, but once those run out and once the lights have burned out, they will be replaced with

LED. Some lights on campus are already LED, especially in the new buildings, but there is still a long way to go (Coffelt 2018).

Emory and Washington University have also found success in holding competitions to motivate students, faculty, and staff to reduce their energy use. The competition that Emory University is involved in currently is a national competition to reduce energy and water consumption by 20% by 2020. Progress is tracked every year and Emory has continued to be a top performer ("Energy"). Washington University is involved in the Green Cup Competition which occurs every February and challenges students to try to reduce their energy use. "In 2016, students reduced their electricity usage by more than 160,000 kWh in one month, equivalent to the annual usage of 15 U.S. homes" ("Energy & Emissions").

Needs for New/Future Data and Studies

In order to determine the best way to reduce electricity usage at CMU, better metering needs to be put in place. Currently, the only data that the university has is on the total electricity consumption for each building. Electricity usage can come from lights, HVAC, computers, appliances, or a number of other things. With the addition of more extensive metering, the university will be able to determine exactly where our electricity use comes from, and therefore make recommendations based on these usages. Some recommendations may include changing the lights to LED, adding competitions to motivate students to reduce energy use, installing a more efficient HVAC system, shutting down buildings during the night so they are not running 24/7, or adding motion sensors in buildings.

Some new buildings and classrooms on campus already have implemented a motion sensor timer for the lights. After a period of time with no movement, the lights will be turned off. While this will help to decrease electricity use, it is uncertain by how much. A study needs to be conducted to first determine all of the buildings or rooms that have implemented this motion sensor, and then compare the electricity use in these areas to areas that have not implemented the motion sensor. If these motion sensors are helping to reduce electricity use, sensors should be looked at to not only turn off the lights, but the other electricity intensive applications in the room as well.

There is also a need for an inventory of the lights on campus. According to FMS, there is no current list of how many lights there are on campus, what type of lights they are, or when they were last changed (Altschul 2018). FMS currently has a supply of both traditional incandescent lights as well as LED lights. When a light burns out and FMS gets a call about it, the repair is made with whatever light bulb fits and is in stock (Coffelt 2018).

2.5 Steam and Natural Gas Use in Buildings

Steam and natural gas use at CMU is used primarily to heat campus buildings. The current metering system measures the total steam usage for all of the buildings at CMU, not the steam usage from each individual building. The following sections discuss the current trend of steam usage, projections of usage, and how CMU compares to our peer universities.

2.5.1 Steam and Gas Usage Trends and Projections

CMU heats its buildings using steam which is acquired solely from the Bellefield Boiler Plant. Until 2009, Bellefield used both natural gas and coal at their plant, but in 2009 they changed to only natural gas. A key reason the plant switched to natural gas is because natural gas emits fifty to sixty percent less air pollutant emissions than coal ("Environmental Impacts of Natural Gas"). Figure 2.18 shows the progression of steam usage, in millions of pounds, since 2003. The steam use generally has fluctuated over the past 15 years. When the graph was fit with a linear trend, the annual steam use increases at a rate of about one percent per year.

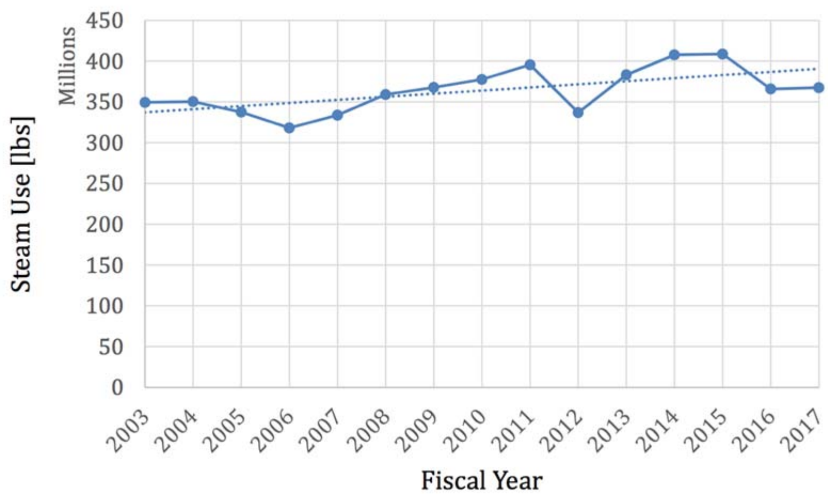

Figure 2.18 Total Steam Use 2003-2017 ("Pittsburgh to Paris" 2017)

Figure 2.19 shows steam use per square foot of campus buildings. While the steam use does tend to fluctuate, the regression line shows a general decrease in steam usage per square foot from 2003 to 2017.

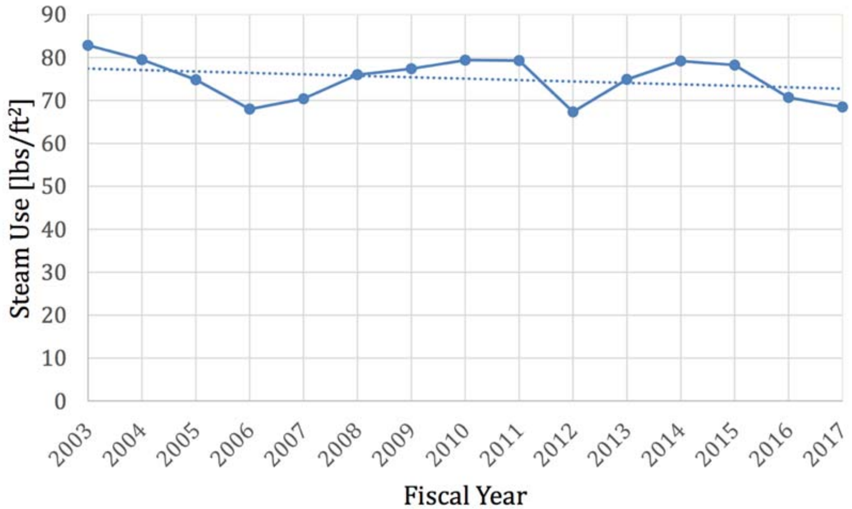

Figure 2.19 Steam Usage per Area 2003-2017 ("Pittsburgh to Paris" 2017)

When looking at steam usage on a monthly basis, it is opposite of electricity usage. Steam use is significantly higher in the colder months than in the warm months. Figure 2.20 shows this direct correlation between the time of year and the temperature. Steam use in January is about five times what it is in June or July. Since buildings are constantly being heated in the colder months, this correlation makes sense.

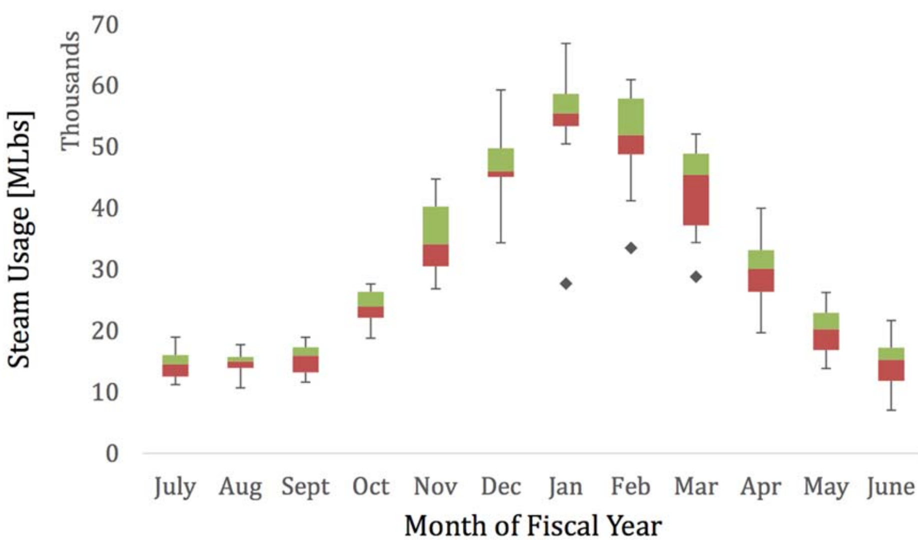

Figure 2.20 Steam Use per Month 2003-2017 ("Pittsburgh to Paris" 2017)

Given the past data on steam use, a graph of projected steam use was generated. Figure 2.21 shows the projected steam use will increase slightly in the next five years based on the past trend plus expected increase from the new Tepper Quad, although steam use from year to year is dependent upon the temperature in that year. An extremely cold year with a long winter will result in high steam use.

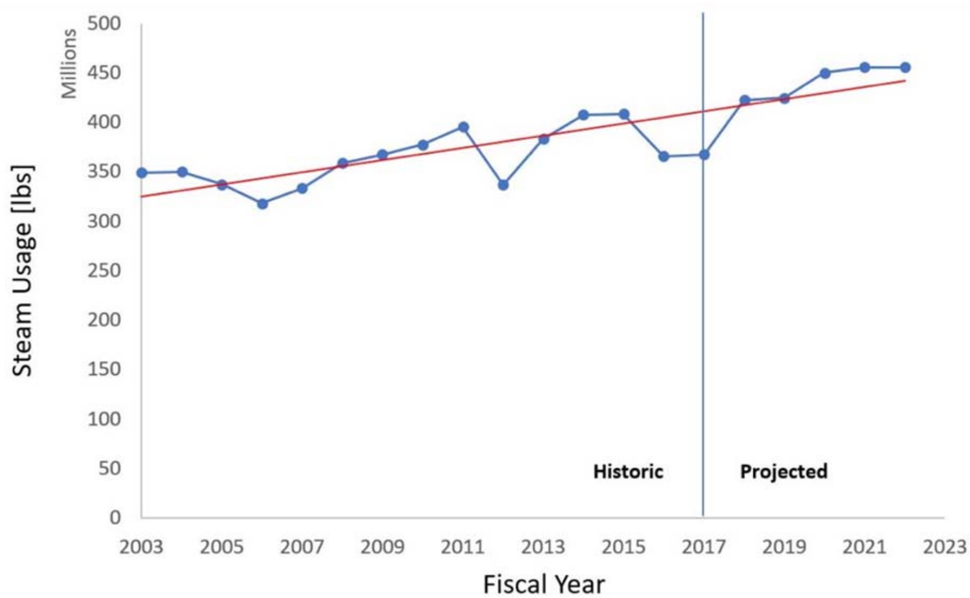

Figure 2.21 Project Steam Use 2017-2022 ("Pittsburgh to Paris" 2017)

2.5.2 Potential for Energy Savings

Similarly to electricity, the biggest concern with steam and natural gas usage is that it continues to increase and is projected to continue to increase over the next five years. The continuous growth will also result in increased emissions. Some of our peer universities as well as other top ranked universities have tried implementing different ideas to help cut down on steam use. Popular strategies include implementing new metering, upgrading HVAC systems and thermostats, and better insulating buildings.

Findings from Past Studies

One possible way to reduce steam usage is to upgrade the HVAC system. Cornell University is currently focused on optimizing their campus heat distribution system to help reduce their steam usage. Cornell predicts that 15% of the metered energy is being lost through the distribution system, and by optimizing the system, the losses could be cut by more than half ("Optimize the Campus Heat Distribution System").

The University of Pennsylvania is focused less on optimizing the current system and more on metering. These new meters are 98% complete and have been able to more accurately determine the steam usage on campus ("Conserving Energy"). Inaccurate meters could result in a university thinking they are using less steam than they are or vice versa.

Needs for New/Future Data and Studies

The only data that CMU currently has on steam and natural gas usage is the total usage. Without knowing the amount of steam being used by each building or the sources of steam and natural gas use, it is difficult to prioritize recommendations. New meters need to be implemented to track this usage in buildings and by certain sources, and once that data is collected, recommendations can be made. If certain buildings are using more steam per area than other buildings, another study may need to be done about the insulation of the buildings. Additionally, if a large amount of heat is being used during hours when not many students are in the buildings, one option could be to close some buildings so that they are not operating 24/7, and lower the temperature of the building a few degrees during hours of little or no occupancy. Metering also needs to be done to compare the amount of steam being produced from the boiler plant with the amount of steam we are actually using. If these numbers are drastically different, then CMU is losing heat energy through our distribution system, and optimizing this system may be a top priority if trying to reduce steam and natural gas usage.

2.6 Environmental Emissions from Energy Use in Buildings

Part of being sustainable is understanding where resources come from and how they affect the environment. Buildings at CMU make up a large portion of campus and require resources to operate effectively. These resources include electricity, water and steam for heating. These resources directly or indirectly produce emissions to the environment. Buildings on campus have two main sources of emissions those being from electricity and heating.

2.6.1 Emissions from Electricity Use

Electricity is generated off-site and is delivered to the university through the PJM West electric grid. CMU purchases the electricity that it needs through the local power company, Duquesne Light. Emissions were estimated using Environment Protection Agency (EPA) carbon dioxide emission factors. The EPA carbon dioxide factors are determined by the geographical area with a zip code where the power is purchased. CMU is in the geographical area where 49.8% of the power is comes from coal generation. This is higher than the national average which is 30.4% coal generation. With the PJM West electric grid also having 16.7% natural gas, the electric grid is being powered by 66.5% fossil fuels. The percent is higher than the national average from fossil fuels which is current at 64.2% according to the EPA. In the context of emissions, this difference is significant. Coal generates 51.2% more carbon dioxide than natural gas generation. A slight increase in coal generation within the grid can mean millions of tons of carbon dioxide emissions.

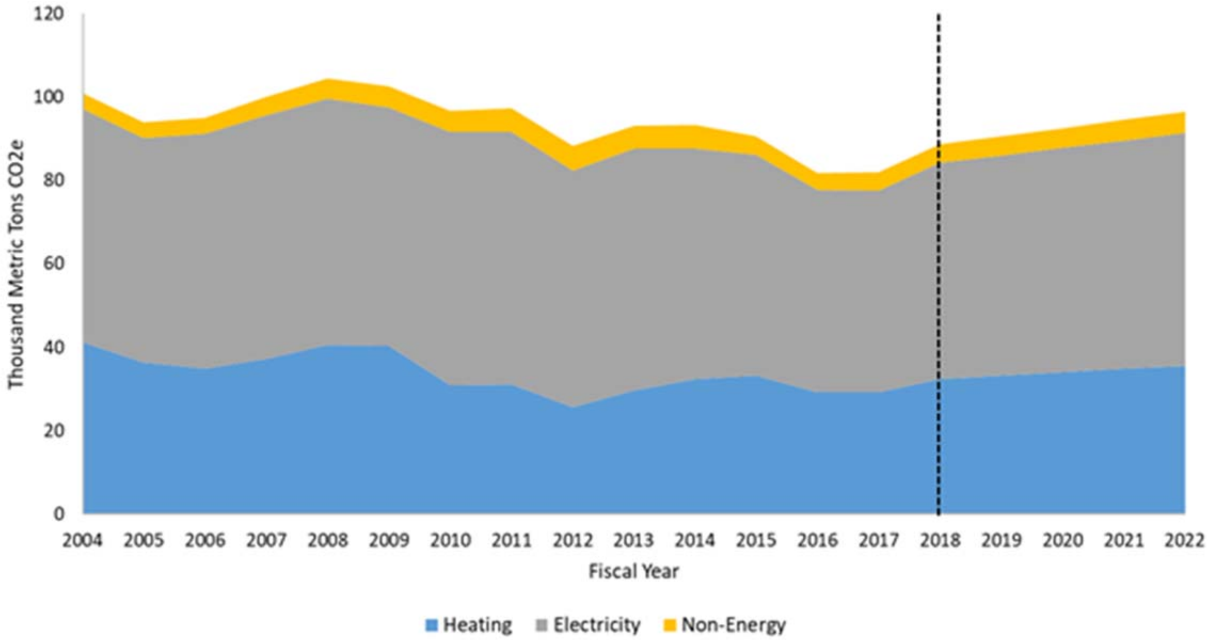

Figure 2.22 Carbon Dioxide Emissions from Campus Energy Use ("Pittsburgh to Paris" 2017)

An analysis of carbon dioxide emissions from energy use in buildings at CMU shows that roughly 59% of CO_2 emissions come from electricity generation (see Figure 2.22). Figure 2.22 compares the main sources of carbon dioxide which are electricity, heating and other for both past and future fiscal years. Carbon dioxide emissions from electricity are the main source of CO_2 for both past and predicted years. The decrease in CO_2 emissions between 2004 and 2017 is assumed to be caused by the natural gas boom. This time period saw a large amount of switching from coal to natural gas generation in the power industry. As discussed earlier in this section, natural gas generation produces roughly fifty percent less carbon dioxide per unit of electricity generated. The CO_2 emissions from electricity generation are projected to increase if the electric grid is comprised the same way as now by 3.19 percent a year. Therefore, Figure 2.22 shows a slight increase in carbon dioxide emissions in future predictions.

Figure 2.23 shows the carbon dioxide emissions due to electricity use in the academic building on campus for the fiscal year of 2017. As seen in section 2.4, non-academic buildings consume the least amount of electricity. As a result, these buildings produce the least amount of carbon dioxide.

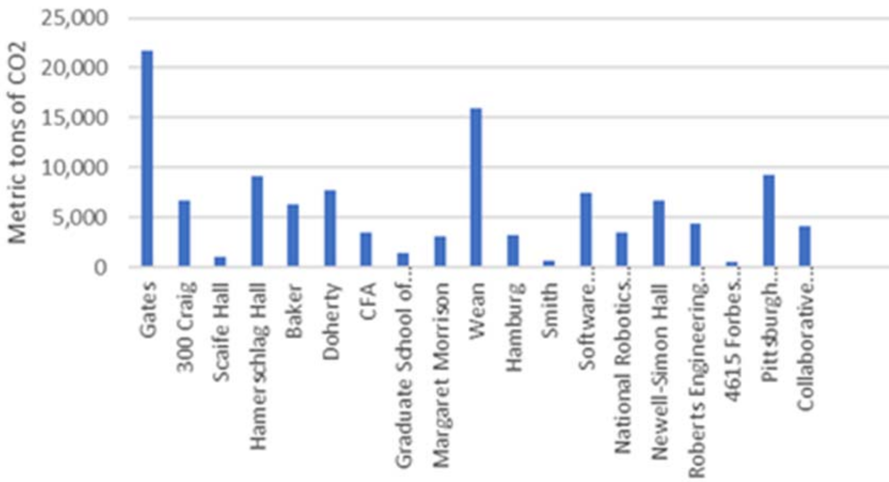

Figure 2.23 2017 Emissions of CO_2 from Electricity Use ("Pittsburgh to Paris" 2017)

Because the breakdown of electricity use within each building is unknown, assumptions can be made by looking at what buildings produced the most carbon dioxide from electricity. The first assumption is that building of comparable size that have more computers labs and laboratory have a larger carbon dioxide footprint. Figure 2.23 shows that Gates, Wean, and Hamerschlag Hall all have higher emissions from electricity when compared to other buildings. Gates, Wean, and Hamershlag halls all have either larger laboratories or computer labs. There are other buildings that have either laboratories or computer labs, but Gates, Wean, and Hamershlag have the biggest laboratories. Gates is home to the computer science department, and Wean houses the physics, material science, and math departments. Finally, Hamerschlag Hall is home to electrical engineering and the maker-space, an area used by all major engineering departments for fabrication. When the big three (Gates, Wean, and Hamershlag) compared are compared to a building that is not primarily used as lab space, like CFA, the difference is over 18,000 metric tons of carbon dioxide. Gates emits approximately 22,000 metric tons of carbon dioxide a year while CFA emits 3,500 metric tons of carbon dioxide. The comparison of these two buildings contributes to the assumption that computer labs and other laboratories are the main source of carbon dioxide emissions because these buildings are about the same size. CFA is about 250,000 square feet and Gates is about 287,000 sq. ft. Gates is 12.2 % larger than CFA but emits six times the amount of carbon dioxide. This analysis of this data when normalized reaffirms the assumptions that laboratory buildings are the leading cause of carbon dioxide emissions when compared to campus building.

Carbon dioxide is a major greenhouse gas from electricity, and can have huge effects on the environment. CMU is a leading research university that is ranked among the best in the world and if sustainably policies are to be considered, emissions of carbon dioxide from electricity is a critical source that needs to be focused on. An approach to carbon dioxide emissions is to identify buildings are indirectly generating the most emissions. From the analysis of the data, it can be assumed that laboratory buildings are the leading emitters and have room to improve by lowering carbon dioxide emissions.

Other air pollutant emissions emitted when electricity is generated can have environmental impacts. These emissions include nitrogen oxides (NO_x), sulfur dioxide (SO_2) and fine particulate matter

(PM), according to environmental agencies like the EPA. These emissions can have a range of effects from the health of a person to acid rain. Limiting these emissions from electricity generation should be considered when talking about future sustainability policy at CMU. To limit these emissions, it's important to understand which buildings are using most electricity.

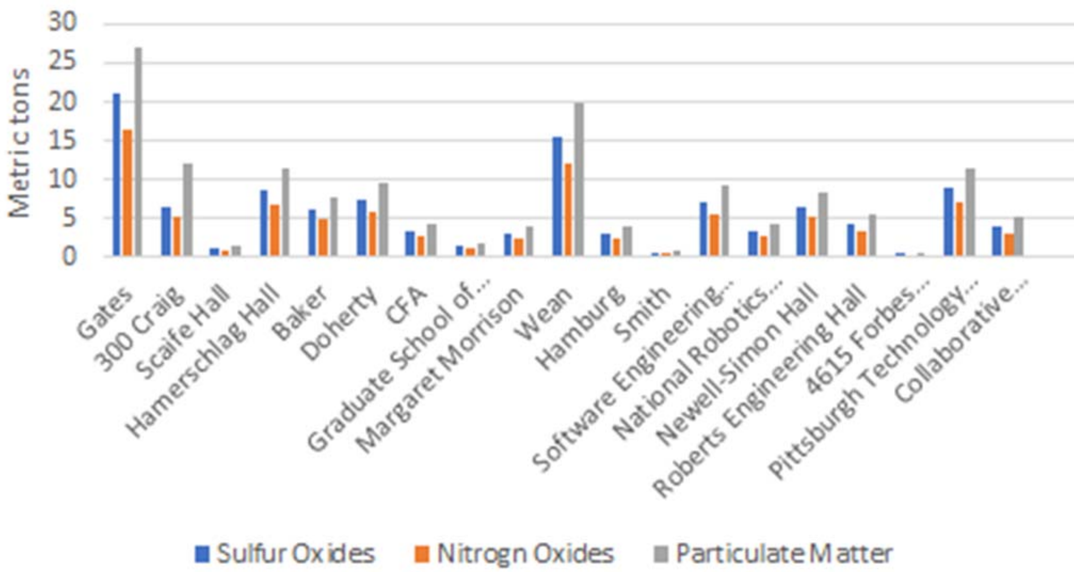

Figure 2.24 Other Emissions Generated by Electricity Production

Figure 2.24 displays the amounts of SO_x NO_x and PM for each building in the fiscal year of 2017. Again, this figure is based on the amount of electricity that is consumed for each building. Figure 2.24 shows that the top three buildings are Gates, Wean and Hamershlag. This would be expected because these three buildings are the largest with many laboratories and computers. All calculations for other emissions were done using EPA emission factors and the equation in Figure 2.25.

$$E = A \times EF \times (1 - ER/100)$$

where:

E = emissions,
A = activity rate,
EF = emission factor, and
ER = overall emission reduction efficiency, %.

Figure 2.25 Emission Factor Equations

There is an opportunity for improvement when it comes to emissions from electricity generation. In the early 2000s, the EPA made a marketplace for Renewable Energy Certificates (RECs). RECs allow institutions, such as CMU, to buy the environmental rights from clean energy generation. RECs are related to carbon emissions trading but have different units of measurements. One REC is equal to 1000 kilowatt-hours of electricity, and is used to offset all emissions from the same amount of fossil fuel electricity generation using coal and natural gas. RECs are verified by the EPA each year to ensure that RECs are only being sold once and are not double counted. The EPA also verifies the source of the RECs to guarantee that RECs offsets 1000 kilowatt-hours electricity. CMU started buying RECs in 2001.

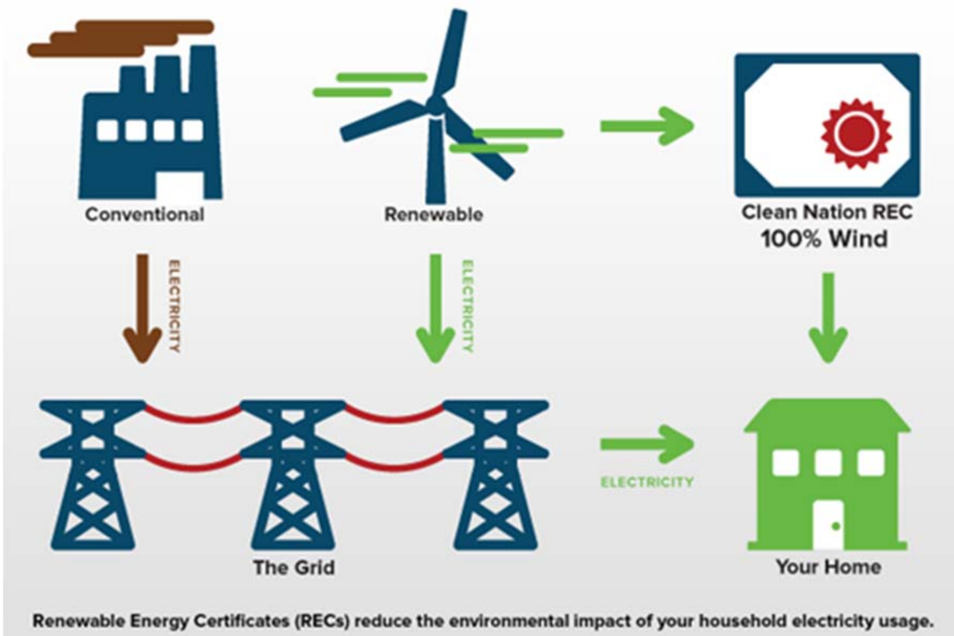

Figure 2.26 The Process of Renewable Energy Certificates

Figure 2.26 simplifies the process of RECs and shows that with the purchase of RECs it allows you claim to all the environmental attributes of renewable energy. CMU has been fully committed to the idea of RECs since the early days of the market. At the time, CMU was one of the leading purchasers of RECs in the country. Figure 2.27 shows how committed CMU has been over time. In 2001 the university purchased about 3.6 million RECs and has increased the number of RECs to over 120 million in 2016. Beginning in 2011, the university owned enough RECs to offset all the emissions from the electricity used on campus. This step was taken by then president Jared Cohon, and the university has continued to purchase enough RECs since to offset emissions from electricity. Important to be clear is that RECs only offset emissions from electricity and not emissions from heating or transportation.

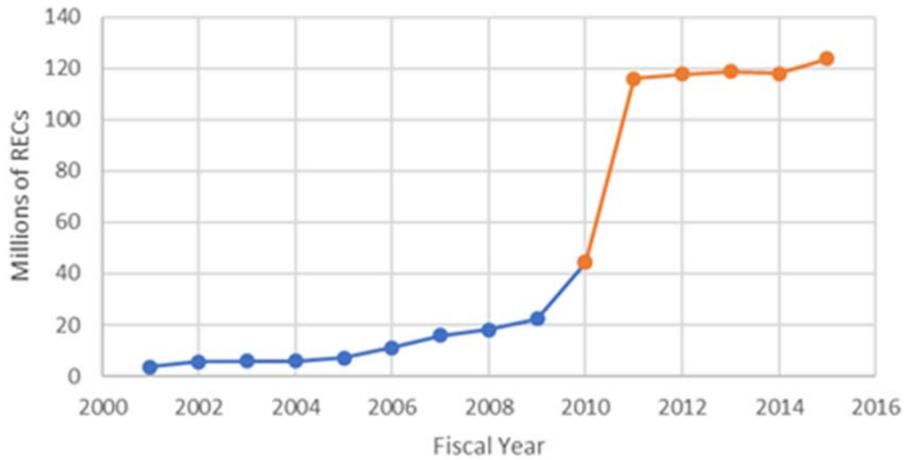

Figure 2.27 RECs Purchased by CMU Over the Past Years

Figure 2.27 displays the number of RECs purchased over time from the university. The blue line (up to 2010) represents the years when there were not enough RECs to offset electricity emissions entirely. The orange line (2010-2015) represents the years with enough RECs to offset all electricity-related emissions.

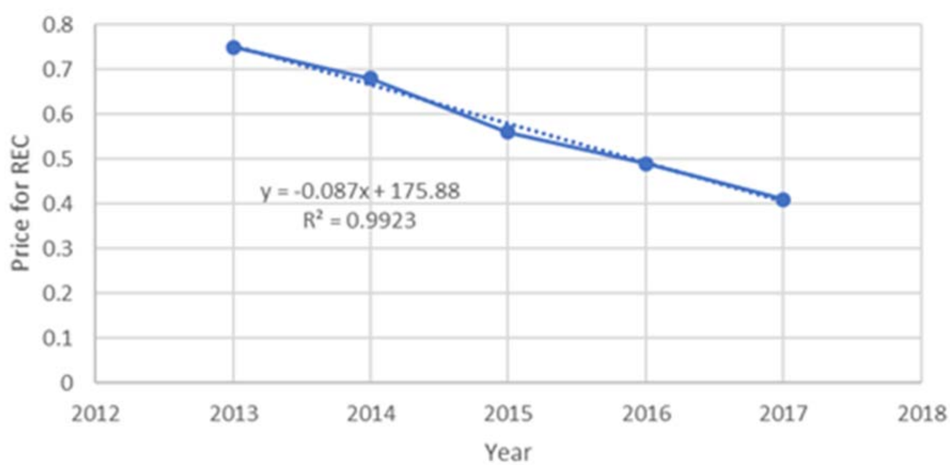

Figure 2.28 The Price of RECs from the Past Five Years ("Pittsburgh to Paris" 2017)

Figure 2.28 shows the price of RECs over the past five years, and it becomes clear that the price of RECs has been dropping. The total amount that CMU spent on RECs in 2017 was around $52,000. In 2017 it was 42% cheaper to offset all of CMU's emissions from electricity than in 2013. RECs have become cheaper over the years even with an increase in the CMU's demand for electricity, which has been steadily increasing at about two percent per year. The low cost of RECs for the past years have brought a few concerns to light. For one, are the RECs really doing what they claim? That is, are greenhouse gas emissions really lower than what they would be without CMU's purchase of RECs?

Secondly, are institutions like CMU only buying RECs because the current market price is low? If a future national policy on climate change were to substantially increase the price of RECs, would they still be affordable and purchased by CMU? These concerns require further research. During the course of this project we interviewed both the head of FMS and the chief engineer at the university. They stated the RECs are validated by the EPA each year to ensure the university's offset claim. Also, that CMU would continue to purchase RECs if prices of RECs were to rise, saying that "RECs have just become part of the utility bill and I imagine that will most likely continue even if prices change." (Coffelt 2018). Thus, in the context of this study, the overall concerns with RECs are addressed sufficiently for us to conclude that the policy of purchasing RECs is a practical way to offset electricity emissions.

2.6.2 Emissions from Steam Use

The emissions from buildings are not all from the generation of electricity. The second largest producer of carbon dioxide emission is from heating. Roughly 36% of carbon dioxide emissions come from heating the building on campus and can be seen in Figure 2.28. When heating is broken down into how it's generated there are two scores for heating here at CMU, steam and natural gas. Much of the campus heating is from steam generation about 90% and can be seen in Figure 2.29.

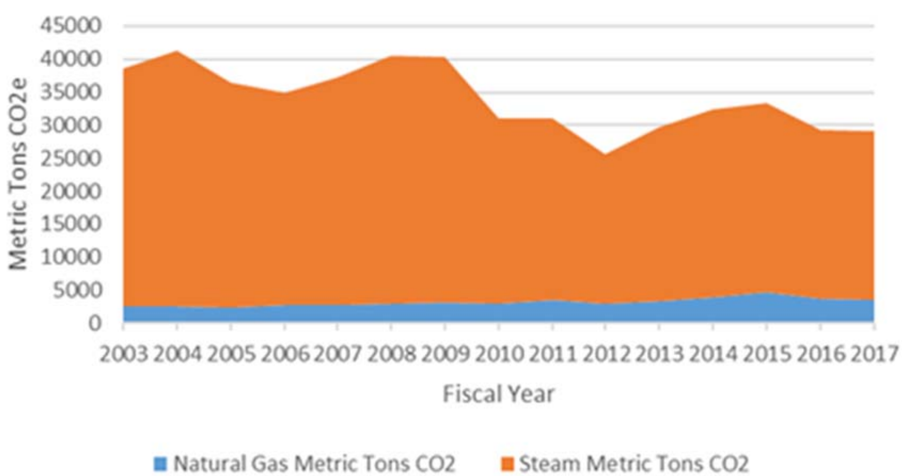

Figure 2.29 CO_2 Emissions from Heating per Year ("Pittsburgh to Paris" 2017)

All the steam is produced at the Bellefield boiler plant, located behind Hamerschlag Hall. CMU does not own the entire plant but is divided with other Pittsburgh institutions like the University of Pittsburgh and the museums. CMU owns about 7% of the Bellefield plant but uses about 20% of the steam generated (Altschul 2018). The Bellefield plant converted from a mixture of coal and natural powered boilers to all natural gas powered boilers in 2011. This lowered carbon dioxide emissions by a round 50% according to EPA calculations. Even with the switch to natural gas the emissions could be lower even more by updating the boilers system in the plant. The EPA models show that current boiler systems can be up to 36% more efficient than older models. The last boiler system update was back in

1994 (Altschul 2018). Boiler technology has improved in the past 24 years since the last update and a complete boiler update could help lower emissions by metric tons per year.

There are other emissions from steam and they are NO_x, SO_x and particulate matters (PM). As discussed earlier in the section NO_x, SO_x and PM are emission that have a range of effects from heath of breathing to acid rain and should be taken in account. Figure 2.30 shows the tons of emissions for these other three emissions for the fiscal year of 2017.

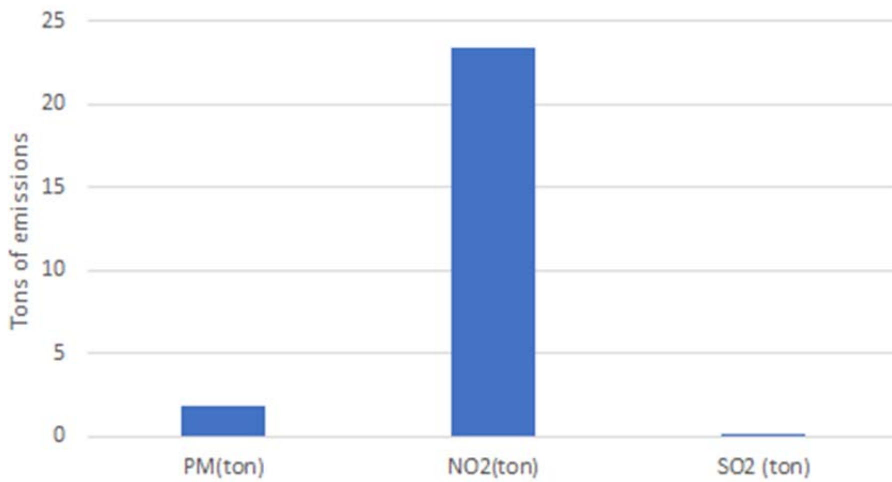

Figure 2.30 Other Emissions from Heating in 2017

As Figure 2.30 displays NO_x and PMs are a lot higher than SO_x this is due to the fact that the boilers are all natural gas. Natural gas when burned has lower SO_x than NOx and PMs. About 23 tons of the NO_x were released in the atmosphere in 2017 from heating. NO_x plays a huge role the quality of the air we breath and the acidity of the rain that falls in the sky. The NO_x can be lowered by a good portion if new boilers were used in the Bellefield plant. As mentioned previously in the section, all emissions in Figure 2.30 were determined using EPA emission factors and the equation in Figure 2.25.

2.7 Cogeneration

A costly, yet effective, way to reduce emissions from steam and electricity usage is implementing a combined heating and power system, also known as cogeneration. In CMU’s case, this would mean changing the Bellefield Boiler Plant into a cogeneration plant.

Cogeneration is when a traditional boiler system either for electricity or steam is retrofitted to produce both heat/cooling and electricity, this process is displayed in Figure 2.30. A traditional boiler system for steam or electricity primarily focuses on one or the other, letting energy in the system be wasted. A normal steam plant, for example, can have losses ranging from 40%-70% depending on the type of boilers are used. With a cogeneration plant, energy loss can be reused and reduced to about 10%. Figure 2.31 displays a graphic comparing traditional plants vs cogeneration plants.

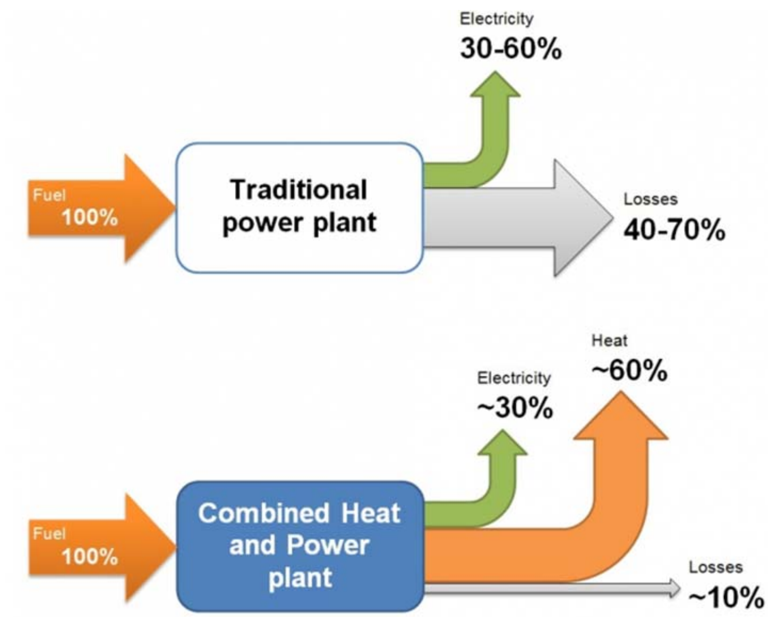

Figure 2.31 Cogeneration Energy Production ("About Cogeneration")

CMU currently receives all its steam for heating from the Bellefield plant located west of Hamerschlag Hall. The plant is owned by a group on institutions in the Pittsburgh area. CMU owns about 7% of the Bellefield plant but uses more than 20% on the output. The Bellefield plant was converted to all-natural gas in 2011, but the boilers are not that new. The newest boiler in the plant was installed in 1994 and the oldest boiler is form 1968. Boiler technology was become more effective in the recent years and a possible upgrade for the boiler would be need if cogeneration is to happen. They are a few ways that CMU can go about achieving cogeneration, but the most straightforward way is to buy the Bellefield plant entirely and update the boiler system. Talking to the chief engineer at CMU on multiple occasions, he has been a big advocate for a cogeneration plant and believes it would definitely make CMU more sustainable in future years to come. His professional assumption was buying the plant would be around $40 million (Altschul 2018).

Compared with a project done by Bucknell University in the early 2000s to purchase and convert the local power plant to cogeneration and adjusting for inflation, this $40 million seemed to be a reasonable price to purchase a power plant. Bucknell also had detailed prices for converting traditional coal boiler system to natural gas cogeneration for $12 million in 1998 and when adjusted for inflation for 2018 that is around $19 million. This would bring the total cost for cogeneration Bellefield plant to about $59 million. Looking back at the Bucknell's project, they are currently saving $1 million per year in utility cost. Bucknell has also reduced emissions by 74-99% when compared to the older boiler system. Table 2.5 displays this data from the study at Bucknell.

Table 2.5 Annual Emissions Reduction from Bucknell University (Buckzon 2007)

Annual Emissions (ton/yr)	1996	2006	Percent Reduction
NOx	94.7	22.4	76.0%
CO	112.3	4.9	96.0%
SOx	703.7	1.5	55.0%
VOC	0.9	0.4	99.0%
TSP	100.4	0.9	99.8%

It's important to note that Bucknell's cogeneration project saw large reductions in emissions due to the conversion from coal to natural gas. CMU emissions reductions won't be as high as Bucknell due to the fact that the Bellefield plant was already converted to natural gas in 2009. The amount of actual emissions reduction based on similar projects is estimated to be around 40%. As the table displays the reduction in emissions have been impressive and this cost of the overall project can be justified with this reduction in emissions.

Bucknell and other peer universities have decided that cogeneration can help their campuses reach sustainability regardless of the large fiscal cost initially. For CMU to reach emissions reduction goals, like in the Pittsburgh 2030 District Goals, cogeneration can significantly help.

2.8 Conclusions for Campus Buildings

For buildings at CMU, sustainability can be broken down into different dimensions including building standards, certifications, energy use, and emissions.

CMU currently has a set of building standards that serve as guidelines for outside parties that are brought onto projects. When the standards are compared to peer institutions, there are a few gaps between the peer institutions and CMU. However, there is a need for the university to update their standards to meet the current needs of the university. The university has a current commitment for all new buildings to be certified to at least LEED Silver and is taking part in the Pittsburgh 2030 District goals. However, the university is currently scoring lower in some LEED scorecard categories compared to other categories, and the university is not on track to meet the Pittsburgh 2030 District Goals.

When energy use on campus was assessed, clear needs were found. Although the campus is becoming more efficient per capita, total energy use continues to rise, as does energy per square foot of building space. In addition, there is not enough metering on campus to know how energy is used within a building. An increase in metering on campus is needed for accurate data on electricity and steam use in different campus buildings. Natural gas use typically comes from the Bellefield Boiler plant, which primarily relies on natural grass for steam production. As the campus continues to grow, CMU is using more of the Bellefield plant than what they own. One option for CMU is to consider switching the Bellefield Boiler Plant to a cogeneration plant to help reduce emissions from electricity and steam usage.

Finally, the emissions that CMU is responsible for from its electricity use are currently being made up for via RECs. RECs are recognized by many as a suitable way to offset the emissions from campus electricity use, and the increase in price is not a current concern for campus as CMU has adopted RECs into annual costs. When looking at options to further reduce emissions, the conversion of the Bellefield Boiler plant to a cogeneration plant was explored. The conversion, although costly, could lead to a decrease in emissions on campus.

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Chapter 3: Sustainable Water and Waste Management

Responsible management of resources is an important aspect of sustainability. Improper disposal of materials and irresponsible consumption of water can have significant impacts. Some examples of improper waste disposal include toxins leaching into the environment from battery disposal, increasingly scarce rare earth metals being lost from electronics, and powerful greenhouse gases such as methane being produced from food waste. As a result, it is important to divert as much waste as possible away from landfills through reusing, reducing, and recycling materials.

Water conservation is becoming increasingly important from both an energy and a materials use perspective. Pumping tap water and treating wastewater properly are large sources of energy consumption and fresh water supply can become strained in the future. CMU uses large amounts of water and produces significant amount of waste to maintain diurnal operations. It is important that the university practices responsible stewardship and maximize the usefulness of resources as the campus grows in both size and population.

3.1 Introduction

Different CMU groups manage the campus's waste and water usage. Outside contractors are sourced to purchase the majority of water and remove waste from waste from campus. Facilities Management Services (FMS) and the Environmental Health and Safety (EH&S) manages campus waste. FMS collects non-hazardous waste, composting, and other recycling into the various campus dumpsters. Waste and recycling are picked up by Republic Services, a solid waste collection company that CMU contracts with, and is sent to the company's disposal sites. Composting is picked up by AgRecycle, an outside contractor that turns composts waste into usable soil. EH&S collects and manages hazardous waste produced from campus groups and research facilities.

FMS also manages the campus piping and sewage system for water distribution. The Pittsburgh Water and Sewer Authority (PWSA) provides the majority of water on campus and also treats wastewater disposed through the sewage system. PWSA is the municipal authority on water treatment and the sewage system in the city.

3.1.1 Metrics of Sustainability

It is crucial to analyze CMU's total water consumption and waste production not only with regard to their total quantities, but also with respect to the scale of the university's activity such as total area and per capita basis. This information will discern what general trends exist with respect to the intensity of resource usage as well as total use.

Table 3.1 Metrics of Sustainability

Dimension	Metric
Lowering landfill waste	lbs. landfill waste per capita; lbs. total annual waste
Water Use Intensity	gal/ft^2-yr; gal/person-yr.
Waste diversion rate	% of waste recycled

These metrics are used to define and quantify sustainability efforts of campus in relation to water and waste management. While CMU will continue to produce waste and use the water to maintain the university's level of research and education, it is important for CMU to lead by example and take efforts to practice responsible stewardship of resources.

3.1.2 Chapter Objectives and Organization

Three aspects of resource usage will be analyzed: water use, solid waste production, and hazardous waste production. Hazardous waste is separated from solid waste due to its toxic, carcinogenic, or radioactive properties. As a result, hazardous waste cannot be disposed of through conventional means. Each section first analyzes the status quo at Carnegie Mellon University with respect to the total consumption or production levels related to waste and water. Afterwards, different analysis is conducted to see what are cost effective methods to manage water and waste. Finally, future needs and options are presented in each section to present suggested actions.

3.2 Water Use

With continuously increasing water consumption due to campus area and enrollment growth, CMU needs to put more efforts to achieve water use sustainability and establish leadership in water conservation among the higher education community. Going forward, commitment is required to reduce the water use by campus buildings, increase rainwater collection, and manage wastewater to mitigate sewage overflow problems.

3.2.1 Water Use in Buildings

CMU has fifty academic and administrative buildings, twenty-seven residential halls, and twelve Greek houses. Each type of building consumes water for different purposes. In order to achieve water sustainability, it is important for us to quantify the total water use and water use intensity (WUI) of each type of building, identify the major source of water consumption, and propose water reduction strategies. In this analysis, the time frame for measuring water consumption in each building is from the beginning of October to the end of next September.Martin Altschul and Michael Frenak from Facilities Management Services (FMS) provided the excel spreadsheets for building area and water consumption.

Currently, thirty of fifty academic and administrative buildings are accurately metered (Altschul[3] 2018). However, water use data from the past two years is only available for fifteen of those accurately metered buildings. Among the fifteen academic and administrative buildings, Mellon Institute consumed the highest amount of water. It used 18.3 and 15.1 million gallons of water from October 2016 to September 2017 and from October 2017 to September 2018, respectively. The total water use for the other fourteen academic and administrative buildings, as presented in Figure 3.1, is significantly lower than that of Mellon Institute.

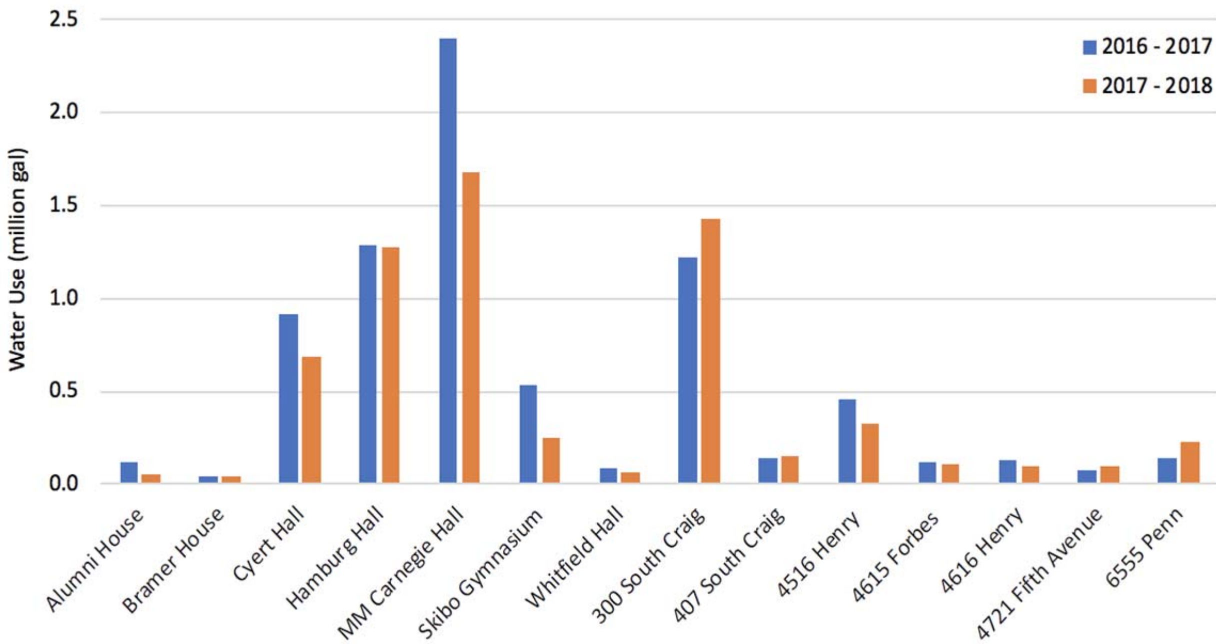

Figure 3.1 Total Water Use (million gal) for CMU Academic & Administrative Buildings, excluding Mellon Institute (which is off scale).

As mentioned by the previous chapter, being one of the property partners of the Pittsburgh 2030 District, CMU needs to reduce the water usage of existing buildings by 50% by 2030. Water use intensity (WUI), as defined by total water use per square footage per year, is adapted by Pittsburgh 2030 District as a metric to measure the water use reduction. The specific reduction goal of WUI for academic and administrative buildings by 2020, 2025 and 2030 is 10.64 gal/ft^2-yr, 8.64 gal/ft^2-yr, and 6.65 gal/ft^2-yr, respectively (Smith et al. 2015).

To examine whether CMU is able to achieve the water use reduction goal of Pittsburgh 2030 District, recent WUI for the fifteen accurately metered academic and administrative buildings is presented in Figure 3.2. As with total water consumption, Mellon Institute has the highest WUI over the past two year, about 2.5 times of the next highest WUI and far away from the WUI reduction goal by 2020. The significantly high total water use and WUI of Mellon Institute might be due to the fact that Mellon Institute has its own cooling tower.

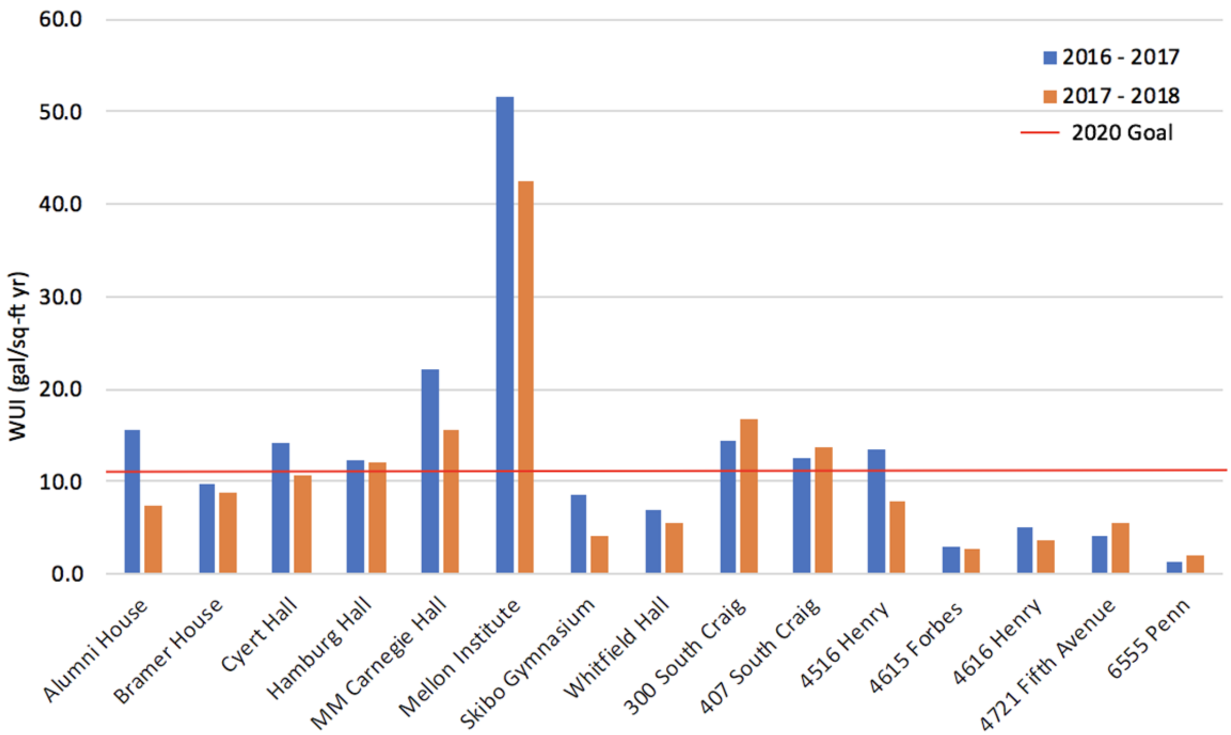

Figure 3.2 WUI (gal/ft^2-yr) for CMU Academic & Administrative Buildings.

Moreover, it is worth noting that nine of the fifteen buildings, including Mellon Institute, experienced a decrease in both total water use and WUI during the past year. The reduction of water use might be contributed by the installation of low-flow, high efficient cleaning facilities and the increasing awareness of saving water among faculty, staff, and students.

By the end of September 2018, ten of the fifteen buildings have achieved the 2020 WUI reduction goal, indicating that CMU has made good progress on reducing building water consumption. However, more efforts are needed to reduce water consumption of other buildings.

The total water use for nine residential halls that have accessible water consumption data is presented in Figure 3.3. Among all the buildings, Morewood Garden consumed the highest amount of water over the past two years, followed by Mudge House and Donner House. The fact that these three residential halls happen to have top occupancies among the nine buildings indicates that the water use of a residential hall might directly relate to its occupancy. As a result, we believe that water use per capita would be a better choice to assess the water consumption status of residential halls, though Pittsburgh 2030 sets water use per square footage per year as the metric quantifying water use reduction.

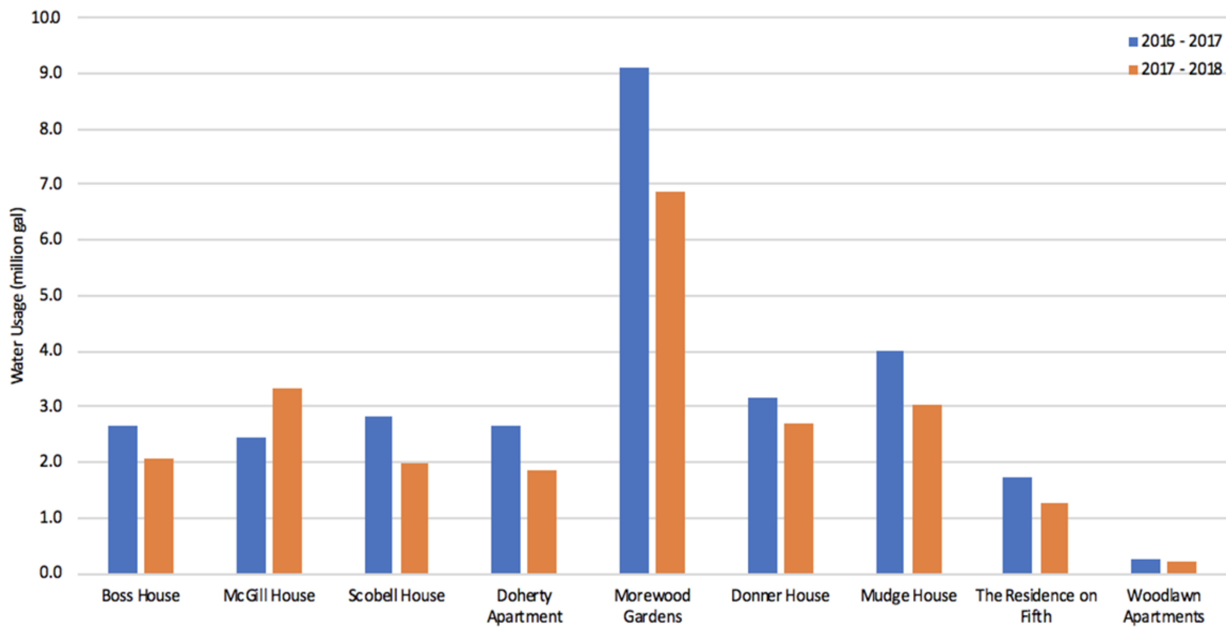

Figure 3.3 Total Water Use (million gal) for Residential Halls.

Figure 3.4 shows daily per capita water usage for the nine residential halls. All the buildings are assumed to be fully occupied during nine out of twelve months in a year. Among all of them, Boss House, McGill House, and Scobell House consumed relatively more water than the other houses in the past two years. From October 2017 to September 2018, the per capita daily water use in McGill House reached 170 gallons per person, significantly higher than the average daily water use per person in the U.S., which is about 80 to 100 gallons (Perlman 2016). To determine the reason for the sharp increase of per capita daily water use in McGill House, detailed records for daily and monthly water consumption are needed.

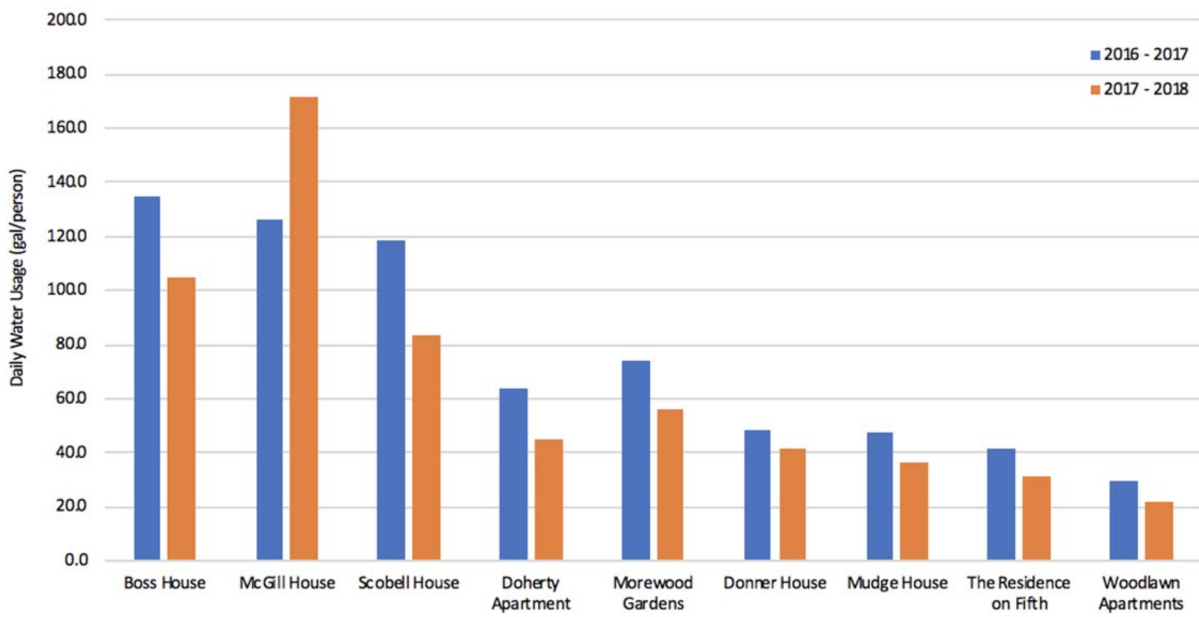

Figure 3.4 Daily Water Usage (gal/person) for Residential Halls

It is important to note that, similar to the water use reduction of academic and administrative buildings, nearly all the residential halls have less total water use and daily per capita water use from October 2017 to September 2018 compared to the previous year. The decrease of water use in residential halls might be contributed by the installation of low flow showers and toilets and the behavior changes among students during cooking, washing, and cleaning.

Besides, total water use and daily per capita water use for nine out of twelve Greek houses on campus is presented in Figure 3.5 and 3.6, respectively. All Greek houses have the same occupancy (36 occupants) and are assumed to be fully occupied during nine out of twelve months in a year. As mentioned in previous paragraphs, the decrease in total water use and daily per capita water use of Greek houses can be attributed to the installation of water saving facilities and the increasing awareness of water saving among students.

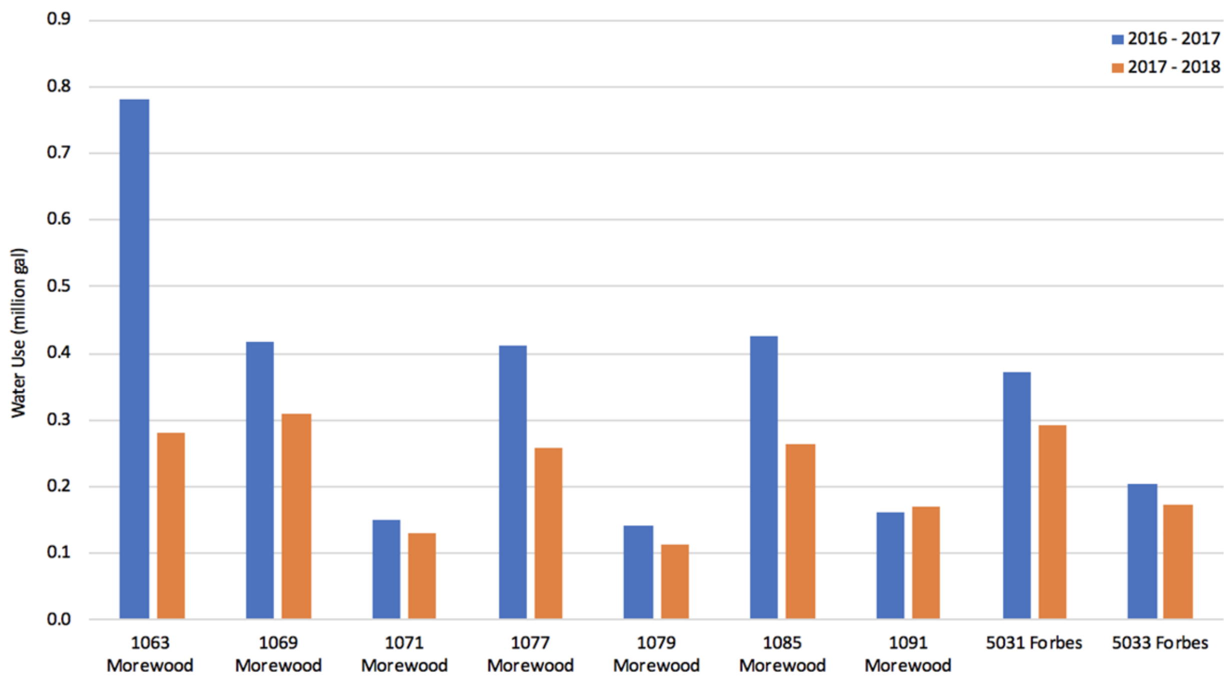

Figure 3.5 Total Water Use (million gal) for Greek Houses

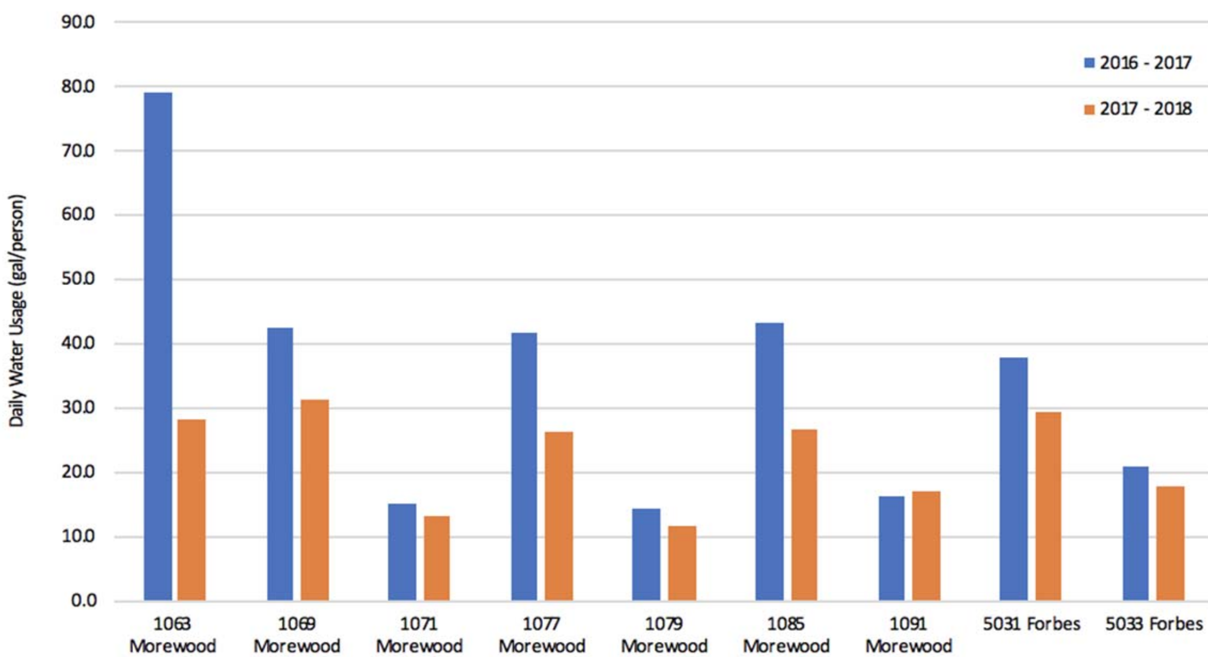

Figure 3.6 Daily Water Usage (gal/person) for Greek Houses

3.2.2 Rainwater Recycle Options

Recycling rainwater is one of the advantageous methods of using natural water in a sustainable manner and reducing sewage overflow. It is crucial to understand the current state of rainwater recycle systems at CMU in order to step forward to achieve water sustainability.

The primary determining factor for adding a rainwater collection system to a building at CMU is whether the building can achieve zero emission with that system ($Altschul_1$ 2018). As a result, rainwater collection system has been installed onto multiple academic and administrative buildings. However, due to lack of attention, time, and money, some of the systems are broken and will not be fixed in the near future ($Altschul_2$ 2018). Moreover, CMU does not have a comprehensive record for locations, built time, and current status of different rainwater collection system (Frenak 2018).

Currently, only the systems in Gates and under the Mall are functioning. The system in Tepper Quad is expected to be functioning "in a few months" (Frenak 2018). Table 3.2 presents detailed information for these three rainwater collection systems ("Environment at CMU" 2018).

Table 3.2 Rainwater Collection Systems

Location	Year	Capacity (kgal)	Function(s)	Current Status
Gates	2008	10	Flushing Toilets	Starting to monitor
The Mall	2016	280	Chiller Make Up Water	Starting to monitor
Tepper Quad	2018	120	Flushing Toilets, Irrigation	Finalizing process

3.2.3 Wastewater Management

The Pittsburgh region's frequent rainfall and snow causes sewage overflow problems ("Environment at CMU" 2018). The damage of sewage overflow on infrastructure at CMU varies from $0.1 Million to $5 Million per year (Altschul 2018). The untreated sewage can overflow from manholes, polluting campus environment and affecting nearby public transportation. The sewage can also back up into basement of buildings, damaging facilities and influencing campus operations. To reduce sewage overflow problems, CMU has taken some steps to capture or divert rainwater during storm events.

The rainwater recycle system under the Mall, as introduced in the previous section, is the largest stormwater management practice on campus to date. CMU is currently finalizing phase one of the project, which has already spent about $1.3 Million (FY18 dollar value) on stormwater capture and is expected to save as much as $5 million per year by preventing damage caused by sewage overflow ($Altschul_1$ 2018).

Besides the rainwater recycle systems mentioned in the previous section, CMU also constructed other facilities, as presented in Table 3.3, to capture or divert stormwater. ("Environment at CMU" 2018).

Table 3.3 Other Stormwater Management Projects

Project	Capacity	Function(s)
University Center Rain Garden	62,000 ft^2	Capture Rainfall
Purnell Center Baffled Cistern	10 kgal	Slow water flow down
4721 Fifth Avenue	N/A	Stormwater Capture

To further reduce the damage of sewage overflow, CMU is currently working with Jacobs Engineering to begin soliciting proposals from firms who could design, build and operate a campus wastewater reclamation and reuse facility. The facility would divert and treat water from sewer pipes underneath campus for non-potable needs, like cooling tower and Bellefield boiler make-up water. Table 3.4 summarizes detailed attributes for the proposed system. This project could reduce 43 to 60 million gallons of potable water use per year on campus, and save up to $15 million (FY 16 dollar value) in water costs during a 30-year period. Moreover, it can acquire water treatment data to support new research and education. Since this would be a major infrastructure project on campus, the evaluation process is long and moving forward slowly (Baird & Altschul 2016).

Table 3.4 Attributes for Proposed Wastewater Reclamation and Reuse Facility

Attribute	Quantity
Hydraulic Capacity	250,000 - 300,000 (gal/day)
Physical Footprint	3,000 - 6,000 (ft^2)
Backup Storage	50,000 (gal)

3.2.4 Future Needs and Options

Currently, there is a lack of accessible records for water consumption of each accurately metered building and status of each rainwater collection system. A systematic recording system is needed to provide comprehensive and accurate water use and rainwater collection data for education and research. Besides, more attention is needed on economic and environmental analysis for the future water reclamation and reuse facility in order to promote the progress of this project.

3.3 Solid Waste Management

CMU engages in a number of activities to decrease the amount of landfill waste through recycling and reusing programs. However as the population of the campus increases, CMU needs to take an initiative to curb its total waste production and engage its students to actively participate in these programs.

3.3.1 Total Waste Production

Carnegie Mellon University regularly publishes data on the total amount of waste it produces and the amount of waste it diverts from landfills (CMU 2018) . Figure 3.3 shows the breakdown of the total amount of waste produced and the amount of that material recycled.

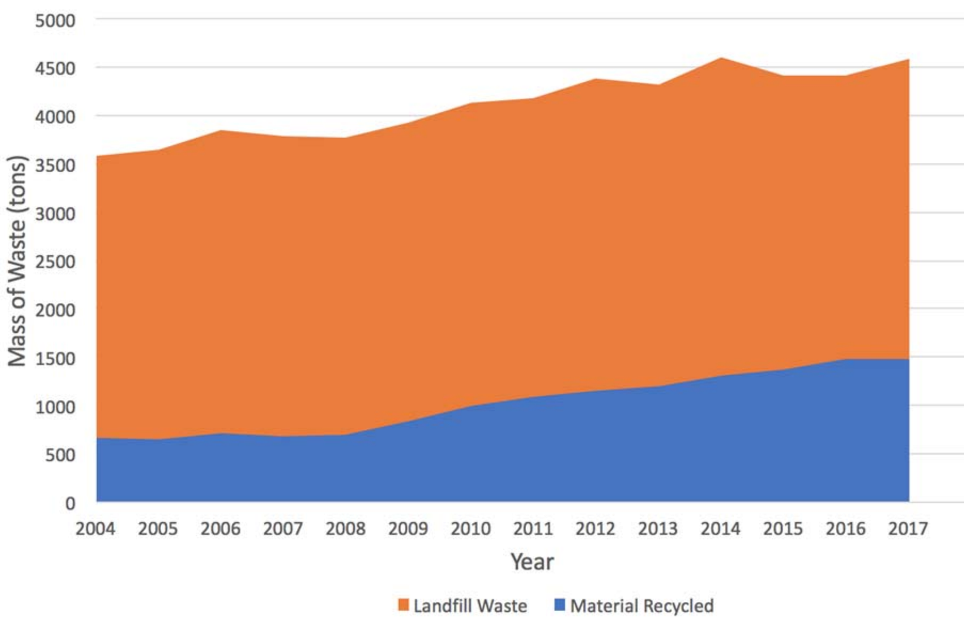

Figure 3.3 Total Amount of Landfill Waste and Material Recycled at CMU Annually (CMU 2018)

The total amount of waste produced by CMU and the total amount of waste diverted from landfills due to recycling and composting has tended to increase each year. The waste diversion rate can be calculated as the ratio of the total amount of material recycled to the total amount of waste generated. The waste diversion rate, as seen in Fig 3.4, has been steadily increasing over the last few years. The large uptick from 2008 to 2010 is because of CMU started their composting program during that time. Due to the increasing diversion rate from landfills, the amount of landfill waste that CMU produces has not increased significantly over the time frame.

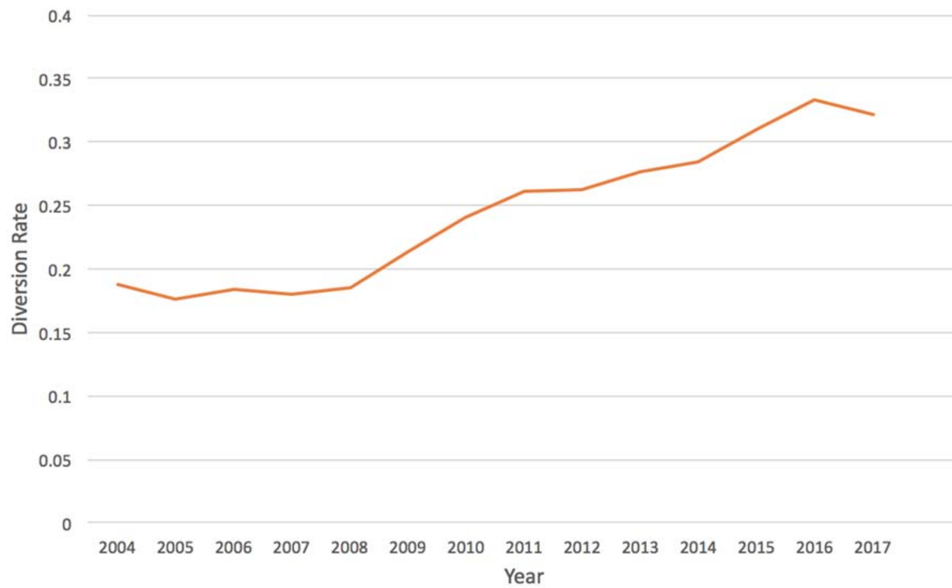

Figure 3.4 Diversion Rate of Waste, Representing as a Percentage of Waste Material Recycled

It should be noted that the population of the CMU campus has been increasing, from about 14,000 people in 2004 to about 20,000 people in 2017. Since people are a large contributor to waste productions on campus, the waste productions per capita were analyzed to see if it had any general trends with time. In Figure 3.5, it can be seen that the annual waste produced per capita has a slight downward trend. The total annual waste is defined as the sum of landfill waste and recycled material. The amount of landfill waste per capita is decreasing much more rapidly due to increased recycling programs at CMU.

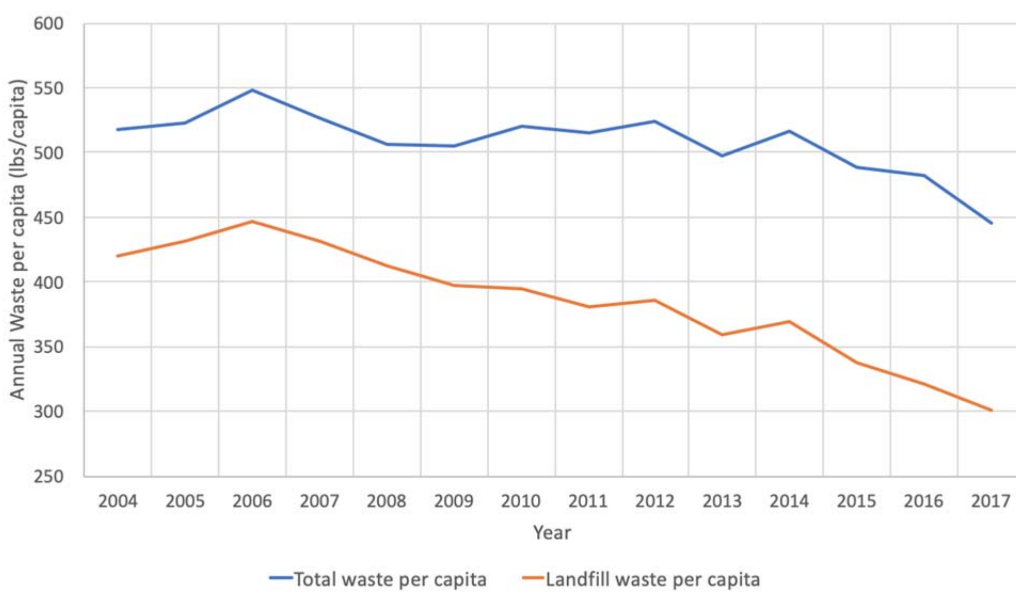

Figure 3.5 Total Amount of Waste Produced at CMU Normalized to Its Population

3.3.2 Food waste and Composting

About 50% of recycled waste at CMU is food waste and plant material in 2016-2017 (CMU 2018). CMU currently partners with AgRecycle to pick up CMU's compostable material and processes it at the AgRecycle facility in Washington county. There are seven large compost collection bins on campus. Three are emptied three times a week and four are emptied two times a week (Kviz 2018).

All CMU dining services participate in pre-consumer composting, meaning any food waste generated during food preparations is composted. Chartwells is the primary food vendor at CMU, managing the majority of on campus dining available since the start of the 2018-2019 academic semester. Prior to Chartwells, Culinart has been the primary food vendor. Both food vendors are subsidiaries of the Compass Group. Culinart and most recently Chartwells has been tracking the total amount of pre-consumption composting its services has created over the last 3 years. In 2017 - 2018, Chartwells estimates that about 32,000 pounds of food waste was produced for pre-consumption composting (Briggs 2018). The majority of this mass is from fruit trimmings, such as melon peels. During the same time period CMU produced about 622 tons of compostable material from food (CMU2018), suggesting that Chartwell's pre-consumption composting accounts for about 2.6% of campus-wide compostable material.

Chartwells is planning to purchase fruit and vegetables pre-trimmed at Paragon Fresh as opposed to trimming foods on campus. Since produce trimmings account for the majority of weight in pre-consumption composting at Chartwells, it is estimated that Chartwell's total composting that goes through CMU to AgRecycle will reduce by 90%. Paragon Fresh sends produce trimmings to a local power plant, where the waste material is used to produce methane and combusted for energy (Briggs 2018).

CMU's post-consumption consumption program is more limited than its pre-consumption program. Post-consumption composting bins are generally only placed in areas that are not open to public access. Most of these bins are localized to offices and graduate student kitchens. Since there is no university mandate on composting, composting bins are only placed in these locations if the department voluntarily asks for a bin. It should also be noted that there is almost no composting bins in any of the on-campus dormitories.

Figure 3.6 Approximate Locations of Post-Consumption Composting Bins. Size Roughly Indicates Number of Bins with The Largest Translating To About Four Bins. (Kviz 2018)

Post-consumption composting bins have been added to many dining locations this year. Resnik, a large student dining location on campus, and the cafeteria at the newly built Tepper Quadrangle have post-consumption composting bins this year. Other dining locations, such as Schatz and iNoodle, still have post-consumption composting. Schatz is a Chartwells dining site and it is estimated that it produces at most 1000 lbs. of composting each week (Briggs 2018). Currently the largest dining location, the University Center, does not have post-consumption composting readily available.

The other large source of post-consumption composting comes from campus events. Chartwells offer catering services that can be zero waste if desired. Currently a list of zero-waste events are readily shown on the Environment at CMU webpage. Chartwells estimates that these events produce a total of 10,000 lbs. of composting each year based on data over the last three years (Briggs 2018).

Post-consumption composting bins have not been expanded as rapidly due to a lack of composting knowledge on campus. There is currently no mandatory training on proper composting practices on campus. People often throw away non-compostable materials into these bins, leading to the composting bags being sent to the landfill. A trial period of placing composting bins inside the University Center has ended in failure due to a lack of awareness and proper practice (Kviz 2018).

Due to these issues, post-consumption composting is not very accessible on campus. This is reflected in a survey conducted last year by a student project team, that asked respondents how easy it was to compost or recycle on campus. It can be seen from Fig 3.7 that most respondents have negative views on how easy it is to compost on campus.

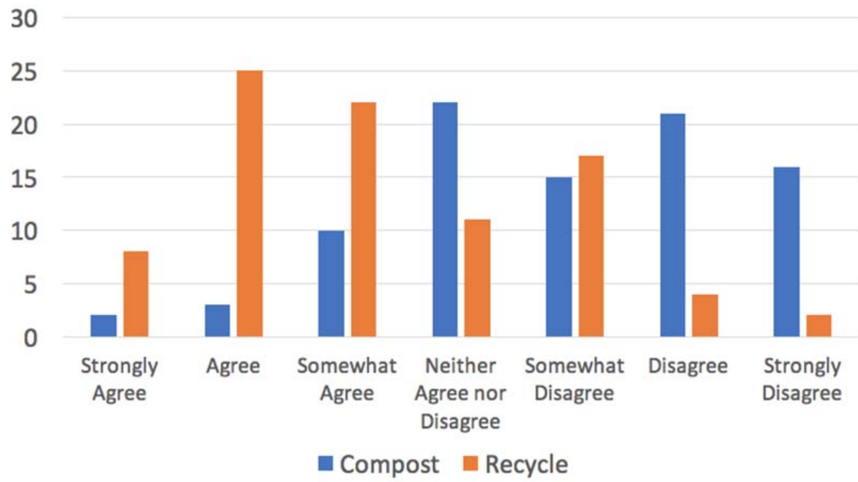

Figure 3.7 Survey Results from Fall 2017 EPP Report Asking Respondents "It Is Easy to Recycle/Compost on Campus" (EPP 2017)

To characterize how effective composting programs are at CMU, waste audits can be conducted to measure how much food is thrown away into the garbage bins rather than into composting bins. The most recent waste audit was conducted in November 2017; however the sample size was only about 30 lbs. (Kviz, 2018). The largest waste audit that CMU conducted was in November 2013. The waste audit sampled about 210 lbs. from different academic and residential buildings. Summary data is highlighted in Table 3.5**.** However, the sample size of this waste audit is still very small compared to the total waste that CMU produces. Furthermore, the data may no longer be representative of CMU's current waste stream because the data is now 5 years old.

Table 3.5 Attributes for Proposed Wastewater Reclamation and Reuse Facility

Waste Sources	Percent compostable (%)
Academic Buildings	23.2
Residential Buildings	29.6

Beyond composting, CMU also engages in other activities to reduce food waste. Schatz dining location donates leftover food to the Food Bank. Based on data from February 2018, it is estimated that about 150 lbs. of food is donated weekly (Briggs 2018).

3.3.3 Other Recycling Activities

Figure 3.8 summarizes the makeup of CMU's recycled materials overall from 2009 to 2017 (CMU 2018). The three largest components are food waste, cardboard, and mixed office paper, making up over 70% of all recycled materials.

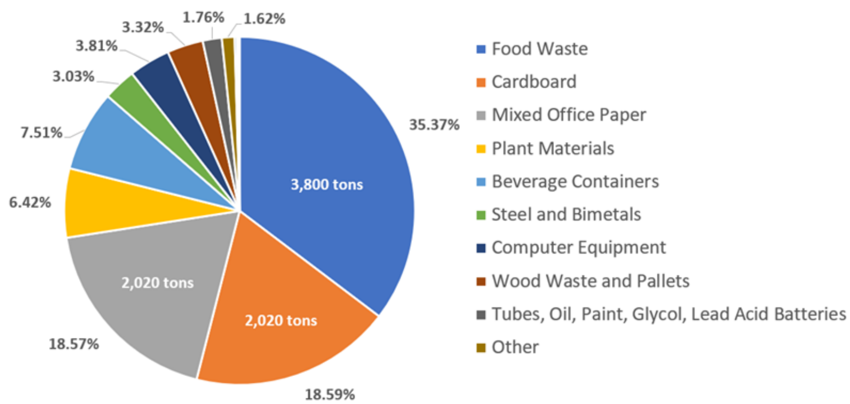

Figure 3.8 Aggregate Total Waste Recycled Since 2009 Broken Down by Different Types

The composition of the university's recycling streams are also available as yearly trends and can be seen in Figure 3.9 below.

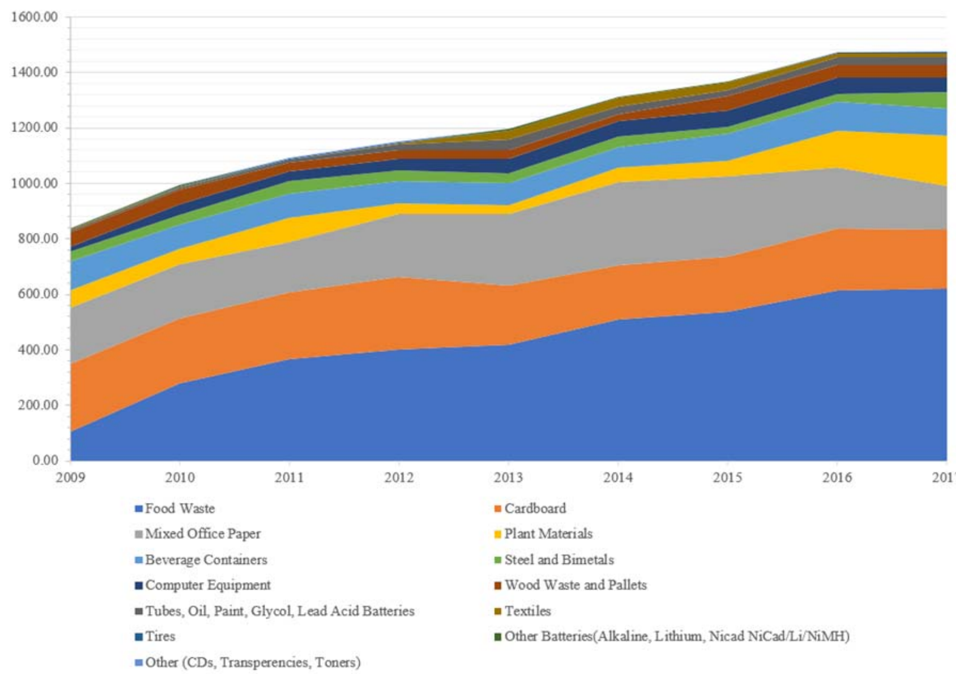

Figure 3.9 Tons of Waste Recycled from 2009 to 2017, by category

The breakdown of recycled waste into different categories, combined with knowledge of the composition that makes up the university's waste, would allow for targeted policies. For example, knowing that food waste, cardboard, and office paper make up the bulk of waste produced and recycled allows for policies that specifically operationalize how departments and groups are to reduce their use of these products, change their use habits, or increase the amount being recycled to further divert waste from landfills. Despite a deep understanding of recycling activities at CMU, there is no current knowledge on the composition of general waste being diverted to landfills.

3.3.4 Future Needs and Options

While there is no current method to effectively and efficiently characterize the university's waste, improved purchasing records could allow for insight into the materials entering campus. Knowing the composition of the university's incoming materials and of the materials being recycled, one can estimate the composition of the waste directed to landfills. One possible project to tackle this is the creation of a material flow analysis (MFA) across all material streams entering and leaving the campus. A MFA would allow the university to develop measures for the efficiency of its purchasing and to characterize its waste. With this information, programs can be instituted in order to decrease the amount of waste created and purchases made, make more informed purchasing decisions, and increase the utility of materials currently in use. The sustainability benefits of this project are both financial and environmental. Altering purchasing and using behavior may result in yearly savings, and reducing the university's yearly waste production would lessen CMU's contribution towards landfills and their associated impacts.

Performing a MFA would need to combine information from procurement and waste management. A material flow analysis would also require understanding of the lifetime of items being used. For example, paper can be assumed to be used over short time periods, while furniture would need some form of lifetime factor. In addition, a material flow analysis would need either a heavily centralized purchasing process or precise monitoring of purchases made at the department and group level. One university currently attempting a material flow analysis for its main campus is Massachusetts Institute of Technology (MIT). While working on the analysis, their Office of Sustainability has identified several methods for characterizing the different areas of the material balance across their campus (Goldberg & Perlman, 2018):

1. INPUTS
    - Centralized Procurement Office's transactional purchase records
    - Purchase records from specific vendors and departments that do not use central procurement system
    - Purchase orders, P-card Purchases, and Reimbursements
2. STOCKS
    - Property Office data which tracks activation and deactivation dates
3. OUTPUTS
    - Facilities waste generation volumes
    - Waste audits
    - EHS hazardous and medical waste
    - Other random flows: donation estimates, events

A similar structure can be adopted for CMU's own material streams. However, before doing so, more categories will be needed in logging materials as they are purchased. Currently, purchasing logs are broken down into overarching categories that cover fields such as "Supplies and Services," "Occupancy and Utilities," and "Capital Expenditures." These fields are further broken down into subfields, within which there is no distinction between physical and non-physical goods. Each category carries with it a description, mapping to grant expenditure, and fields for any changes made, along with dates of the change and the initials of the person making them. An example is shown below, omitting the comment and change columns.

Table 3.6. Examples of Object Code Segment Values.

Segment Value	Object Code Name	Description	Grants Expenditures Type Mapping
A8400	Supplies and Services		
B8410	Supplies and Shipping		
C8460	Information Resources		
84602	Book and Periodical Binding	Costs for binding books and periodicals.	BOOK AND PERIODICAL BINDING
94604	Books	Costs for books.	BOOKS
94606	Electronic Reference Sources	Costs to purchase or subscribe to reference and indexing sources available electronically.	ELECTRONIC REFERENCE SOURCES
84608	Periodicals	Costs to purchase or subscribe to periodicals.	PERIODICALS
84610	Reprints	Costs to purchase reprints or to acquire copyright permissions.	REPRINTS
84612	Videotapes	Costs to purchase pre-recorded videotapes.	VIDEOTAPES
84614	Other Information Services	Costs for information resources not falling under one of the other Information Resources object codes.	OTHER INFORMATION SERVICES

To help granulate the information gathered about purchased materials, several categories are needed. First, a clear distinction must be made between physical and non-physical goods and services. Such a category would allow for easy sorting of purchases made. Another category that would help in characterizing incoming materials is the weight of all physical items. Knowing the weight quantities of materials coming in, along with estimations and assumptions about material make-up, can inform metrics about recycling. Comparisons between outgoing and incoming streams, as well as recycled quantities, will provide insight into the effectiveness of different programs and initiatives. A third category that will help characterize materials is the source of the material. This information would inform the university of its indirect impact via the vendors it purchases from. A last category that will help track materials as they make their way through campus is appointing a contact person, per item or per department/entity, that will be able to provide more detailed information about how materials are used and disposed of without any responsibility over these.

Besides changes in cataloging practices, more information is needed regarding the time that materials spend on campus. These can be conceptualized as the lifetimes of materials, how long they can be used before they are discarded of. Lifetime quantities can be developed from material studies as well as from documented deactivation times. Deactivation times, greater than a year, are recorded for all materials with costs above $1,000 that are covered by grants. These times are documented for tax exemption purposes and should be accessible by procurement services and other administrative entities. These deactivation times can be used as a baseline to create estimates for a range of materials used across the university, particularly larger equipment.

The useful lifetimes of materials also present a dimension for improvements in sustainable purchasing, use, and waste management. Extending effective lifetime, and utility, has two benefits: a decrease in quantities being purchased over a given time period, and a reduction in the waste produced annually. Increasing useful lifetimes can be accomplished using two methods. The first is the purchase of more durable materials. Though this option would increase the lifetime of items, it has to be balanced against their increased cost. The second option is to improve practices around the use and handling of materials. Education and training, which may incur some costs, has the potential to alter behavior that would otherwise inflict damage or unnecessary wear on items.

With help from University Procurement and individual departments and organizations, a dedicated team could compile a log of all incoming items and materials. Active inventories and lifetime estimates, using recorded deactivation times, could help define how long materials are used for and when they are disposed. Collaboration with FMS and EH&S and the completion of more extensive waste audits would help characterize outgoing streams. An approach to completing this analysis is outlined below.

1. Gather purchasing and waste data into a central location, collaborating with departments, laboratories, and student/faculty organizations.
2. Characterize expected useful lifetime for different items using information recorded for grants and tax purposes, applying averages to items throughout campus.
3. Characterize waste streams through sampling, recording and estimation/extrapolation.
4. Calculate surplus and purchasing efficiencies.
5. Make modifications to waste practice and stock sizes, and extend lifetimes by modifying use practices and procuring longer-lasting materials.

As of right now, there exists no central structure that could gather and process all this information, and there is no organization to spearhead the collaboration necessary for such a task.

In addition to a MFA, additional measures can be taken to promote sustainability in the university's purchasing process. Currently, the university holds a list of preferred vendors. The companies belonging to this group are evaluated by their prices and competitiveness. There is currently no assessment of a vendor's commitment to sustainability or any practices relating to sustainability (McAdoo). One avenue to incorporate this facet into assessing potential vendors is to include such questions in the Supplier Questionnaire. The questionnaire gauges a company's past history with the university, any relationships between company administrators and university employees, and the ability to accept certain forms of payment ("Supplier Questionnaire"). Including questions regarding 1) the company's current commitments to sustainability, 2) their sustainable practices, or 3) their willingness to adhere to university policy around sustainability can lay the groundwork for such a category. Classification as a sustainable vendor will also require standards for accountability in order to ensure that companies keep to their commitments. Assessing the sustainability of vendors can be done in conjunction with a MFA as it would assess the recyclability of materials, the useful lifetime of purchased goods, and the impact that switching to these vendors has on the university's waste management.

3.4 Hazardous Waste Management

Sustainability at CMU must also include the use of hazardous materials and the generation of hazardous waste. These substances have meaningful impact on the health of students, faculty, and staff. These materials also carry an environmental impact and can carry negative drawbacks if not disposed of properly.

3.4.1 Hazardous Waste Generation

To examine the generation of hazardous waste, one must first look at the procurement of hazardous materials (hazmats). Laboratories only need approval from Environmental, Health and Safety (EH&S) for highly hazardous materials. These are defined as being either acutely toxic, radioactive, or a known carcinogenic. If a material does not fall under any of these categories, even if hazardous, it may be purchased without prior authorization by EH&S. This is different for student organizations, which require approval for all hazmat purchases. While considering a request, EH&S will consider the appropriateness of the purchase, any training requirements for handling the material, and any volume limitations to the substance being purchased. Nearly all training, whether for laboratory teams or student organizations, takes place through the Bioraft online platform, where individuals can find many different training courses. Depending on the laboratory or group, EH&S will recommend specific courses suited for the space's substances and procedures (Harris 2018).

There is currently no centralization on chemical procurement, as each individual laboratory buys in accordance with their needs and available budget. There is also no centralized process for distributing purchased chemicals to the different laboratories. While EH&S does receive and then distribute some of these purchases, the majority are shipped directly to their corresponding departments and spaces. While there is no current method for efficiently monitoring the procurement of chemicals, it is known that about 90% of chemical purchases are ordered from two of the university's preferred vendors, Fisher Scientific and Van Water Rogers (Harris 2018).

All chemicals, including hazmats, are required to be inventoried using the university's ChemTracker system. These inventories are verified by annual inspections. A team of five EH&S personnel is tasked with inspecting all 342 teaching and research labs on a rotating basis. This number is not limited to wet chemistry labs, but also includes machine shops, studios, and workshops that may be using chemical products. Depending on the contents of the inventory, a laboratory can then be assigned a hazard label of high, medium, or low. The inspections also document any necessary changes, updates, or missing elements (Harris 2018). The results of last year's inspections can be seen below. The reported shortcomings are reported under generalized categories. Given the sensitive nature of some of the research done on campus, information about waste generated by or the chemical inventories of individual labs are not available.

Having reviewed the state of chemical procurement and inventory at CMU, one can look at the waste generated by the use of hazardous materials. According to the Pennsylvania Department of Environmental Protection (DEP), CMU is classified as a large quantity generator when it comes to hazardous waste. To meet this classification, an entity must generate over 2,000 pounds of hazardous waste each month. This is true of both the contiguous campus and of the Mellon Institute, both of which are classified as separate entities by the DEP. Last year, CMU and the Mellon Institute combined generated about 48,000 lbs of hazardous waste. As a generator, CMU must report its waste streams to the DEP on a biennial basis, detailing the streams total quantity and composition. Below is a figure detailing hazardous waste generation since the year 2004, with a linear forecast reaching up to 2022. The trend was created using a line of best fit in Excel. A linear fit makes the most sense as waste would increase directly with an increasing population from year to year. Any deviations from the trend can be attributed to an increase or decrease in the usage of hazardous materials by the university's laboratories. The quantities in which these materials are used are not available or predictable.

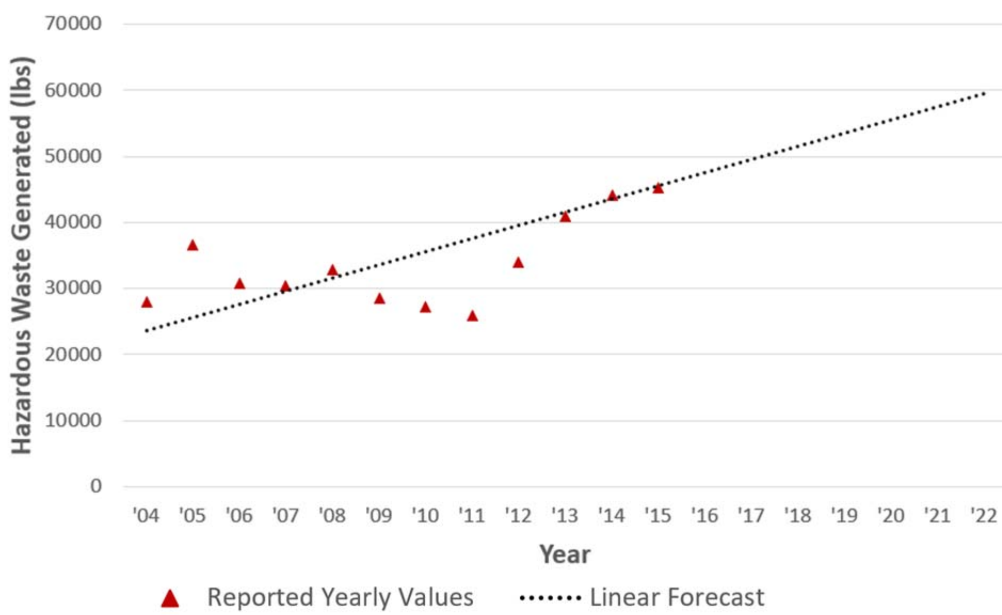

Figure 3.10 Annual Hazardous Waste Generated at CMU

3.4.2 Exposure to Hazardous Materials

To reduce the potential for overexposure to hazardous materials, EH&S conducts annual reviews of Potentially Hazardous Substances (PHS) and known carcinogens kept in inventory. The review asks the lead investigator for each laboratory containing these materials a set of three questions:

1. Is there a need for the material or can it be replaced with a different substance?
2. Is there a use for the material or can it be disposed of?
3. If the material is being used, what are the operating procedures and would the individual(s) handling the substance be willing to undergo a Personal Exposure Sampling Survey?

This systematic questioning allows EH&S to dispose of hazardous materials that are no longer needed or in use, hence decreasing the potential for accidental overexposure (Harris 2018).

EH&S requires Personal Exposure Sampling Surveys for all laboratory members who handle known carcinogens outside of a contained environment (i.e. a glove box). These surveys are made up of two parts. The first is a standard operating procedure review. This consists of an EH&S staff member overseeing equipment operation and the handling of the hazardous substance. The observed practices are compared to published standards and recommended practices, ensuring that all individuals exposed to these substances are following proper practices. The second part of the survey uses dosimetry badges and a monitoring pump. These objects monitor the exposure to the hazardous substance, and are analyzed at certified, third-party labs. Following the results of this analysis, EH&S personnel can either approve the proposed practices if exposure levels are within allowed quantities, or recommend changes to these if levels exceed those recommended. The survey certifies individuals to work with the specified substances using the reviewed practices. Should the laboratory need to use a new known carcinogen or change its operating procedure, a new survey would be required. The Personal Exposure Sampling Survey is required for all members of the university working with known carcinogens, but is available upon request for individuals working with other hazardous substances. To date, the Personal Exposure Sampling Survey has never documented an instance of overexposure (Harris 2018).

3.4.3 Management of Hazardous Wastes

The management of hazardous waste is led by a collaboration between EH&S and CMU's hazardous waste contractor, Veolia North America. Waste pickups can be scheduled by contacting EH&S, and these are available every other week. The pick-up schedule for each year can be found on the EH&S webpage. Materials eligible for hazardous waste pickup are the same as those regulated and defined by Resource Conservation and Recovery Act, which can be found on the EPA's webpage. Such materials include hazardous chemicals, oils, radioactive waste, and universal waste (paints, pesticides, mercury-containing substances, etc.). In addition, EH&S also collects alkaline batteries from each department though they are not regulated. These are broken down in order to recover and recycle their metal. Biowaste is incinerated or autoclaved. Chemical waste, the majority of which is mixed as flammable liquid, is used by Veolia in their waste to energy program. All waste is collected from the individual laboratories, also known as satellite accumulation areas, and moved to CMU's hazardous waste vault, known as the central accumulation area. Here, university staff works with Veolia staff to package and ship the waste to Veolia's Illinois and Ohio facilities (Harris 2018).

Veolia's waste to energy program take flammable liquids and processes them in order to recover as much and as many of the individual components making up the mixture. The remaining, unrecoverable components are blended with energy generating liquids like oil to make alternative fuels. These fuels are then sold to energy generators like steam, cogeneration, and electric plants. To ensure that Veolia is complying with regulations and with its promised service, EH&S conducts an annual audit, sending personnel members to the contractor's facilities. There, personnel complete a compliance history report, ensuring that the facilities' general practice and conditions are in agreement with the promised service. About 90% of CMU's hazardous waste is treated via Veolia's waste to energy program (Harris 2018).

3.4.4 Future Needs and Options

While the current situation around hazardous materials and hazardous waste is very optimistic, there are two avenues around this area with room for progress. The first is the formalization of a campus-wide chemical sharing program. The second is the propagation of green chemistry throughout the practices and processes adopted in the university's laboratories.

A chemical sharing program allows students, faculty, and researchers to access common inventories. These inventories contain chemicals no longer used, or owned in excess amounts, by other entities on campus. Such a program may reduce the quantities of chemicals purchased, as well as reduce the amount of hazardous waste being produced. Currently, sharing programs exist at the departmental level across the university. However, there exists no formal structure for exchange between departments, and there is no infrastructure like an accessible database that people across the university can use.

Chemical sharing programs in other universities are built on accessibility and the prioritization of safety. The University of Florida has a program named "Chem Swap." It allows faculty and lab personnel to access a list of freely available chemicals that can be requested as needed. These chemicals are then delivered by a member of the university's EH&S department along with a Safety Data Sheet (SDS) that informs the requestor about the hazards associated with the delivered substance. The chemicals are kept in their original, unopened containers in order to minimize the deterioration of these materials and accidental exposure to their hazards ("Chem Swap" 2018). The University of Louisville has a similar program, named "CHEMEX." Like University of Florida's "Chem Swap," the program offers an inventory that seeks to prevent duplicate purchases and unnecessary waste generation. Additionally, they specify criteria for the acceptable chemicals, guidelines that disqualify chemicals and materials, and instructions for submitting chemicals to the sharing program ("CHEMEX" 2018). Both of these programs can serve as examples for a possible program at CMU with accessible interfaces, comprehensive criteria, and clear instructions for use of the program.

The second area with promise for improvement towards a sustainable CMU is the university's investment in green chemistry. As defined by the EPA, green chemistry is a discipline that seeks for the design of materials and processes that reduce or eliminate hazardous materials and waste ("Green Chemistry" 2018). It seeks to achieve this by replacing hazardous chemicals or materials that lead to the generation of hazardous materials, as well as develop new methods for the management of hazardous wastes. At CMU, the Institute for Green Science, part of the Mellon College of Science, leads in the development of education, standards, and technologies centered around green chemistry. The institute has sought to practically implement these goals by inviting guest lecturers, structuring courses teaching sustainability in chemistry, and publishing free online coursework for the public to access. In addition to these projects, the institute is also involved in researching oxidizing agents that break down hazardous waste. This has resulted in activators and processes which help in the catalyzed oxidation and destruction of hazardous waste (Ruben 2018).

The Institute for Green Science is a promising step toward the incorporation of sustainable principles and practices in hazardous chemicals. Its accomplishments so far can be built upon through closer collaboration with departments across the university, more widespread publicizing, and greater investment. So far, the institute is responsible for the structuring of one course, “Chemistry and Sustainability.” Involving the institute with other classes, particularly laboratory courses, may lead to the direct adoption of green chemistry principles and guidelines.

3.5 Conclusions for Waste and Water Management

CMU currently engages in a number of activities to reduce the campus’s water use intensity and waste production. However, better data tracking across all of the sections is required to better assess CMU’s current state. Currently, there is an inadequate break-down of which buildings consume the most water. More detailed descriptions of these areas can help the university discern trends and make better targeted policies.

Although many of the water metered buildings are well on their way to meet the 2020 WUI goals set by Pittsburgh, more measures are needed to reduce the water use intensity of laboratories. However, it is noted that water use per capita may be a better measurement to assess trends in CMU’s water usage and management.

CMU has also taken a number of steps to reduce the campus’s landfill waste per capita through better composting and recycling programs. It can be seen that increased pre-consumption composting has significantly decreased the total landfill waste production. Despite a detailed characterization of the university’s overall recycling efforts, it does not track the composition of waste headed to landfills. While the university is taking active measures towards composting food waste, it needs to take further steps to actively engage its population to make its post-consumption composting more of a success. Current post-consumption composting bins are under-utilized or too contaminated from improper usage.

CMU’s total hazardous waste is expected to increase in the upcoming years. Better centralized monitoring of which department’s purchase what kind of chemicals could allow the university to make targeted policies to help reduce the total hazardous waste production. The current steps taken by EH&S effectively address health and waste management, and could be enhanced by policies centered around chemical sharing and the fostering of the Institute for Green Chemistry, an established entity on campus.

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Chapter 4: Sustainability in Transportation

4.1 Introduction

This chapter examines sustainability aspects of transportation systems associated with university operations and activities. The chapter is organized into different sections for various modes and contexts of transportation necessitated by the university. In structuring this way, the objective is to provide a systematic analysis of all transportation impacts while highlighting those that are most urgent. The sections for different transportation modes are ordered by size of environmental impact found in previous research: first is university business travel by air and then by non-air modes such as car travel. Next is commute by driving, with a focus on faculty and staff behavior since driving commutes are rare among students. After that are alternative transportation modes on CMU's campus such as the campus shuttle system and biking.

4.1.1 Current Transportation Systems at Carnegie Mellon University

Carnegie Mellon utilizes a variety of transportation types for different purposes. These fall into three categories: campus operations, university travel, and commuting. Each of these three categories can be further broken down as shown in Figure 4.1.

Campus operations encompass transportation used by university employees in carrying out work tasks on campus. This includes vehicles operated by Facilities Management Services, Carnegie Mellon University Police, and the campus shuttle system, which is also operated by University Police. University Travel is comprised of transportation modes used by faculty, staff and students in traveling for university-sponsored business, such as air travel, car travel, and bus or rail travel. The Commuter category includes transportation modes used by faculty, staff, and students for everyday travel to and from campus, including driving, biking, and public transportation.

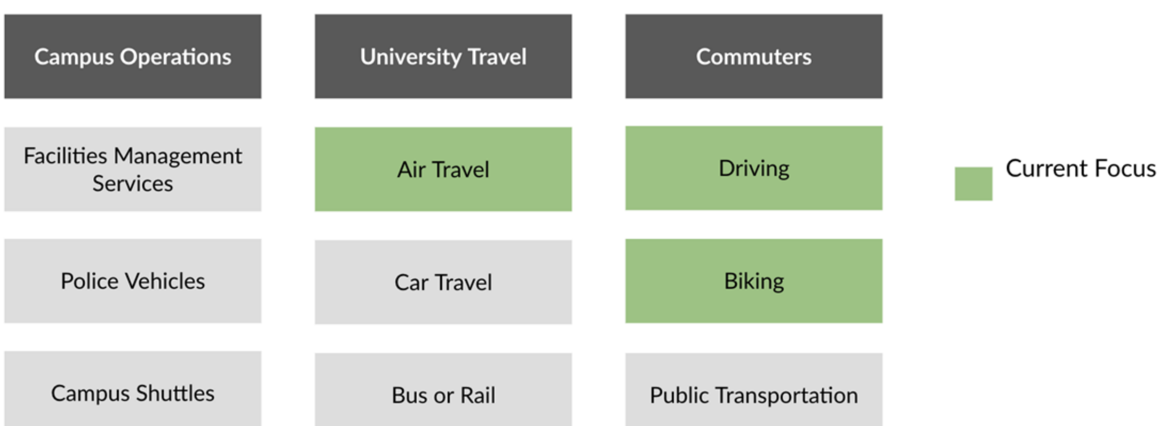

Figure 4.1 Categories and forms of transportation used at Carnegie Mellon

4.1.2 Dimensions and Metrics of Sustainability in Transportation

To analyze the sustainability of Carnegie Mellon's transportation systems, we define four dimensions and three corresponding metrics, shown in Table 4.1.

Table 4.1 Sustainable transportation goals, dimensions, and metrics

Dimension	**Metric**
Lowering GHG emissions	CO_2 emitted per person; total GHG emissions per year
Increasing efficiency	CO_2 emitted per person, per mile traveled
Conserving resources	Reduction in the number of cars
Facilitating mobility	Improved infrastructure for alternative transportation modes

The purpose of defining these dimensions and metrics is to keep transportation sustainability goals well-aligned with the university's overall plans and values. Carnegie Mellon includes sustainability as one of its eight key values, including a "commitment to lead by example", "preserving and protecting natural resources", and "responsible financial planning" in its definition ("Our Values"). The transportation dimensions and metrics defined in Table 4.1 will help support those stated values, allowing for the current trajectory of campus expansion to accommodate Carnegie Mellon's growth in a sustainable manner.

Multiple dimensions address Carnegie Mellon's desire to maintain a leadership role in sustainability. All four dimensions will reduce the environmental impact of transportation and spur CMU decision-makers to produce creative solutions, contributing to CMU's ability to be seen as a leader in sustainability. In particular, the first dimension of lowering total GHG emissions aims to produce measurable and sizeable reductions in carbon emissions per person, which is among the most salient environmental impacts of transportation. The fourth dimension, facilitating mobility, also contributes to this goal while enhancing the capacity for members of the university and the local community to engage with CMU's campus.

In addition, multiple dimensions address the need to manage financial and natural resources effectively. The second dimension, increasing efficiency, would motivate saving money on cost-intensive modes of transportation wherever possible, and lead to lower energy and natural resource use. The main metric of increased efficiency would be reductions in carbon dioxide emitted per person, per mile traveled. The third dimension, conserving general resources, such as building space, would contribute to more responsible financial planning by driving better utilization of campus resources for academic and business purposes, instead of spending money on building parking structures. Additionally, conserving resources contributes to natural resource preservation by promoting more efficient and sustainable transportation modes that consume less fossil fuel. The main metric for resource conservation would be the reduction in the number of cars driven to campus. Finally, the fourth dimension of facilitating mobility would also aim to promote alternative modes of transportation on campus. reducing environmental impact and strengthening sustainable connections between campus and the Pittsburgh community, while reducing costs and resources for supporting cars on campus. The primary metric for facilitating mobility would be measured improvements in infrastructure for alternative transportation modes.

4.2 University Business Air Travel

According to a recent study (CMU 2017), the most significant source of travel-related carbon emissions at CMU is university-sponsored air travel. To update that previous analysis of faculty, staff, and student university-sponsored air travel, this report draws on updated datasets, and disaggregates existing datasets in a more informative manner. The analysis presented below shows that overall, for faculty and staff air travel, certain colleges and other operational units of the university were identified as having high rates of carbon emissions from air travel, while student organization air travel was determined to be relatively insignificant.

4.2.1 Carbon Emissions from Faculty and Staff Business Air Travel

An aggregate analysis of CMU-sponsored air travel was conducted in 2017 (Cedillo et.al 2017). Here, we re-analyzed this data at a more disaggregated level. This data was provided by Procurement Services at CMU, and included total university spending on air travel from FY 2012 through 2017, as well as total spending on air travel through two university-approved travel agencies, Egencia Travel and Direct Travel, from FY 2012 through 2017, plus a Direct Travel generated CO_2 estimate for all travel purchased through their agency from FY 2012 through 2017. The latter data were first used by the agency to estimate CO_2 emissions based on the air mileage of purchased flights. This also yielded an estimate of the CO_2 emissions per dollar of air ticket cost. We then used this factor to estimate the CO_2 emissions from all university-purchased air travel by each major unit of the university.

To estimate miles traveled, we used the same conversion relationship from the 2017 analysis of faculty and staff business air travel. The key assumptions are that a fully-occupied plane emits 53.3 pounds of carbon dioxide per mile traveled (the CO_2 factor) and that the average capacity of a plane is 129 passengers (based on the average capacity of a Boeing 737, which is the most commonly used model of an airplane). Using these assumed values, and inputting the mileage of the flight, the average carbon dioxide emitted per passenger can be estimated with the following equation:

$$\frac{1\ passenger}{avg.\,plane\ capacity} * Flight\ Mileage * CO2\ Factor\ \left(\frac{metric\ tons}{air\ mile}\right)$$

Equation 4.1 Estimation of carbon emissions per flight

Figure 4.2 shows the total airfare spending from FY 2012 to FY 2017, with an average of $10.8 million per year and a 15% average increase per year over this period. The data show a spike in FY2015, for which we could not find a clear explanation.

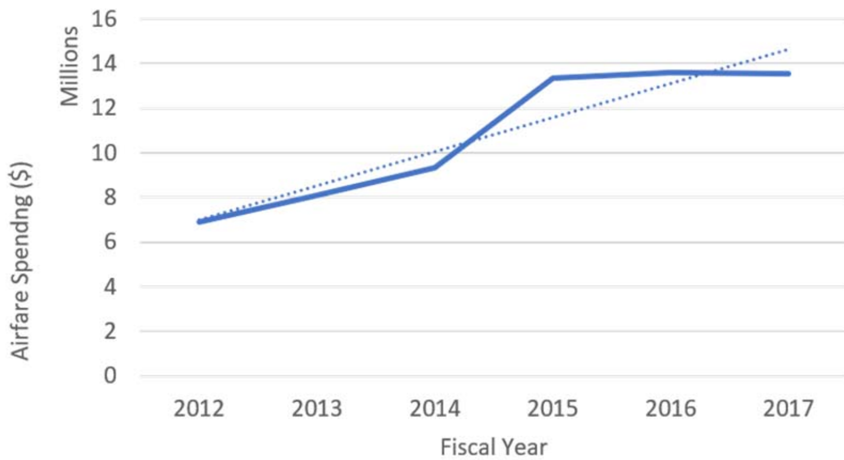

Figure 4.2 Airfare Spending for Faculty and Staff FY 2012-2017

Figure 4.3 shows total airfare spending and CO_2 emissions from air travel with projections from FY 2018 to FY 2022. Due to the large increase in spending in FY2015, we believed the average 15% increase per year is not a reliable predictor, therefore, averaging the increase in spending for FY 2016 and 2017, an increase of 0.67% per year was used to estimate spending from FY 2018 to 2022, assuming there will be no large increase in spending as occurred in 2015.

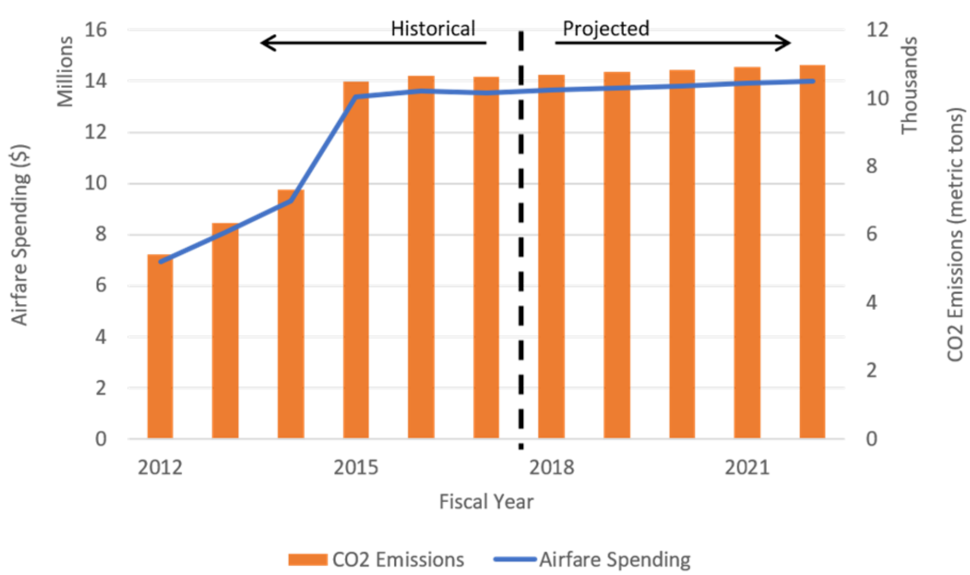

Figure 4.3 CO_2 Emissions from Faculty and Staff Air Travel FY 2012-2017, Projected FY 2017-2022

Using the prior data, we can further disaggregate air-travel emissions by academic colleges, interdisciplinary centers, and non-academic units (see Figure 4.4). Figure 4.5 shows the breakdown of emissions by groups from FY 2012 to FY 2017. We can see that the 2015 spike in emissions largely comes from Unit 20, while emissions from the other groups increased a smaller amount.

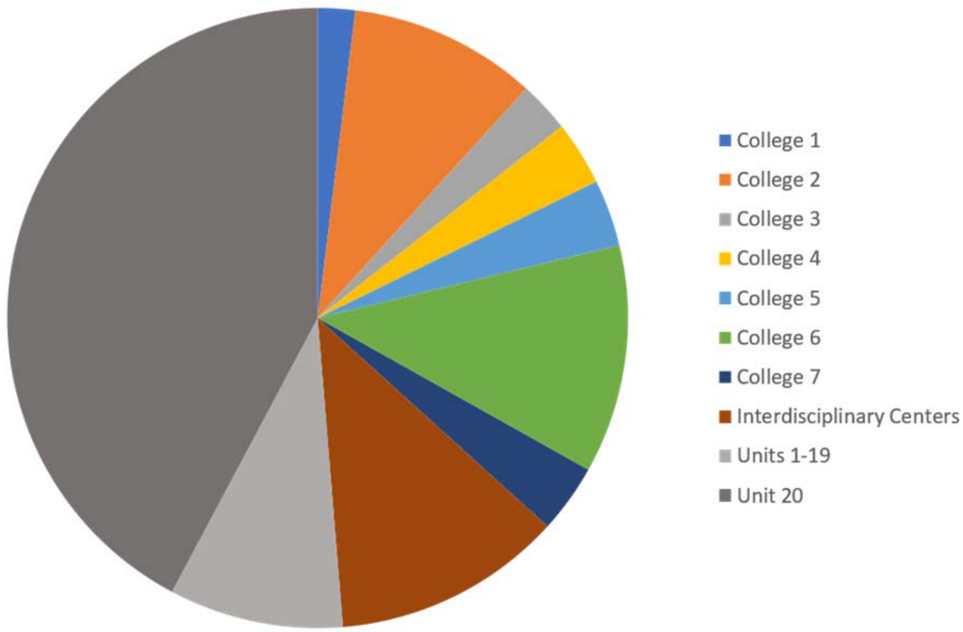

Figure 4.4 Breakdown of Cumulated Air Travel CO_2 Emissions by Affiliation, FY 2012-FY 2017

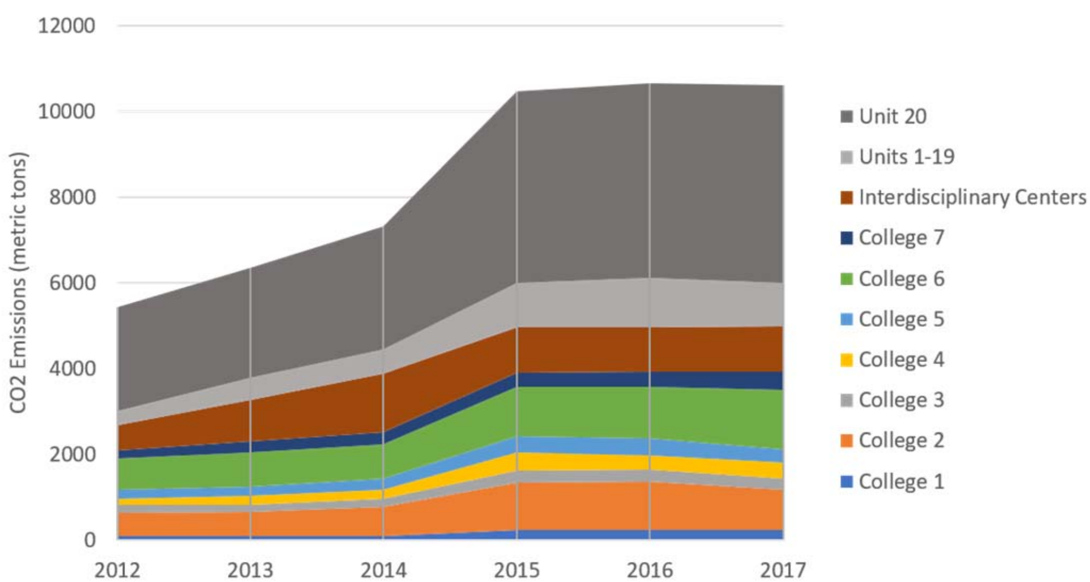

Figure 4.5 Air Travel CO_2 Emissions by Affiliation, FY 2012-FY 2017

Looking more closely, although the largest increase in spending and emissions can be contributed to Unit 20, the fastest increasing body is College 1, due to its small starting point (see Figure 4.6).

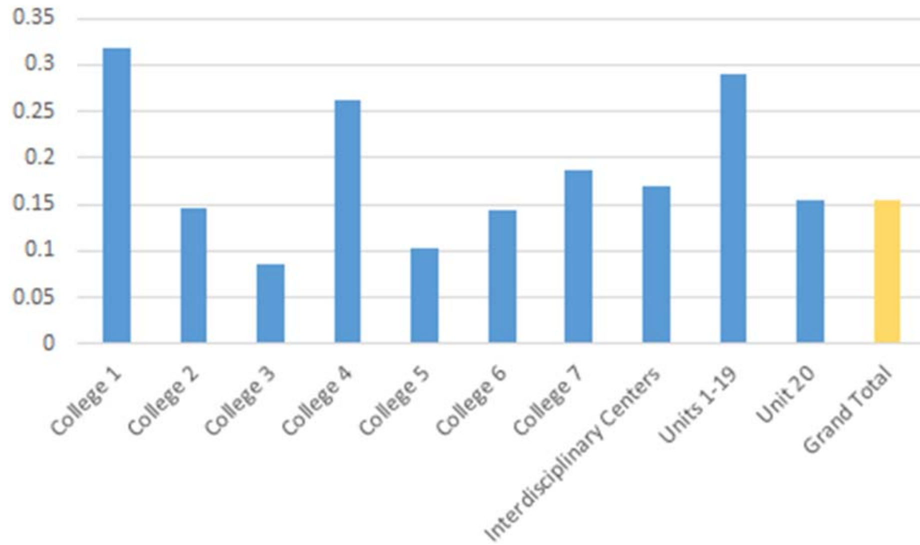

Figure 4.6 Average Annual Increase in CO_2 Emissions by Affiliation, FY 2012-FY 2017

Now that we have looked at spending and emissions by affiliation as a whole, we want to see if the number of people associated with each college is affecting the amount spent and ultimately emissions. Figure 4.6 shows total emissions by affiliation and emissions per faculty by college from FY 2012-FY 2017. Total emissions for a college for a fiscal year was divided by the number of primary appointment faculty members in that college during that year. This data was found in past university factbooks. Only faculty was included in the calculation because most of the air travel is done by faculty. We did not include interdisciplinary centers and non-academic units because the number of primary appointees was not clear.

We see from Figure 4.7 that although the School of Computer Science generates the largest emissions, it also has more faculty, therefore it is not the biggest emitter per faculty. Heinz College has relatively low total emissions, but it has the smallest number of faculty and is the biggest emitter faculty, this might be contributed to the large number of foreign locations of Heinz College. When we consider in staff for each college, CIT becomes the highest emitter per capita, closely followed by SCS, Heinz, and Tepper. Then, in hope of finding a connection between the amount traveled and the amount of research dollars each college spends, we see Heinz, Tepper and CFA have the highest emissions per $1,000 research spending, where these colleges have the significantly lower research spending than the other colleges.

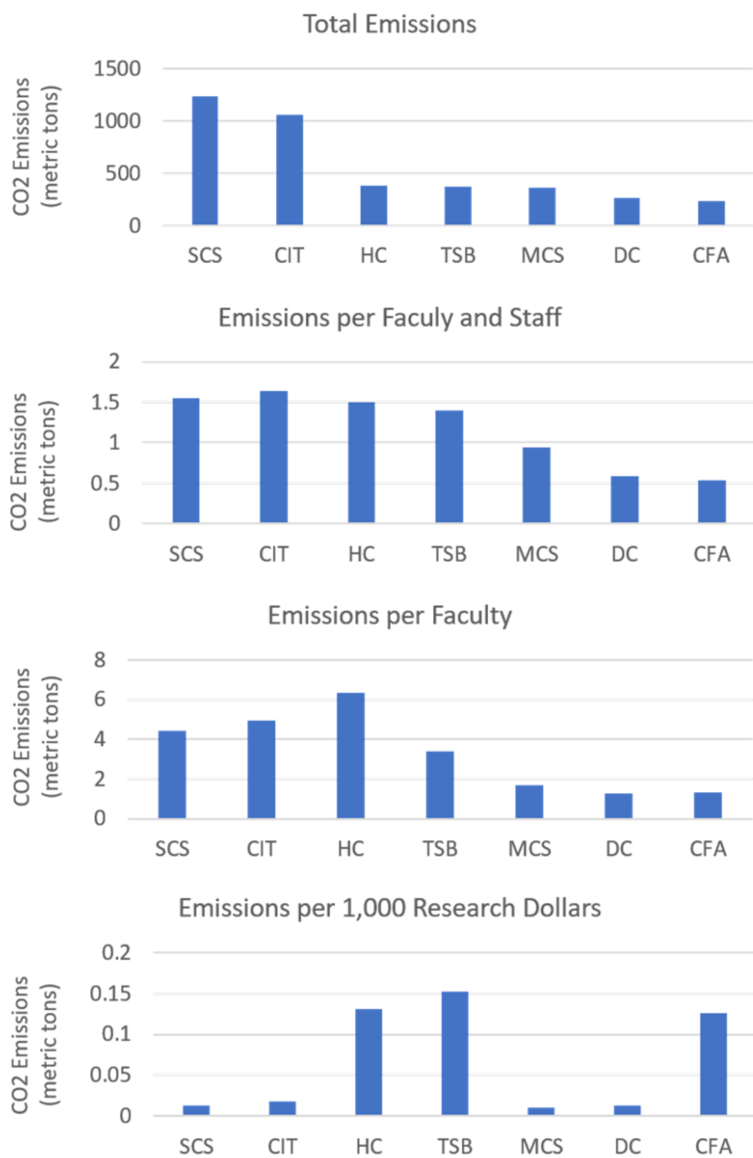

Figure 4.7 Air Travel CO_2 Emissions by Affiliation, Total, Per Faculty and Staff, per Faculty, and per 1,000 Research Dollars, FY2012-FY2017

4.2.2 Carbon Emissions from Student Organization Air Travel

Beyond faculty and staff business air travel, CMU sponsors air travel by student organizations for organization-related activities. The previous year's report included analysis on student organization travel from fiscal years 2013 to 2017. To update that analysis, this report draws on student organization travel data from fiscal years 2010 through 2018, obtained from SLICE.

Within that dataset, the air travel data was separated into foreign and domestic categories. However, we analyzed the two categories together to obtain the total carbon emissions for each fiscal year. To calculate the carbon emissions for FY 2012 to 2015, the average airfare per pound of carbon dioxide was obtained from data supplied by Direct Travel for the 2017 study (CMU 2017). In the other years (2010, 2011, and 2016 - 2018), an average cost per pound of carbon dioxide was determined from the Direct Travel values. It was assumed that the Direct Travel values were representative of all student organization travel. To calculate the estimated carbon dioxide for each year, the total spending on air travel was divided by the cost per pound of carbon dioxide. The resulting values are shown in Figure 4.8.

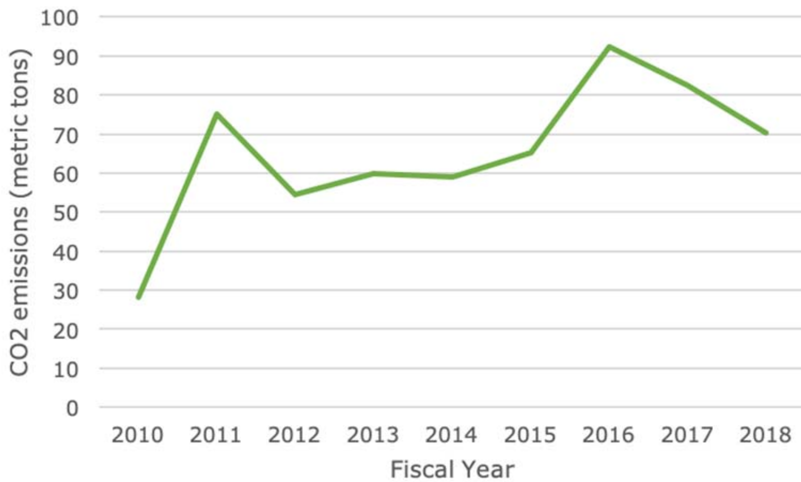

Figure 4.8 Student Organization Air Travel Emissions from FY 2010 - 2018

A generally increasing trend can be seen in the data, with a dramatic spike from 2010 to 2011, and slight decreases from 2011 to 2012 and 2016 to 2018. Comparing these values to other segments of university travel, student organization air travel emissions are less than 1% of faculty and staff air travel emissions, and thus are relatively insignificant when considering CMU transportation emissions as a whole.

In conclusion, while it may be beneficial to set policies encouraging student organizations to reduce air travel where possible, the emissions are not significant enough to be a high priority in CMU's transportation emissions reduction plan.

4.3 University Business Non-Air Travel

4.3.1 Faculty and Staff Business Non-Air Travel

Faculty and staff business non-air travel primarily involves travel via rental cars. The previous report included basic data on total car rental spending from FY 2012 to 2015. Since the authors only had data reported by the Direct Travel agency, which represented only part of total car rental spending, they modeled total spending on car rental as approximately 188% of that reported by Direct Travel. This comes from their assumption that the proportion of car rental spending reported by Direct Travel was

53% of the total, since they had determined the proportion of air travel spending reported by Direct Travel to be 53% of total air travel spending.

Updating the previous year's analysis, the current analysis draws on car rental data from FY 2012 to FY 2017. To obtain the estimated carbon emissions per year, an estimate of car rental spending was calculated by determining an average ratio of car rental spending to air travel spending, using values from reports provided by Direct Travel in the previous year's report. A ratio of car rental emissions to car rental spending was also obtained using the Direct Travel data. It was assumed that these ratios from the Direct Travel data were representative of all rental car travel in our current dataset. Once the estimated car rental spending and ratio of emissions to spending were obtained, these values were multiplied to obtain the estimated emissions per year, shown in Figure 4.9.

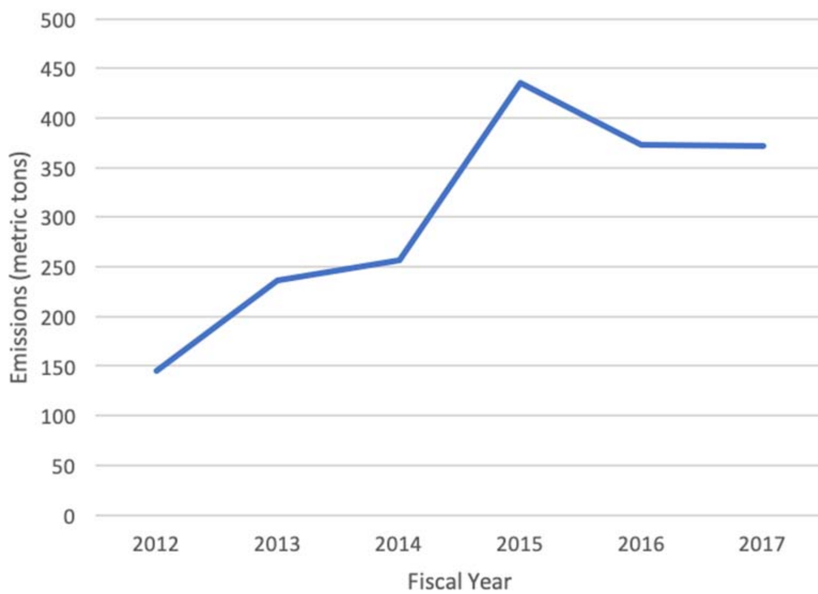

Figure 4.9 Estimated total spending on faculty and staff rental cars

In the data, a general positive trend can be seen. Additionally, comparing these values to other travel segments, it was determined that faculty and staff car rental emissions are generally between 2.4% and 7.2% of faculty and staff air travel emissions.

While this is not a negligible fraction of travel emissions, and the trend shows an increase in emissions, any policies to reduce car rental emissions should most likely be connected with policies to reduce air travel emissions, since car rentals usually occur as a result of air travel, as air travelers require ground transportation in some destinations.

4.3.2 Student Organization Non-Air Travel

Driving makes up most student organization travel that is not air travel. For driving to destinations, students have the option of renting cars, or driving personal vehicles. To update the previous year's analysis, the current analysis draws on student organization car rental and gas spending data from FY 2010 to 2018. The relevant data for car rentals and gasoline purchases were found in the categories for car rental and "other travel".

In order to determine the estimated annual carbon emissions from student organization gas purchases, the total spending on gasoline was obtained for each fiscal year from 2010 to 2018. To convert the spending to quantity of gasoline, average national gas prices per gallon from each fiscal year were obtained. Then, to convert quantity of gasoline to carbon emissions, a value for carbon dioxide per gallon of gasoline was obtained. Once the total spending, cost per gallon of gasoline, and carbon dioxide per gallon of gasoline were determined, the following relationship was used to obtain the estimated carbon dioxide emissions per year.

$$Lbs\ of\ CO_2 = \$ * \left(\frac{gallons\ gasoline}{\$}\right) * \left(\frac{lbs\ CO_2}{gallons\ gasoline}\right)$$

Equation 4.2 Car Rental Emissions

The resulting values are shown in the figure below.

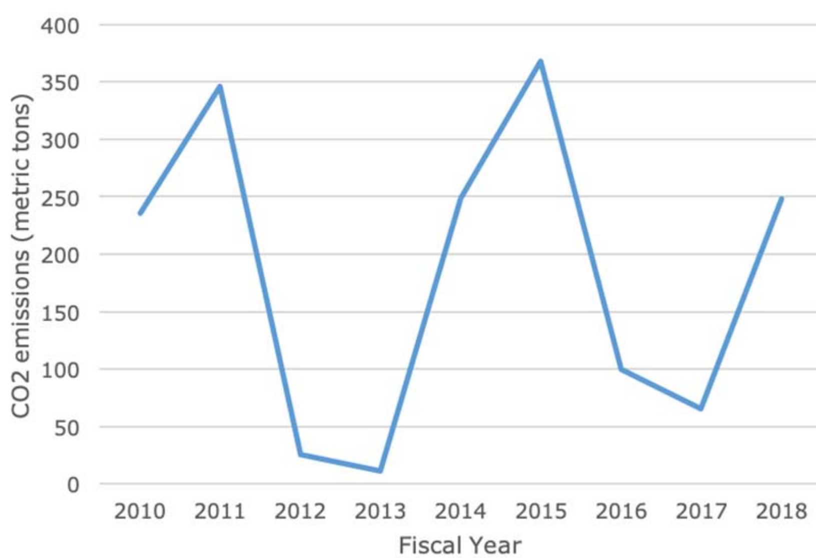

Figure 4.10 Student Organization Emissions from Gasoline, FY 2010 - 2018

The data shows a generally increasing trend. However, while there are dramatic peaks and troughs, the accuracy of these is uncertain, as it simply reflects the number of times fuel purchases were specified in the SLICE dataset. In low years, there were many instances of student travel simply being specified as “Other Travel”, without description of whether the spending included gasoline.

Comparing these values to other transportation segments, it was determined that student organization gasoline emissions are generally less than 1.5% of faculty and staff air travel emissions, the largest emissions segment. So, as with student organization air travel, it may be beneficial to promote reduction in car travel by student organizations, but since the emissions are relatively low compared to other segments, this should not be an area of first focus in reducing transportation emissions.

For rental cars used by student organizations, carbon emissions were determined using the same ratio of car rental emissions to car rental spending using the Direct Travel data. Again, it was assumed that these ratios from the Direct Travel data were representative of all rental car travel in our current dataset. Once the estimated car rental spending and ratio of emissions to spending were obtained, these values were multiplied to obtain the estimated emissions per year, shown in the figure below.

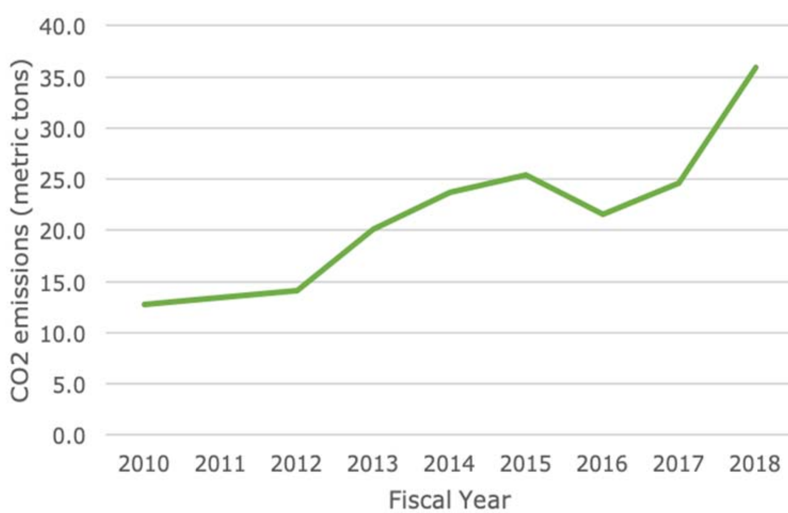

Figure 4.11 Carbon Emissions from Student Organization Car Rentals

From this data, a general upward trend can be seen from year to year, with a slight decrease between 2015 and 2016. Additionally, student organization rental car emissions are generally less than 2% of faculty and staff air emissions.

As with other student organization travel, it can be concluded that while policies reducing rental car use would be beneficial, the emissions are not significant enough to place student organization rental car travel as a high priority in reducing CMU’s overall transportation emissions.

4.4 Strategies to Mitigate Emissions from University-Sponsored Travel

Indirect emissions from university-sponsored travel is a significant portion of CMU-related emissions, although it occurs off campus, as global citizens, CMU should consider taking part in mitigating such emissions for the benefit of not only our campus but the world.

The 2017 student report (Cedillo et.al) proposed a 5-year carbon offset program for university-sponsored air travel, which entails a $15 fee for every metric ton of CO_2 emitted. For a trip from Pittsburgh to San Francisco, this would mean an extra $12 added to the base ticket price. A total of around $1 million would be collected through this program over five years and this would go towards sponsoring sustainability-related research and project grants.

An alternative to sponsoring sustainability research, the whole or a portion of the carbon offset fund could be redistributed among each department, weighted by the number of faculty with primary appointment, assuming faculties of each department are responsible for the majority of trips. This would mean that the more a department spends towards travel, the less it would get back. This can further incentivize departments to control the number of trips its people are taking, and disincentivize departments to fund unnecessary or less-justified trips. This program can be extended to all types of university-sponsored travel, with different offset standards for each mode of transportation.

4.5 Faculty and Staff Commuting

The goal of this section is to propose ways of reducing driving to campus through better group transportation programs like carpooling. To examine the potential feasibility and usefulness of such programs, we need to understand the target audiences and stakeholders. For example, what can we make incentives for faculty and staff to carpool to campus? How would this affect the number of permit registrations? How would this then affect the revenue from permit fees each year? Looking at the change in available and occupied university-owned parking spaces from 1986 to 2017, we observed an average increase of 1.28% in availability and 1.08% increase in occupancy every year, but with a 10% decrease in occupancy from 2016 to 2017. With trends like this, how necessary will group transportation programs be?

With these questions in mind, this section explores faculty and staff driving commute between their residences and the CMU main campus. By understanding the distribution of residences and where parking permit holders are driving from, we can get a better sense of commuting patterns of faculty and staff, and therefore better understand the stakeholders in group transportation programs.

4.5.1 Residence Zip Code Mapping

Data on faculty and staff residence zip codes were provided by CMU Human Resources. Using this data we can estimate the likely commuting distance for these groups. We assumed that the zip code listed on file is in fact one's residence zip code, and no two faculty and/or staff live in the same residence.

Point-to-point distances between their zip code and CMU main campus were calculated and weighted-averaged to provide a more accurate average commute distance. The true average commute distances will be larger than the average point-to-point distance that was used.

Figure 4.12 shows where faculty residences are located, the darker the color, the denser the population. Squirrel Hill (15217) has the highest faculty residence count at 388, accounting for roughly 30% of the 1,324 faculties. The average point-to-point distance between faculty residences and CMU main campus is 12.2 km.

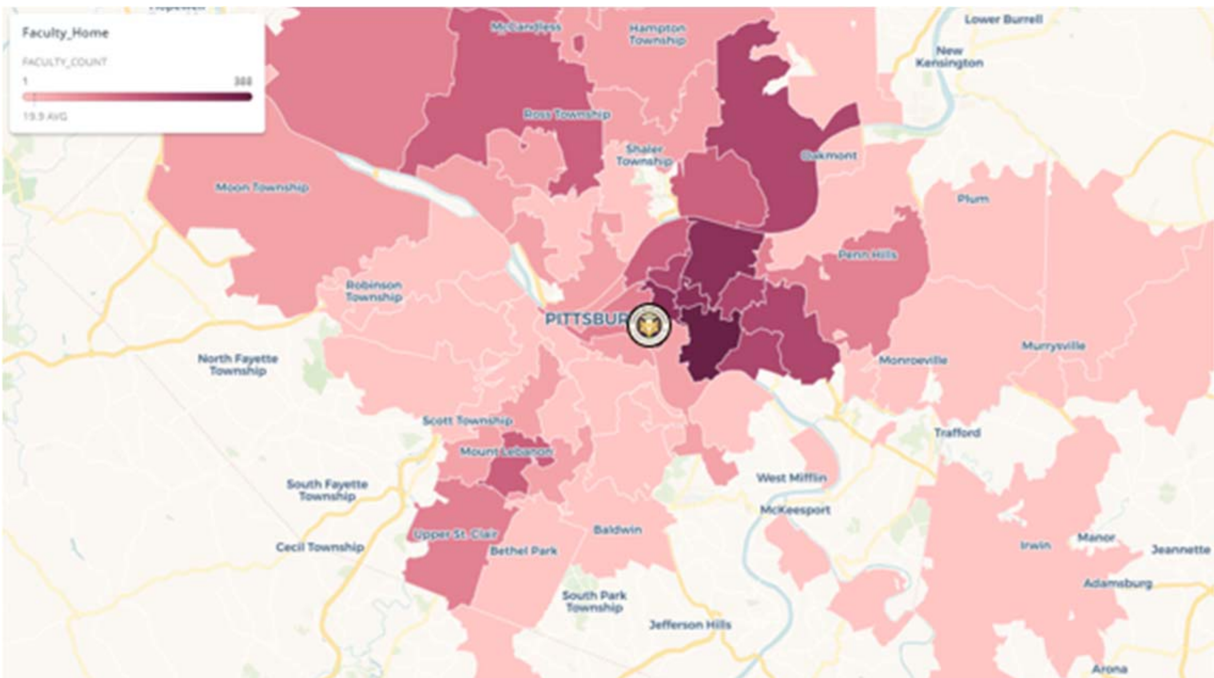

Figure 4.12 Faculty Residence Zip Code Density

Figure 4.13 parallels the prior figure, but for staff. Again, Squirrel Hill (15217) has the highest staff residence count at 373, or roughly 10% of the 4,104 staff. The average point-to-point distance between staff residences and CMU main campus is 23.4 km, almost twice as far as the average faculty distance. The purple rectangle depicts the borders used in Figure 4.6, showing staff residences are more spread out than that of the faculty.

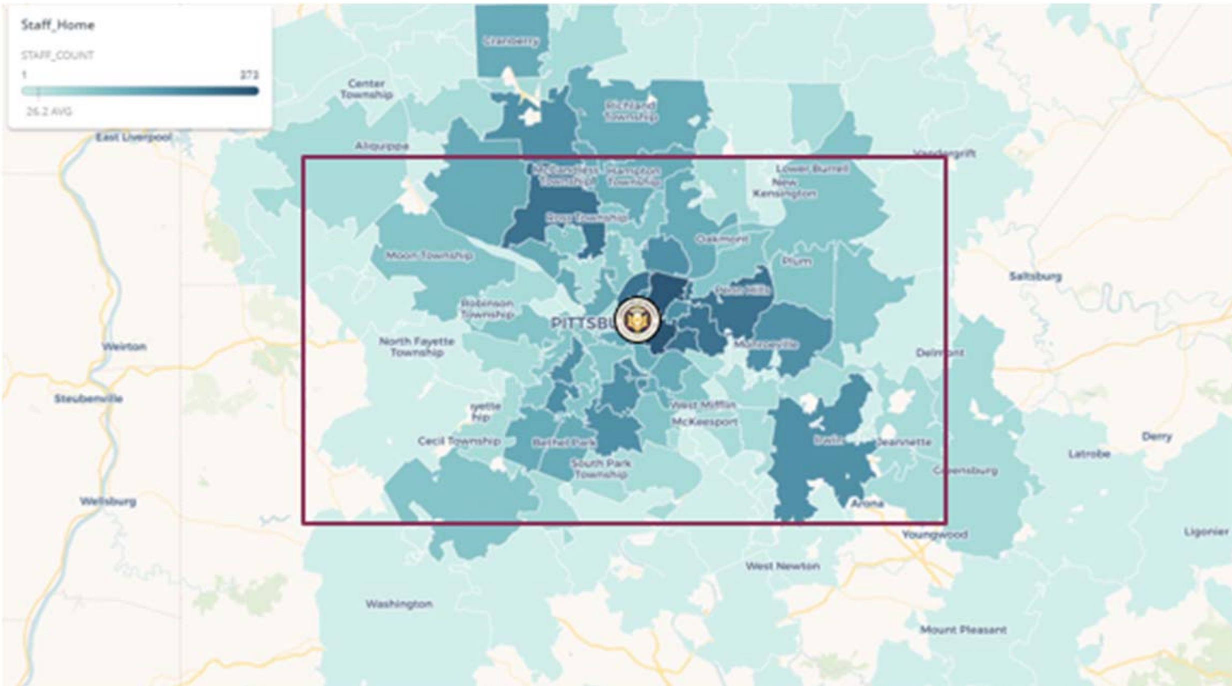

Figure 4.13 Staff Residence Zip Code Density

4.5.2 Vehicle Zip Code Mapping

Data on residence zip codes of CMU parking permit holders were provided by CMU Parking and Transportation services. Figures 4.14 and 4.15 show the ratio of issued parking permits to residents by zip code for faculty and staff respectively, with darker colors indicating higher ratios. Note that some of the zip codes have a permit-to-person ratio higher than one, likely indicating a data issue caused by inconsistencies in the parking permit registration system and the residence information system used by Human Resources. Notwithstanding these inconsistencies, it appears that individuals living further from campus are more likely to purchase a parking permit and drive to campus.

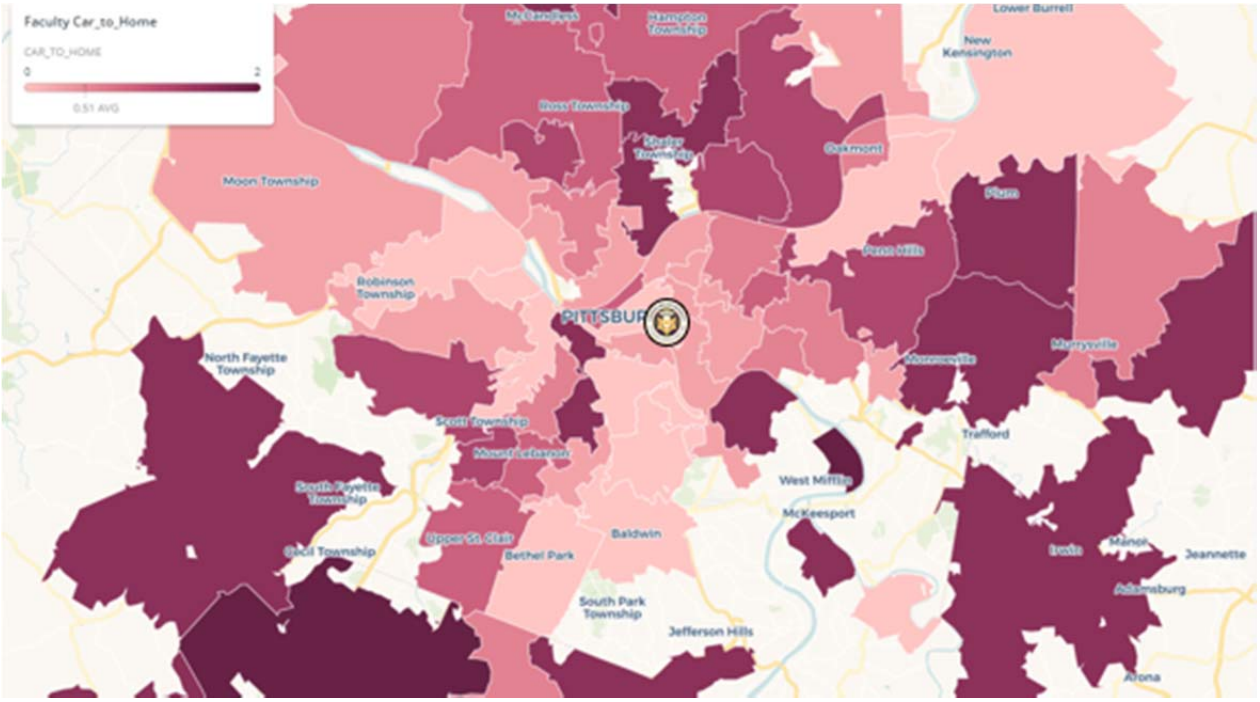

Figure 4.14 Faculty Parking Permit Distribution

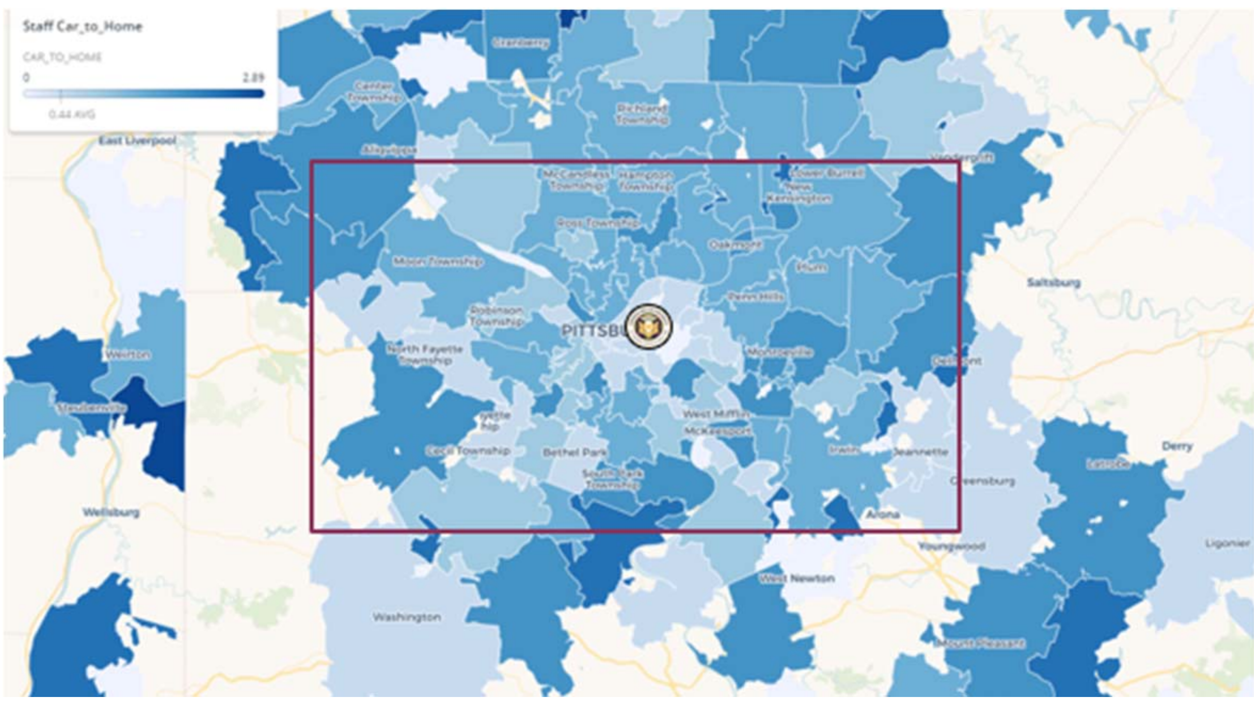

Figure 4.15 Staff Parking Permit Distribution

4.5.3 Strategies to Reduce Driving Commutes

Commuting is a part of our daily lives that simply cannot be ignored. However, given the option and opportunity, the CMU community can all take part in consciously choosing commuting methods that are lower in emissions than driving personal vehicles.

Currently, faculty travels an average of 15.2 miles per round trip between campus and their residence, and staff travels an average of 29.1 miles per round trip between campus and their residence. A weighted average of the daily cost of campus parking totals about $6/day. Using an online calculator (commuteinfo.org 2018) that incorporates the cost of fuel and other fees associated with car ownership, a faculty member spends on average about $2800 annually on commuting to and from campus, and a staff member $5260 per year.

However, the current carpool program that CMU offers has only 72 carpool permit holder participants. Each permit holder can get a $10 monthly discount from their permit fee, which saves $120 per year per vehicle. This is a very small savings (roughly 7%) in the total annual cost of commuting noted above. And since none of the passengers that signed up with the 72 carpool drivers are permit holders themselves, at best the current program is effectively reducing the number of personal vehicles driven to campus every day by only 72 (assuming all carpool passengers would be driving individually if they were not carpooling).

Therefore, CMU might consider revising the current carpool program to save more money for faculty and staff, lower emissions, and more importantly, push people into the mindset of choosing group transportation. One option could be to give heavier parking discounts to carpool participants. A heavier discount also needs more intense monitoring of whether people are actually riding together and not just signing up for the discount. According to CMU's parking policy, only one car from the carpool group can park on campus for any given weekday, however, because currently there is only one car associated with every carpool group, there is no need to physically implement this policy.

Another way to potentially expand the number of carpool participants would be to set up a platform where people with the intention of participating can find each other. For example, a list of open routes can be put up online for people to sign up for. Or an app could be developed to optimize routes, departure times, and persons for each carpool group.

To further reduce driving commute, CMU can consider increasing parking fees, or alternative payment plans, as opposed to monthly permit fees which may encourage permit holders to drive as often as possible since they've prepaid for their right to drive. One option can be a daily pass that costs slightly more than the daily average of the monthly fee, with no guaranteed space in popular lots. This can incentivize people to drive only when they must. People can pre-purchase passes through their online parking account whenever they need to, and one pass can be used throughout the day with multiple reentries.

4.6 Bicycling

Bicycling is an economical, healthy, and emissions-free mode of transportation. Furthermore, bicycling provides people a wide range of health and wellness benefits including lowered levels of stress, reduced risk of obesity, and reduced risk of depression (Department of Health & Human Services 2013). A study conducted in the Netherlands even demonstrated people who commuted to work by bike had lower rates of absenteeism than people who did not (TNO Quality of Life 2009). In addition, unlike driving and taking public transportation, bicycling is emissions-free so it does not diminish air quality nor produce greenhouse gases. Given the economic, health, and environmental benefits of bicycling, increasing the population using this mode of transportation may improve CMU's sustainability.

Recently, CMU has been encouraging more of the community to bike by improving the safety and convenience of its bicycle infrastructure. It has also begun to host more programs to educate and promote more cycling. Much of these efforts are contributed by the Bicycle Advisory Committee, headed by Karen Brooks, which consists of stakeholders across the University including Michelle Porter, Director of Parking and Transportation Services, Barbara Kviz, Sustainability Committee Chair, Martin Altschul, University Engineer, and various professors, graduate students, and undergraduate students. As a result of CMU's improvements in its bicycling infrastructure and culture, CMU was awarded as a Silver-Level Bicycle Friendly University by League of American Bicyclists in 2018. However, there are still many improvements that can be made to facilitate bicycling at CMU.

4.6.1 Current Status of Bicycling At CMU

A university's infrastructure is an important factor in its "bikeability." The university needs to create an environment that is safe and convenient for people to ride and park their bicycles. The two key aspects in assessing a university's bicycling infrastructure are conventional and protected bike lanes and secure and convenient parking.

Currently, CMU does not have any secured bike lanes on and surrounding campus. The lack of bike lanes around CMU increases the risk of crash related injury and deaths of bicyclists (Teschke 2012), and thus prevents commuting by bicycling from being a safe experience. Furthermore, because there are no designated bike lanes cyclists may utilize narrow sidewalks to avoid vehicles, which increases the probability of injury for pedestrians. If there were bike lanes around CMU, then there would be fewer cyclists on the sidewalk which would reduce the risk of collision between pedestrians and cyclists. This relationship between the installation of bike lanes and fewer cyclists on sidewalks has been shown by the D.C. Department of Transportation (DDOT 2013). DDOT conducted a study that indicated that an average of 56% of pedestrians find that there are fewer cyclists riding on sidewalks after the construction of bike lanes (DDOT 2013). Lastly, without designated bike lanes for cyclists, drivers are also at risk. When cyclists are on the road, they currently interfere with vehicles that are traveling significantly faster than they are. Overall, because of the lack of secure bike lanes to travel to and from CMU, not only are people are often discouraged to have bicycles as their primary mode of transportation, but stakeholders other than cyclists such as pedestrians and drivers are also at risk as well.

CMU does provide bicycle parking scattered throughout the campus that can accommodate around 1,500 bicycles. CMU's bicycle parking consists mostly of bike racks located in popular areas such as near classrooms buildings, libraries, and dormitories, bike cages in some garages, and one indoor bike room in Mellon Institute (CMU 2018).

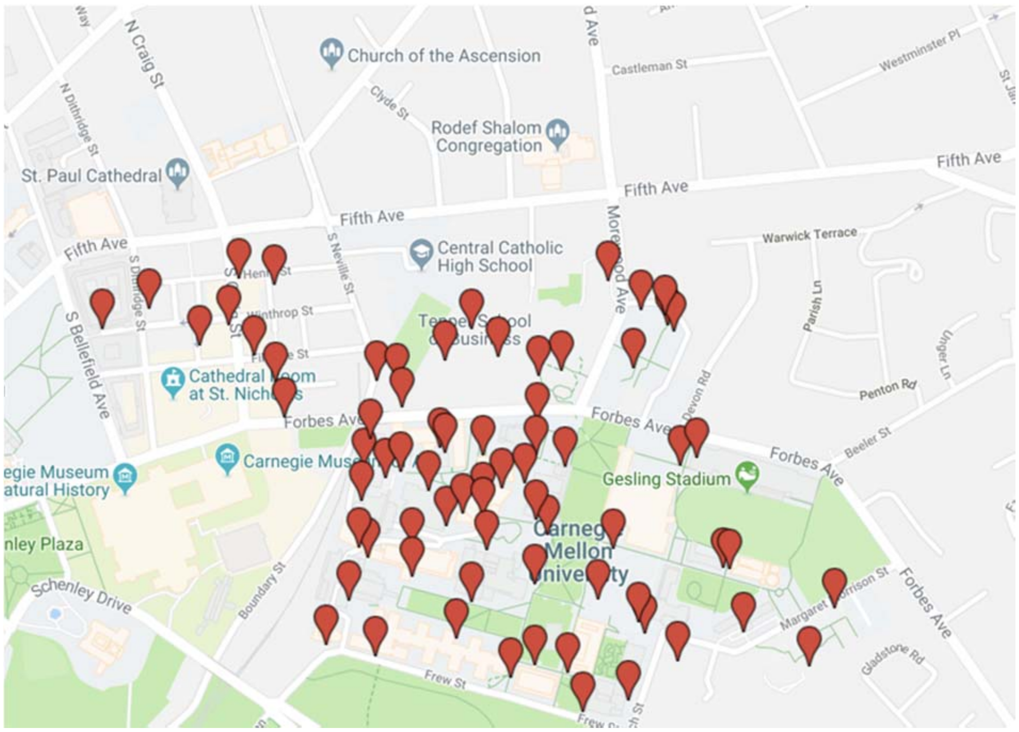

Figure 4.16 Map of Bicycling Parking Spots at CMU (CMU 2018)

While the university does provide resources for people to park bicycles on campus, bike parking remains as a key area to improve. In the past, CMU students have expressed difficulty parking their bikes due to bike racks being crowded and bike racks not being implemented in desired locations (Trimboli 2015). Furthermore, the majority of bike parking at CMU are outdoor bike racks which expose bikes to inclement weather and theft. . Since there remains flaws in bicycle parking that make bike commuting inconvenient, improving bicycle parking can help encourage members of the community to use bicycles as their primary mode of transportation.

Another aspect, along with bike infrastructure, that promotes bicycling at a university is thorough public education. Currently, CMU hosts many events throughout the school year to encourage and educate people about cycling. For example, there are the annual Fall and Spring Bike Kickoff events held near the Cohon University Center. During these events, CMU's Bicycle Advocacy Committee sells used bikes, promotes people to register their bikes, and informs the community about Pittsburgh bicycling, the local Healthy Ride Bike Share program, and answers any other questions raised by participants. In addition, CMU provides resources that help people build skills and confidence to ride safely on the road. Some of these resources include classes on city cycling, bicycle maintenance, and even how to dress warmly for cycling. However, while CMU does provide the educational resources for the community, the community does not widely utilize and engage with these resources. Members of the community often report that they do not know about bicycle resources, and annually only around 60 individuals participate in the educational bicycle classes (Brooks 2018).

4.6.2 Plans in Progress

Realizing that the infrastructure has been discouraging members of the community from using bicycling as their primary mode of transportation, CMU has been working closely with the City of Pittsburgh and other partners to ensure that streets surrounding campus are as safe and accommodating for bicyclists and pedestrians. One major project that the Campus Design & Facility Management Department has been working with PennDOT, the City of Pittsburgh and others is the "Forbes Avenue Betterment Project." This project reconstructs Forbes Avenue, one of two main thoroughfares that borders CMU, between Bigelow Blvd. and Margaret Morrison Street to have two buffered bikes lanes that replace two of the current four lanes dedicated to automobile traffic. Furthermore, there will be new and updated signing and signals for bike infrastructure such as intersection crossing markings, two-stage left turn boxes, and right corner islands (PennDOT 2016). This project began construction in Spring 2018 and is hoped to be completed mid-2019 (Brooks 2018). In addition, representatives of CMU have been involved with the Neville Street Working Group to work on projects to improve the bicycle and pedestrian conditions on Neville Street, which connects CMU with Junction Hollow Trail, one of Pittsburgh's most popular trails (City of Pittsburgh 2018). These projects will significantly reduce the risk of bicycling around CMU, and thus can encourage more members to use cycling as a mode of transportation .

Another project that CMU is in the process of developing is the expansion of bike share infrastructure on campus. Bike share allows students to have the convenience of riding bicycles at inexpensive prices without the inconveniences of owning and maintaining a bicycle. CMU has partnered with Healthy Ride, Pittsburgh's Bike Share System, to install five stations in the heart of campus by the end of 2019 (Brooks 2018). In addition, there are plans to install more stations in locations near to campus, such as in Squirrel Hill, where many of CMU's faculty, staff, and students currently live (Healthy Ride Pittsburgh 2018).

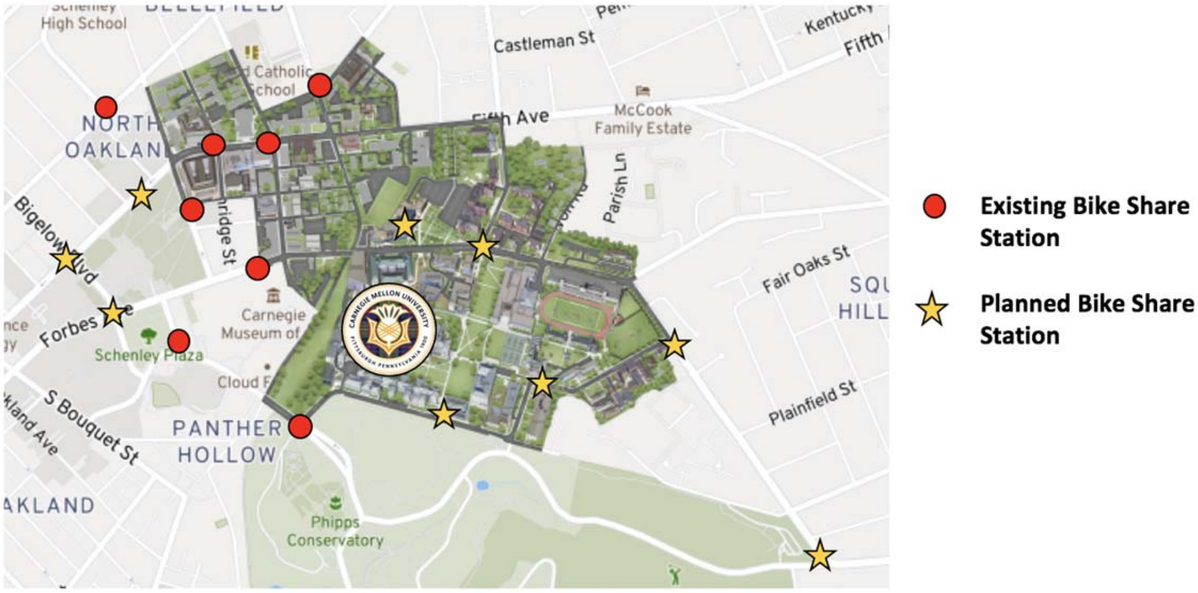

Figure 4.17 Map of Existing and Planned Healthy Ride Bike Share Stations
(*Healthy Ride Pittsburgh* 2018)

Furthermore, there is speculation that the bike share membership may be incorporated into CMU's tuition structure, providing unlimited access to students (Brooks 2018). This plan will be similar to how CMU charges a fee to students for unlimited use of public transportation. This method of implementing a fee in CMU's tuition for public transportation has shown to encourage students to take advantage of the public transportation, so similar results might arise with the Bike Share system. Once these bike share plans are implemented, further investigation should be conducted to indicate the success of the program and whether more stations should be implemented.

4.6.3 What is Preventing Bicycling?

Before developing strategies to increase bicycling, we first examined what prevents the community from bicycling. In 2015, a survey was conducted by CMU's Bicycle Advocacy Committee and was given to CMU community members at Bicycle Advocacy Committee's events. This survey recorded the community's thoughts of biking at CMU. 83% of the participants recorded that they commute by bicycle at least once a week in an average week so the responses were representative of CMU cyclists. One of the survey questions was, "What factors would keep you from commuting to campus by bicycle?" The survey responses indicate that weather is the primary factor that hinders people from commuting by bicycle as shown in Figure 4.18. Since weather is an uncontrollable variable, we cannot develop strategies to prevent this factor from keeping people from commuting to campus by bicycle.

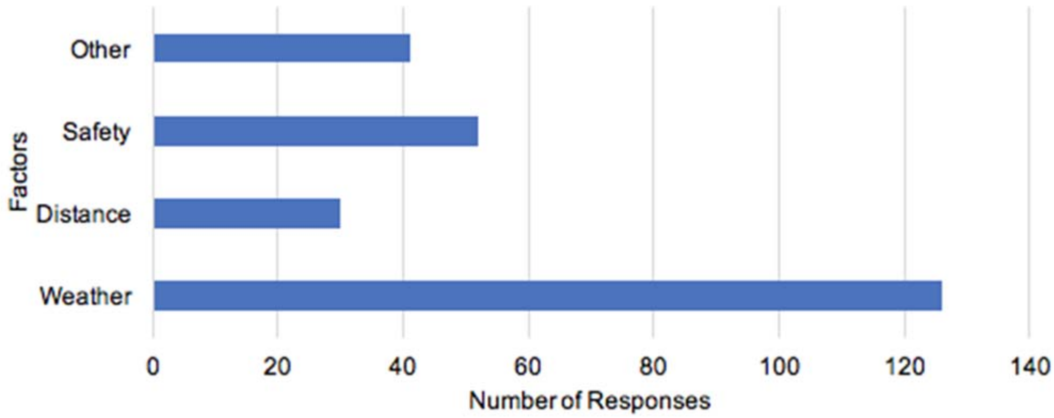

Figure 4.18 "What factors would keep you from commuting to campus by bicycle?" Survey Results (Brooks 2018)

Another factor that prevent people from commuting by bicycle is safety which could include bike theft. From February 6, 2016 to October 3, 2018, there have been 72 reported cases of bike theft at CMU (Bruno 2018). Figure 4.19 maps out all of the bike thefts that have occurred during this period.

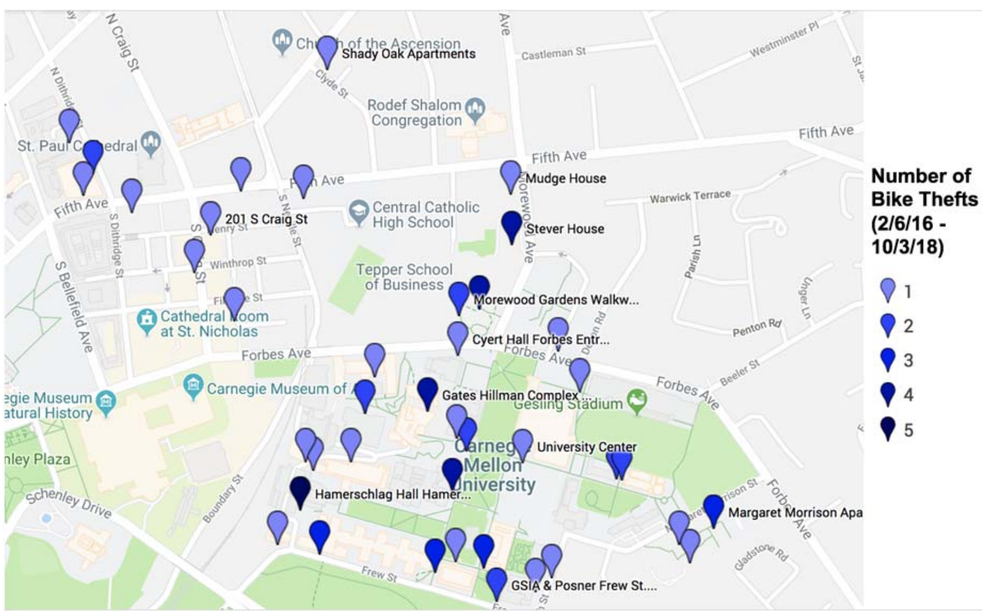

Figure 4.19 Map of Bike Thefts at CMU and vicinity from February 6, 2016 to October 3, 2018 (Bruno 2018)

There appears to be no concrete relationship between bike theft frequency and location. Some of the common areas of theft occur even in secured locations with good lighting and high community presence such as on the Cut near Doherty Hall and Morewood Gardens. In an interview with Sergeant Bruno from the CMU Police Department, he commented that majority thefts occur due to poorly secured locking or even no lock or a poorly secured cable lock that can be cut easily (Bruno 2018). This issue of bike thefts can be prevented by improving educating the community about properly securing the bicycle with a secure lock such as a U-lock.

4.6.4 Strategies to Increase Bicycling

We analyzed options to continue the current progress of enhancing CMU's bicycle infrastructure as well as its bicycling education. For bicycle infrastructure, we looked at ways to provide more secure and convenient bicycle parking for the CMU community. Improving the current system can encourage more cyclists, and there is already a plan to develop buffered bike lanes on Forbes Avenue (which is now managed by PennDOT). For bicycling education, we investigated successful practices of other universities that can be implemented at CMU. We also analyzed programs that other universities have implemented to increase bike commuting. From our analysis, we developed recommendations, discussed later in Chapter 9, which hopefully can help attract more people to biking to the university.

Improving Bicycle Parking

Improving the current bicycle parking infrastructure can encourage more members of the community to use bicycles as their primary mode of transportation. The survey conducted by CMU's Bicycle Advocacy Committee mentioned previously indicates how CMU community members prioritize bicycle parking in its infrastructure. When asked "On the main campus, how should we prioritize bicycle infrastructure," survey respondents indicated "Bicycle Rack (Covered)" and "Bicycle Racks" as their two highest priorities, as shown in Figure 4.20.

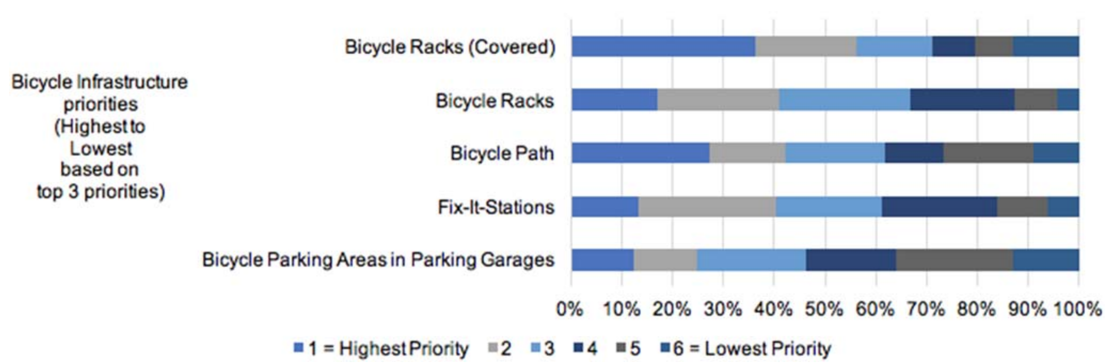

Figure 4.20 "On the main campus, how should we prioritize bicycle infrastructure?" Survey Results (Brooks 2018)

The survey responses indicate how bike commuters prioritize bicycle parking more than other infrastructure features such as bicycle path and fix-it-stations. Thus, an improvement in the bicycle parking infrastructure can enhance the biking experience at CMU, and potentially attract more members of the community to bike.

On the same survey, members of the CMU community were asked: “On campus, where do you usually park your bicycle?” As shown in Figure 4.21, less than 2% of the survey participants indicated that they parked their bicycles in a parking garage. Furthermore, Figure 4.22 indicates that when the participants of the survey were asked, “Do you ever utilize the bicycle parking areas in the parking garages?” over 80% of the participants responded that they have not and will not use them. The low percentage of the population currently utilizing biking parking in parking garages and the high percentage of the population indicating that they will not use them leads us to conclude that expanding bicycle parking in garages will not further encourage more people to bike.

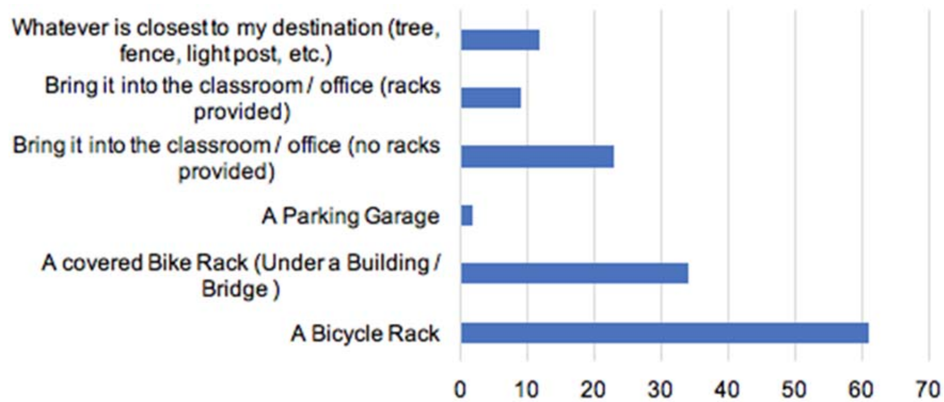

Figure 4.21 “On campus, where do you usually park your bicycle?”
Survey Results (Brooks 2018)

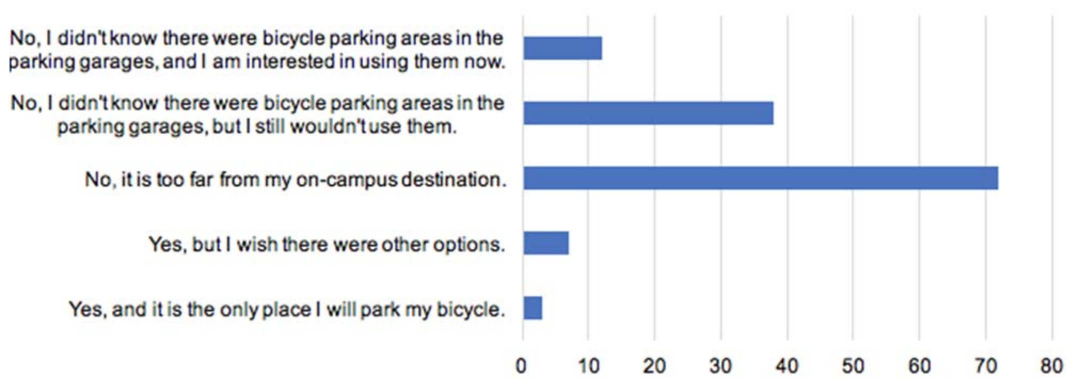

Figure 4.22 “Do you ever utilize the bicycle parking areas in the parking garages?”
Survey Results (Brooks 2018)

Based on responses shown in Figure 4.22, it seems that bike commuters value the ability to conveniently park their bicycle near their on-campus destination. So we recommend the university to continue to survey the community to understand where the community wants more bike parking locations. In addition we recommend the university to also consider other options to bicycle parking along with bike racks such as indoor bike rooms.

Indoor bike rooms are an option that can appeal to bike commuters for their security and convenience as well as the university for their economics. Because they are indoor and can have security mechanisms installed with them such as key card door locks and security cameras, indoor bike rooms can protect bikes from harsh weather and theft. Ideally installed in common university buildings, indoor bike rooms would be near bike commuters' campus destination. In addition, indoor bike room are relatively low cost. Ground Control Systems, a specialty contractor of bike and board parking who has implemented bike parking infrastructure universities including Stanford, Harvard, and University of Kentucky, offers an organized layout design that can fit 24 bicycles in a 12x18 room for around $6000 (Grounds Controls System 2018). Lastly, because indoor bike rooms do not require a large area to neatly hold many bicycles. CMU currently has one indoor bicycle room in Mellon Institute. Since indoor bike rooms are an safe, convenient, and economical option, we recommend further study of implementing indoor bike room in common university buildings.

Bike lockers are another safe and convenient form of bicycle parking; however they are not as economical and viable as bike racks and indoor bike rooms. Bike lockers protects bicycles from theft and inclement weather. Universities including Stanford, UC Davis, and the University of Pittsburgh have all implemented bike lockers. However, bike lockers require significant space. Furthermore, bike lockers are costly. The price per bike in a bike locker built by Ground Controls System can range from $800 to $1600 (Grounds Controls System 2018). In the past, CMU had bike lockers in the Gates Parking Garage. However, the university had remove them due to little use which could have been because the lockers were located in unappealing area and they were unknown by many. (Brooks 2018) Because bike lockers require more cost and area than bike racks and indoor bike rooms and their implementation at CMU have not been successful in the past, we conclude that they are not promising for Carnegie Mellon.

Improvements in bicycle parking would complement the undergoing construction of bike lanes around CMU and can help community members commute by bicycle. The improved bicycle experience potentially can draw more members to use bicycling as a primary mode of transportation. Furthermore, an increased percentage of the community cycling can potentially enhance the CMU's bike culture, which can further encourage more people to bike.

Improving Bicycle Education

Improving bicycle education can have more of the community utilize and engage with bicycle resources as well as learn bike practices that can help improve their biking experience.

One way that CMU can continue enhancing its bicycle education is by adding and improving its bicycle signage. Other universities have demonstrated that bicycle signage can effectively instruct cyclists and improve matters such as shared use pathways (Martini 2013). Signage can be used at CMU to help bicyclists navigate parking, discover safe bike path networks, and enforce good bicycle practices such as properly locking bicycles. The education that signage can bring to cyclists can facilitate bike commuting which can make bike commuting more attractive.

Another strategy to improving bicycle education is implementing a university-run bike shop. University-run bike shop provides more opportunities for the community to be engaged with bicycling through “hands shop” workshops and communication with bike experts. Furthermore, university-run bike shops allow for more of the community to be bicycle leaders which improve the bicycle education among the community. Bicycle Friendly Universities such as Stanford University, University of Kentucky, and Chatham University have all implemented successful university-run bike shops. While bike shops can effective in enhancing bike education at CMU, bike shops require much space which can be problematic for the university. We recommend the university investigate the feasibility of implementing a university-run bike shop.

Programs that can increase incentive to commute by bike

A method to further encourage more of the community to shift to bike commuting is a bike reimbursement program where bike commuters can be periodically reimbursed for bike-related expenses such as bike improvements, repairs, and storage. This method is incorporated by recognized Bicycle Friendly Universities such as University of Pennsylvania and Harvard University. This option is feasible and can potentially only if there is thorough education about CMU biking among the community. (Brooks 2018) If an adequate bicycle culture becomes established and education on biking becomes more widespread, then we recommend investigating the possibility of a bike reimbursement program.

4.7 Conclusions for Campus Transportation Systems

In this chapter, we examined sustainability aspects of transportation systems associated with university operations activities, including CO_2 emissions from university-sponsored travel, status quo of driving commute, and issues in our biking system.

In examining CO_2 emissions from university-sponsored travel, we discovered that faculty and staff air travel is the largest emitter among the various groups and modes of transportation. Faculty and staff car rental, student organization air travel and car rental are almost insignificant emitters in comparison, although they should not the counted out if a carbon offset program were to be implemented.

Within faculty and staff air travel, we discovered that cumulative spending over the last five years is evenly split between academic and non-academic units, although we do not have data on specific trips, therefore we cannot determine how much was actually spent for academic reasons and how much for administrative reasons. Looking at academic colleges, and weighing air travel emissions by the number of faculties, we discovered that the ranking of per capita emissions differs from the ranking of total emissions, showing a potential difference in travel habits between faculties of each college.

In examining faculty and staff driving commute, through mapping all residence locations and permit holders’ residence locations, we discovered that staff on average need to commute twice the distance as faculty, and the further away their residence is from campus, the more likely they are to hold a parking permit. Through contacting the parking office, we learned that the current carpool program has a limited number of participants and is not effectively reducing the number of personal vehicles driven to campus.

Looking at the current state of bicycling at CMU, we discovered that while CMU is making significant progress to improve bike commuting with the Forbes Avenue Betterment Project and expansion of Healthy Ride Stations on campus, there are still many improvements that can made to facilitate bike commuting and to increase the community's participation in biking. We analyzed current problems regarding CMU's bicycle parking infrastructure and its public bicycle education. By addressing these current issues, we provided recommendations based on survey responses provided by the Bicycle Advocacy Committee and based on practices at other bicycle friendly universities. These recommendations included continuing to survey the community to know where the community wants more bike parking locations, considering other options to bicycle parking along with bike racks such as indoor bike rooms, adding and improving bicycle signage, and investigating the feasibility of implementing a university-run bike shop.

In addition, we also examined the use of campus shuttles. We obtained data on the total number of persons who used the shuttle service for the past three years, but without data on detailed addresses of students, the majority of shuttle riders, we were unable to determine whether the shuttle routes effectively cover student residences. However, current shuttle routes do not overlap with city bus routes that stop on campus, so we can conclude that the shuttles do provide a good alternative to walking or biking, especially during and night and harsh weather conditions. Facilitating other commuting alternatives such as walking can be investigated in future studies.

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Chapter 5: Sustainability Education and Research

As a major educational and research institution, Carnegie Mellon University (CMU) has the opportunity to play a key role in promoting sustainability at a variety of levels. CMU graduates often go on to occupy leadership roles in both private and public institutions, so incorporating the teaching of sustainability may have lasting impacts. CMU is also a major research institution with the potential to enhance sustainability research and to develop novel and productive solutions that address issues surrounding sustainability. This chapter provides an analysis of sustainability education and research at CMU and its twelve peer universities. This analysis is used as the basis for recommendations about CMU's future activities in sustainability education and research.

5.1 Metrics of Sustainability Education and Research

To determine activities in sustainability education at both CMU and its peer institutions, keywords tied to both environmental and non-environmental sustainability were searched across major educational activities, such as courses, degrees, departments, and certificates. Interviews were also conducted with faculty to assess the current state of sustainability education on campus.

To explore current research efforts in sustainability at CMU and peer institutions, we determined the major research focus areas across the various institutions. To explore CMU's engagement in sustainability research, we analyzed sponsored research grants tied to sustainability using a set of keywords. Interviews with campus experts were also conducted to assess CMU's current research focus areas and possible future directions within the domain of sustainability.

5.2 Educational Activities in Sustainability

Education provides opportunities for students to learn about sustainability challenges and their potential solutions. This section focuses on sustainability educational programs, including courses, degrees (bachelors, minors, masters, and PhD programs), academic departments, and certificates provided at CMU and its peer institutions. Since the definition and scope of sustainability varies widely across different universities (see Chapter 1), the frequency of sustainability-related keywords was analyzed. Comparisons between CMU and peer institutions in the specified areas are crucial to determine potential recommendations for future focus areas within sustainability education.

5.2.1 Benchmarking Other Universities

The educational activities of twelve peer institutions were investigated. Most of these institutions use a broad definition of sustainability education, encompassing the environment, economy, and society. This broad definition allows a wide range of courses and degrees to be classified as related to sustainability. Here, we consider only those programs that contain the keyword sustainability or sustainable. Table 5.1 shows the number of peer universities that have at least one degree, certificate, minor, or course with either of these keywords. The table shows that all of the searchable peer institutions offer at least one course with the word sustainability or sustainable. However, none of the twelve universities had a department that met this criterion.

Table 5.1 Keyword Search Results on Sustainability for Twelve Peer Universities

Category	Number of Peer Universities with at Least One Occurrence of the Keyword in the Given Context
Courses*	9/9*
Minors	7/12
Certificates	4/12
Degrees	2/12
Departments	0/12

*A centralized course list was not found for three peer universities, which were excluded in this category.

Some peer universities did have other types of programs, not considered above, that likely increase their activities in sustainability education. Specifically, Emory University and the Georgia Institute of Technology both have faculty training programs in which faculty learn how to incorporate sustainability topics into new and existing courses. In addition, six of the peer universities use their campus as "living laboratories" to conduct local studies on sustainability, test potential interventions, and explore whether these interventions can be applied to outside communities.

5.2.2 Sustainability Education at Carnegie Mellon

This section provides an overview of educational activities in sustainability at CMU. Categories from Table 5.1, including departments, degrees, minors, and courses were analyzed to determine the scope of sustainability education at CMU. To understand which areas within sustainability CMU focuses on, we analyzed the frequency of a broad set of sustainability-related keywords (see Appendix 5-1). Additionally, this section provides a closer look at some of these programs as well as some faculty assessments regarding sustainability education on campus.

5.2.2.1 Sustainability Programs

To determine the amount of sustainability education at CMU, the frequency of fifty-three sustainability-related keywords (see appendix 5-1) was analyzed. The keywords were sourced from sustainability definitions at peer universities (see section 1.2.3) and the United Nations' sustainable development goals ("United Nations Official Document" 2015).

To establish current sustainability course offerings at the Pittsburgh campus, we did a keyword search of the most recent (2017-2018) course catalog. Overall, there were 207 courses (see appendix 5-2) found with at least one sustainability-related keyword in the title. Courses that included multiple keywords were counted for each specific keyword. For instance, the course *Energy, Policy, and Economics* (19-666) contains the keywords ‘energy’ and ‘economic,’ therefore this course was counted for both words. Some courses with homographic words, such as *Biological Transport and Drug Delivery*, were included in the count, even though the keyword, here ‘transport,’ is not tied to sustainability (in this context it is about mass and energy transport rather than the moving of goods and people). The keyword search results for CMU current courses are shown in Figure 5.1. ‘Econ,’ ‘material,’ ‘learn,’ and ‘health’ were the most frequently occurring keywords among CMU course titles. The explicit use of the words ‘sustainable’ or ‘sustainability’ was much less frequent, occurring in five and four courses (see appendix 5-3) respectively. The keywords ‘infrastructure,’ ‘safe,’ ‘poverty,’ and ‘consume,’ were found in only one course each. Twenty-two of the fifty-four keywords did not appear in any CMU course titles.

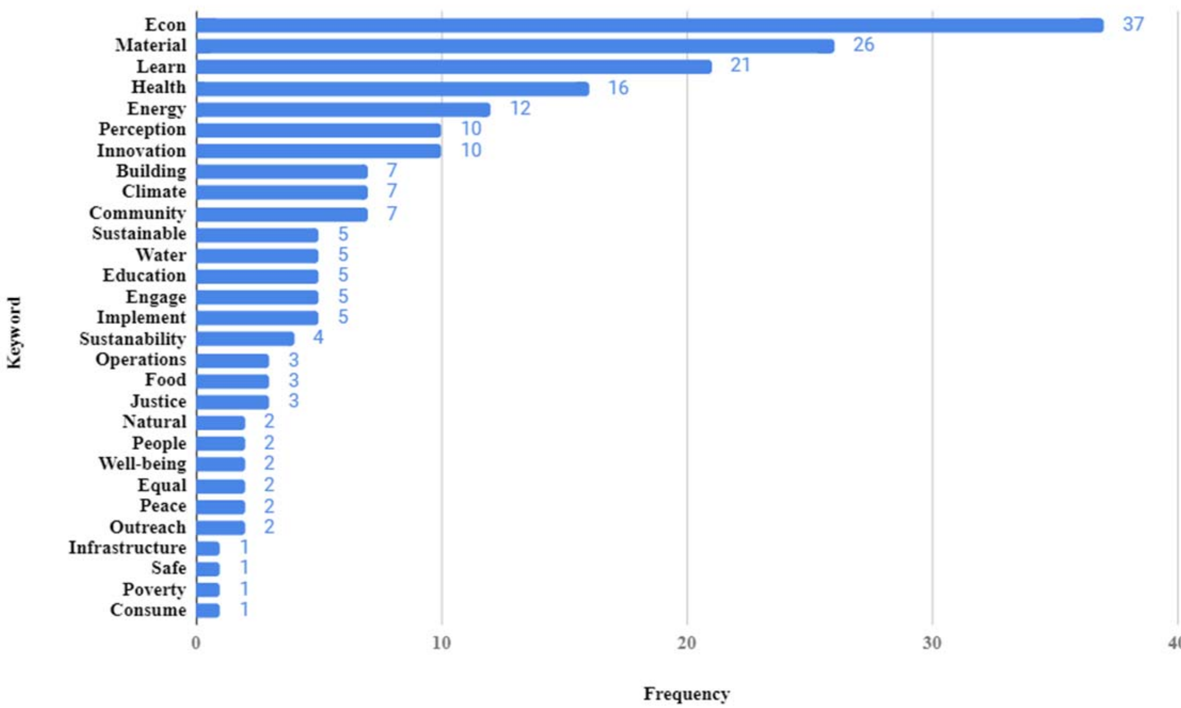

Figure 5.1 Keyword Search Results for CMU Courses 2017-2018

Each course shown in Figure 5.1 can be mapped to its college (Figure 5.2) and department (figure 5.3). Figure 5.2 indicates that all of CMU’s colleges offer at least one course with the requisite keywords. Dietrich College (DC) contains the most keywords among its courses, while CMU-wide courses contain the least. Furthermore, the most frequent keywords from Figure 5.1, ‘econ’ and ‘material’ are concentrated within DC and Tepper (econ) and the College of Engineering (material).

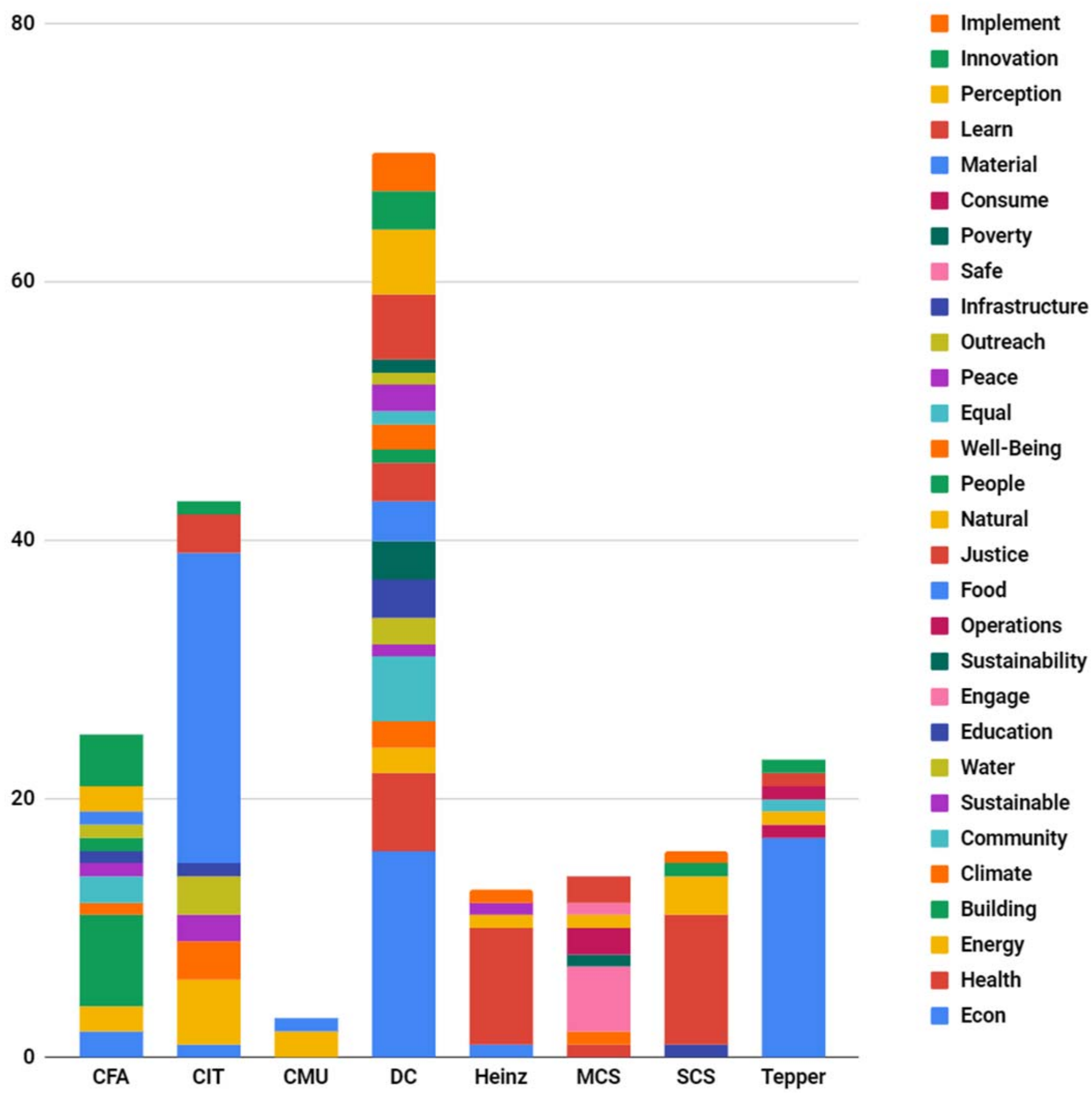

Figure 5.2 Keyword Search Results for CMU Courses by College, 2017-2018

The keyword search results by department are shown in Figure 5.3. Courses in Economics had the most keywords, frequently tied to 'econ.' Similarly, 'health' occurs most frequently in courses offered by the Heinz College and 'material' in courses offered by MSE. Note that some department-specific courses may have restricted enrollment depending on the course and college.

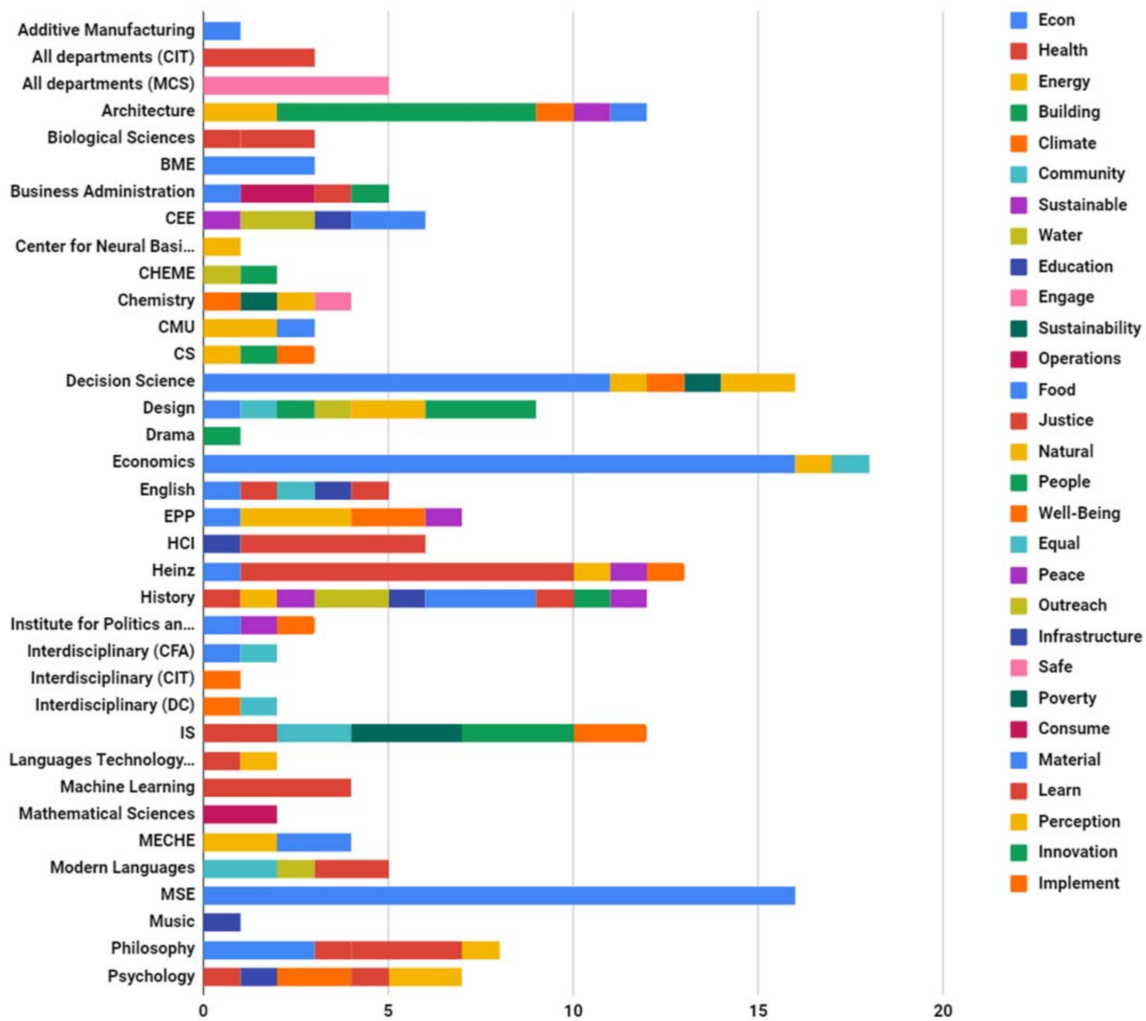

Figure 5.3 Keyword Search Results for CMU Courses by Department 2017-2018

The frequency of sustainability-related keywords among departments, degrees (bachelors, masters, PhD, minors) was also analyzed (see appendix 5-3). The keyword search results for CMU department titles are shown in Table 5.2. All departments are located in different colleges and three contain keywords that occurred frequently among courses, 'econ,' 'material,' and 'learn' (see Figure 5.1). There are no departments that contain the keywords 'sustainable' or 'sustainability.'

Table 5.2 Keyword Search Results for CMU Departments

Keyword	Number of Departments	College
Econ	1	DC
Material	1	CIT
Learn	1	SCS
Innovation	1	University-wide

Table 5.3 shows the keyword search results for CMU minors. There are eleven minors, which include at least one sustainability-related keyword. 'Material', one of the most frequently occurring keywords among courses (see Figure 5.1), is also the most frequently occurring among CMU minors and is concentrated within CIT. Other keywords appear in minors that are available within six different colleges and eight departments. One minor within CIT contains the keyword 'sustainability.'

Table 5.3 Keyword Search Results for CMU Minors

Keyword	Number of Minors	College	Department
Building	1	CFA	Architecture
Econ	1	Tepper	Economics
Education	1	CFA	Music
Health	1	Interdisciplinary (Heinz, DC, MCS)	
Innovation	1	Tepper	IDEATE
Learn	1	SCS	Machine Learning
Material	3	CIT	All departments (CIT), MSE
Operation	1	Tepper	Business Administration
Sustainability	1	CIT	All departments (CIT)

Table 5.4 shows the keyword search results for CMU bachelor's degrees . There are seven degrees, which include at least one sustainability-related keyword. 'Econ,' one of the most frequently occurring keywords among courses (see Figure 5.1) is also the most frequently occurring for bachelor's degrees and it's concentrated within DC, Tepper, and MCS. Other keywords, 'material' and 'learn,' were also frequent among courses and they appear in bachelor's degrees within three different colleges and two departments. There are no bachelor's degrees that contain the keywords 'sustainability' or 'sustainable'.

Table 5.4 Keyword Search Results for CMU Bachelor's Degrees

Keyword	Number of Bachelor's Degrees	College	Department
Econ	5	DC, Tepper, MCS	Economics, Mathematical Sciences, Statistics and Data Science
Material	1	CIT	MSE
Learn	1	DC/SCS	Statistics and Data Science

Table 5.5 shows the keyword search results for CMU master's degrees. There are sixteen master's degrees, which include at least one sustainability-related keyword. 'Innovation' is the most frequently occurring among CMU master's degrees and it's concentrated within CIT, Heinz, SCS, and the Integrated Innovation Institute. 'Education,' 'material,' and 'learn' are the second most frequent and they also appeared often among courses. Other keywords appear in master's degrees that are available within six different colleges and eleven departments. One master's degree within the department of architecture contains the keyword 'sustainable.'

Table 5.5 Keyword Search Results for CMU Master's Degrees

Keyword	Number of Master's Degrees	College	Department
Building	1	CFA	Architecture
Education	2	CFA, SCS, DC	Music, HCI
Energy	1	CIT	Interdepartmental
Health	1	Heinz	Public Policy & Management
Industry	1	Heinz/CFA	Public Policy & Management (Heinz)
Infrastructure	1	CIT	CEE
Innovation	4	CIT, Heinz, SCS, Integrated Innovation Institute	Interdisciplinary, Public Policy & Management, Computational Biology/ Language Technologies Institute
Learn	2	SCS, DC	HCI, Machine Learning
Material	2	CIT	MSE
Sustainable	1	CFA	Architecture

Table 5.5 shows the keyword search results for CMU post-doctoral degrees. There are eleven post-doctoral degrees, which include at least one sustainability-related keyword. ‘Learn’ is the most frequently occurring among CMU PhDs and it’s concentrated within DC, SCS, and Heinz. ‘Econ’ also appears often and both keywords were frequently occurring among courses. Other keywords appear in PhD’s within six different colleges and five departments. There are no PhDs with the keywords ‘sustainability’ or ‘sustainable.’

Table 5.6 Keyword Search Results for CMU Post-Doctoral Degrees

Keyword	Number of Post-Doctoral Degrees	College	Department
Building	1	CFA	Architecture
Econ	2	Tepper, Heinz	
Infrastructure	1	CIT	CEE
Learn	4	DC, SCS, Heinz	Center for Neural Basis of Cognition, Machine Learning
Material	1	CIT	MSE
Operation	2	Tepper	

Analyzing the frequency of keywords revealed that CMU programs focus on a few distinct sustainability topics. The most frequently occurring keywords among courses, especially ‘econ’ and ‘material’ were present within departments, degrees (bachelors, masters, PhD’s and minors). Furthermore, the most frequently occurring keywords were concentrated within a few colleges, including DC, Tepper, and CIT.

CMU offers one master’s degree and one minor that contain the keywords ‘sustainability’ or ‘sustainable.’ Specifically, the School of Architecture has a Master of Science degree in Sustainable Design and the Mellon College of Science (MCS) has a minor degree in Environmental and Sustainability Studies (ESS). The minor in ESS, introduced in 2018, was designed to be interdisciplinary and open to all CMU undergraduates. This minor was created to replace minors in Environmental Science (in MCS), Environmental Studies (in DC), and Environmental Engineering and Sustainability (in CIT)---all of which were discontinued in the fall of 2018. These previous three minors were decentralized and had very limited enrollment with only one or two students per minor and five students per year. Currently, there are twenty students enrolled in the new ESS minor, including students from Tepper, SCS, Engineering and Public Policy, Civil and Environmental Engineering (CEE), and the College of Fine Arts (CFA).

5.2.2.2 Student and Faculty Engagement

Interviews with the CEE Department Head, David Dzombak, and FMS Sustainability Coordinator, Barbara Kviz, suggest relatively low student and faculty interest with regards to sustainability education. According to Dzombak, CMU has developed modules to help implement environmental components into the existing curriculum, but very few professors have incorporated them into their courses thus far. Professor of Chemical Engineering, Chemistry, and EPP, Neil Donahue, is currently building a series of modules for climate education to be imbedded within chemical engineering courses. He has been coordinating the development of these modules with other professors to encourage their adoption. CIT has also supported the development of modules through the Dowd fellowship, which is awarded to a faculty member in engineering and includes funding to support an educational project.

5.3 Research Activities in Sustainability

CMU received more than $387M in sponsored research funding in fiscal year 2017 (CMU Factbook 2017-2018). Sustainability research was performed in the various academic departments within the different colleges and in over 100 research centers and institutes (CMU Research Office 2018). Given the importance of sustainability to society, and its elevation among the priorities of some research funding agencies, it is useful to track research related to sustainability at CMU. Understanding the trends and distribution of sustainability research funding at CMU can identify potential opportunities in this area.

5.3.1 Benchmarking Other Universities

The research programs at CMU's twelve peer institutions were first reviewed to gain an understanding of their research activities in sustainability. Out of twelve peer institutions, nine had online platforms that provide comprehensive information on that institution's sustainability research (see appendix 5-3). These nine institutions had platforms that specified their key research areas in sustainability, their faculty involved in such research, various funding opportunities, and their existing collaborations with either external organizations or the local community. While the other three universities had online resources for sustainability research, they did not have a comprehensive, "one-stop" information site dedicated to such research.

Among peer institutions, Cornell University's David R. Atkinson Center for a Sustainable Future had one of the most comprehensive sites (Cornell 2018). For example, using this site one can search for faculty involved in sustainability research filtered by college, department, and faculty interests (see Figure 5.4).

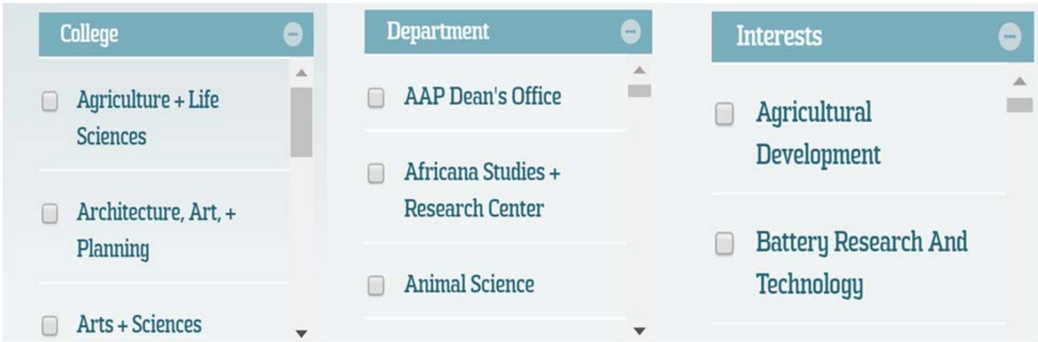

Figure 5.4 Sample Screen Shot from Cornell University's David R. Atkinson Center Search Engine for Sustainability Research (Cornell 2018)

Emory University (another one of CMU's peer institutions) tracks its sustainability research trends over time (Emory 2018). Figure 5.5 shows a graph of sustainability research engagement at Emory University. Their measure of engagement is based on the requirements for the AASHE Sustainability Tracking, Assessment & Rating System (AASHE 2017). For example, department engagement is given by the percentage of academic departments that included at least one faculty or staff member that conducts research in sustainability. Faculty engagement is given by the proportion of faculty or staff that are engaged in sustainability research.

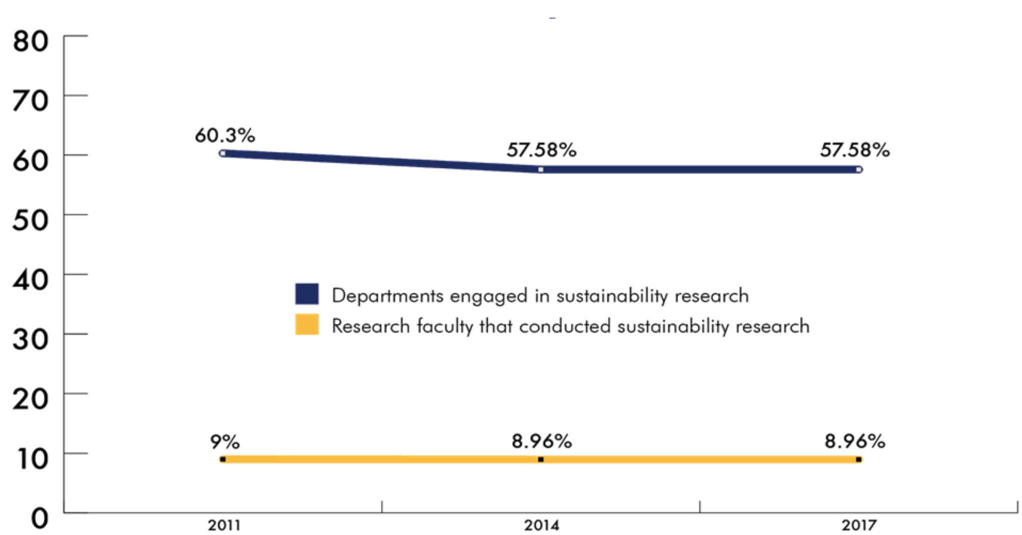

Figure 5.5 Emory University's Statistics for Engagement in Sustainability Research

Many of CMU's peer institutions have specific research foci in sustainability. Some, such as the Georgia Institute of Technology, express their focus areas in lists and descriptions of research centers dedicated to sustainability (GIT 2018). Others, such as Northwestern University (Northwestern 2018) and Princeton University (Princeton 2018), list "research areas" on their sustainability webpage. Using a keyword, we found that many of our peer universities were involved in diverse topics in sustainability research (see Appendix 5-4) . This set of keywords was then used to inform our analysis of CMU's sponsored research tied to sustainability.

5.3.2 Sustainability Research at Carnegie Mellon

There are twenty research centers at CMU related to the environment and sustainability (CMU 2018). Two distinct areas of research are 1) urban infrastructure and sustainable cities and 2) energy transition strategies and the environment. Sustainability research at CMU was further illuminated by discussions with key faculty involved in sustainability. These faculty members included the CEE Department Head, David Dzombak, the Director of the Steinbrenner Institute for Environmental Education and Research, Neil Donahue, and the Co-Chair of CMU's Green Practices Committee, Nina Baird. All three faculty felt that CMU has the potential to expand its sustainability research. All three also discussed how there is a limited amount of "top-down" influence on research areas on campus, and that most research initiatives are initiated by individual faculty members.

Sponsored Research Funding

To understand better CMU's sponsored research funding in sustainability we conducted a keyword search on the Spex Award Management System maintained by the Office of Sponsored Projects. Using our analysis of sustainability research at peer universities as well as the topics discussed in Chapter 1, we defined a set of keywords (see Table 5.7).

Table 5.7 Keywords Searched in Project Titles to Identify Sponsored Research Funding At CMU

Keywords		
Air	Health	Sustain
Agri (For Agriculture, Agricultural)	Fuel	Solar
Carbon	Mitigat (For Mitigate, Mitigation)	Transport
Clima (For Climate, Climatology)	Pollut (For Pollute, Pollution)	Urban
Conserv (For Conserve, Conservation)	Power	Water
Energy	Photovoltaic	Wast (For Waste, Wastage, Wasteful)
Emission	Renew (For Renewed, Renewables)	

From the total sponsored research funding per year (CMU Factbook 2017 - 2018) and the total sustainability research funding per year, the proportion of total sponsored research that was related to sustainability was computed and tabulated in Table 5.8. The proportion of sponsored research relating to sustainability has increased from 2013-2016, but did not change from 2016-2017.

Table 5.8 Funding for Total Sponsored Research and Sustainability-Related Sponsored Research Over the Past 5 Years

Year	2013	2014	2015	2016	2017
Total Sponsored Research (million dollars)	410.0	388.1	378.6	391.8	387.4
Sustainability-related Sponsored Research funding (million dollars)	36.7	30.0	36.9	47.1	46.7
Proportion of sustainability related funding	0.09	0.08	0.10	0.12	0.12

Figure 5.6 shows the research dollars per year from 2007 to 2017 for sponsored research for projects with the given keyword in their title. Multi-year awards were allocated in equal amounts across the project's stated duration. If a given project contained more than one keyword, it was included separately for each of its keyword, resulting in a potential double counting of research funding for those keywords.

Figures 5.6 and 5.7 show the total funding and number of active research projects for a given keyword from 2007 to 2017. The total research dollars per year (Figure 5.6) has generally increased over the past decade. In 2017, the total sponsored research funds with sustainability keywords in their titles (which include double-counted projects with more than one keyword) was $46.7M, which was 12% of CMU's total sponsored research funding that year Out of the total sustainability-related sponsored research funds, $32.4M or 69%, was attributed to the keywords 'energy,' 'air,' 'transport,' 'power,' and 'health,' a pattern that has remained consistent over the last decade. The number of sponsored projects per year (Figure 5.7) has also increased over the last decade, with less extreme variation than funding dollars during 2014 and 2016.

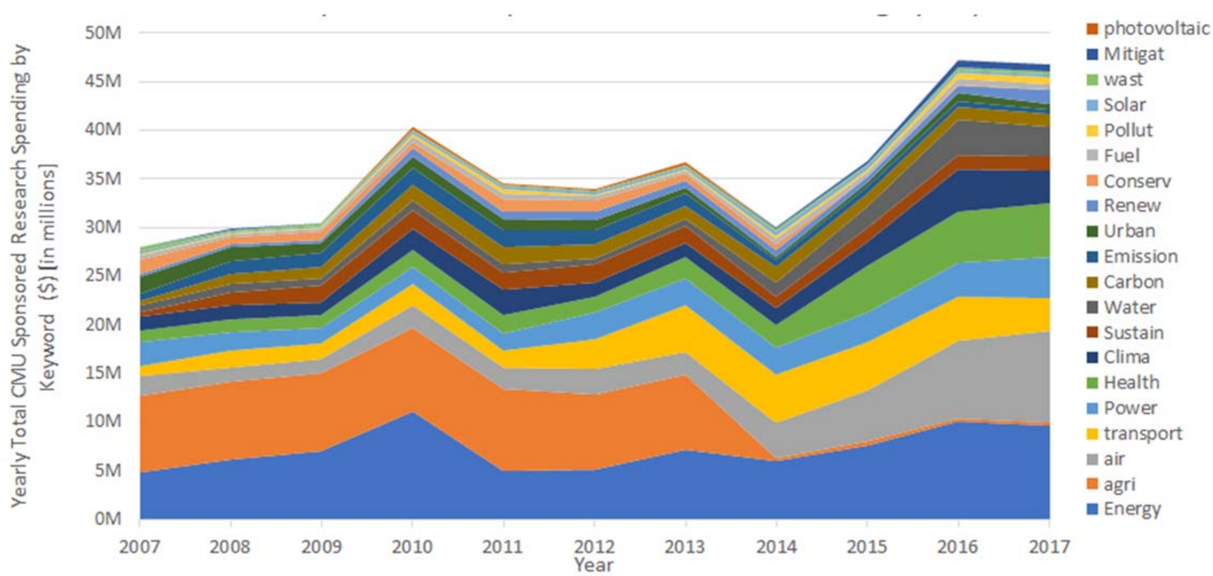

Figure 5.6 Total Sponsored Research Dollars Per Year ($) with Sustainability Keywords in the Project Title

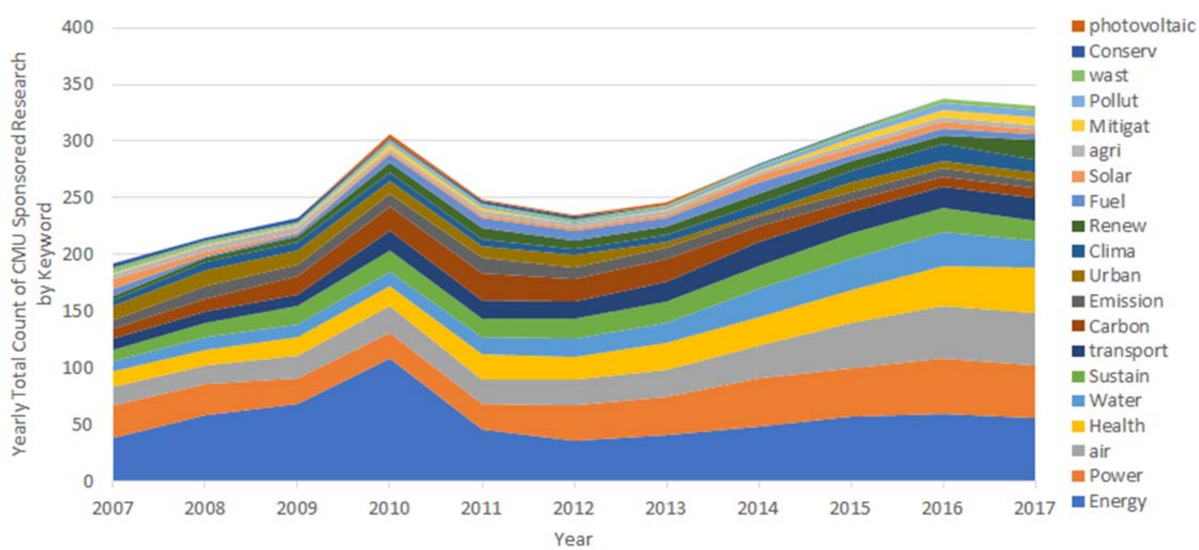

Figure 5.7 Total Number of Projects Per Year with Sustainability Keywords in the Project Title

The distribution of total research dollars over the last five years and number of sponsored projects across colleges by keyword is shown in Figures 5.8 and 5.9 respectively. Both figures indicate that the funds and projects related to sustainability are concentrated in a few colleges, namely the Carnegie Institute of Technology (CIT), the School of Computer Science (SCS), and the Mellon College of Sciences (MCS). Within these three colleges, the sponsored research funding was mainly from nine out of twenty keywords ('air,' 'carbon,' 'clima,' 'energy,' 'power,' 'health,' 'renew,' 'transport,' and 'water').

Another noticeable difference between research funding per year and dollar projects per year is the relative position of Dietrich College (DC). While DC has the least sponsored research funding among the colleges, it has a significant number of research projects, suggesting that it has a large number of projects with relatively low amounts of funding.

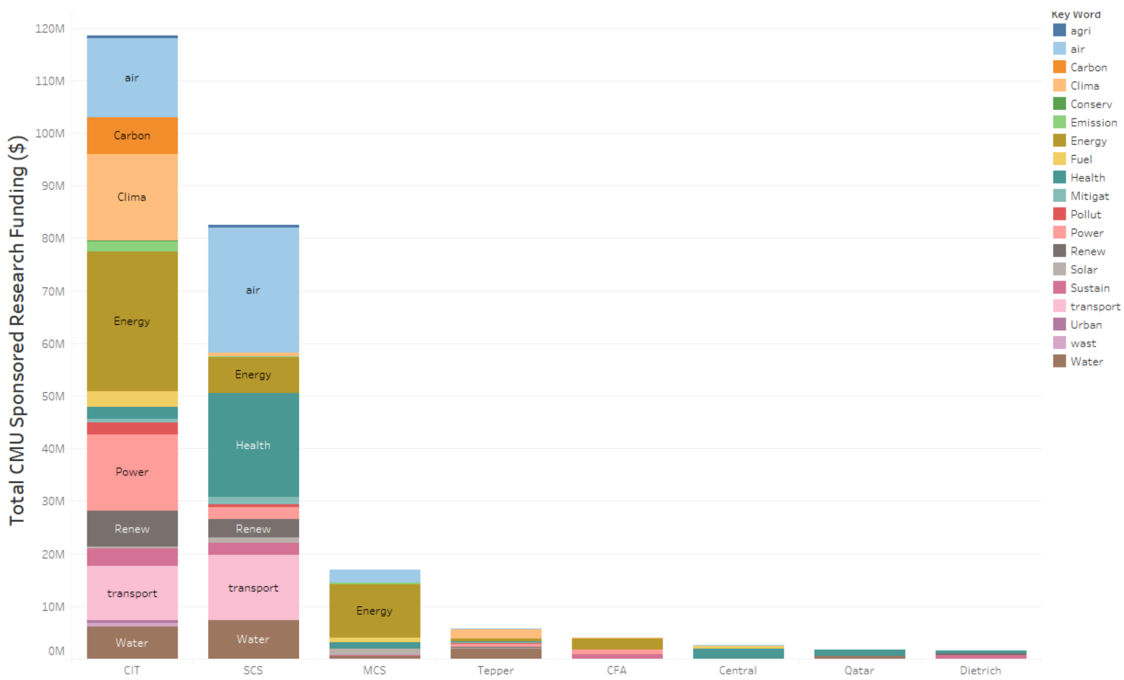

Figure 5.8 Distribution of Sponsored Research Funding ($) Across Colleges by Keyword

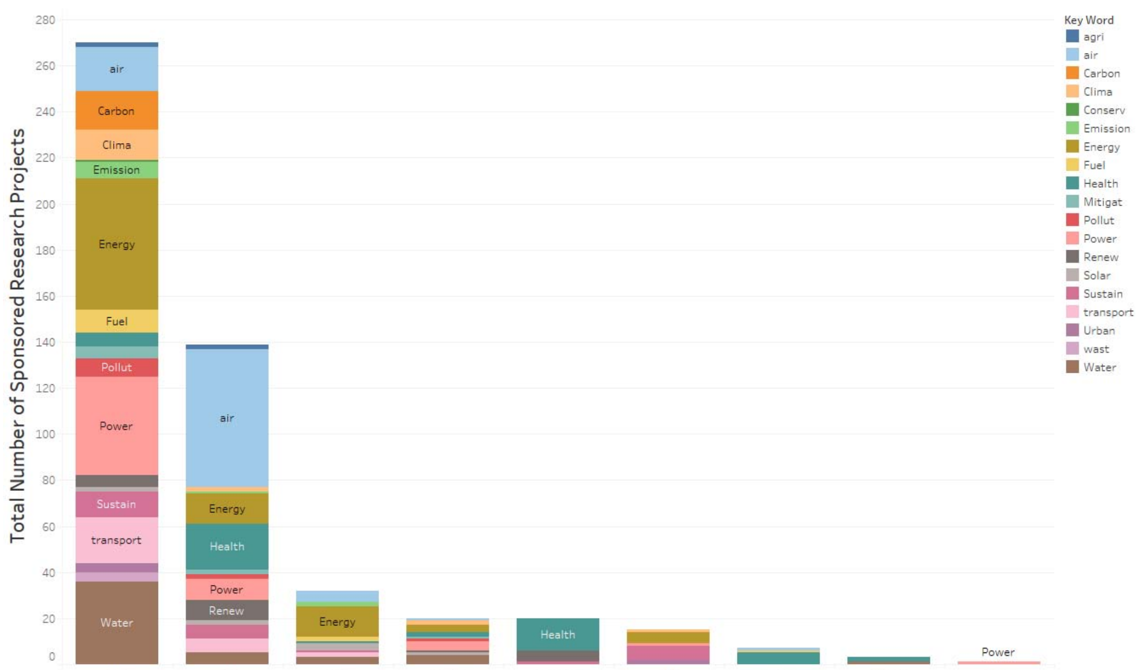

Figure 5.9 Distribution of Projects Across Colleges by Keyword

Figures 5.10 and 5.11 provide the distribution of sponsored research dollars and number of projects by department. As indicated in the figures, funds and projects in CIT and SCS were spread across a variety of departments. Mechanical Engineering (MechE), Electrical and Computer Engineering (ECE), and Engineering and Public Policy (EPP) were the three most significant contributors to CIT's sponsored funds in sustainability, while MechE, ECE and Civil and Environmental Engineering (CEE) were the three most significant contributors to the number of projects in CIT. In SCS, robotics and the machine learning department (MLD) contributed significantly to the research funds and number of projects. As previously mentioned, there is the potential for the keyword search to admit homographs, for example, robotics research into "repair" might be flagged by the keyword search on 'air.'

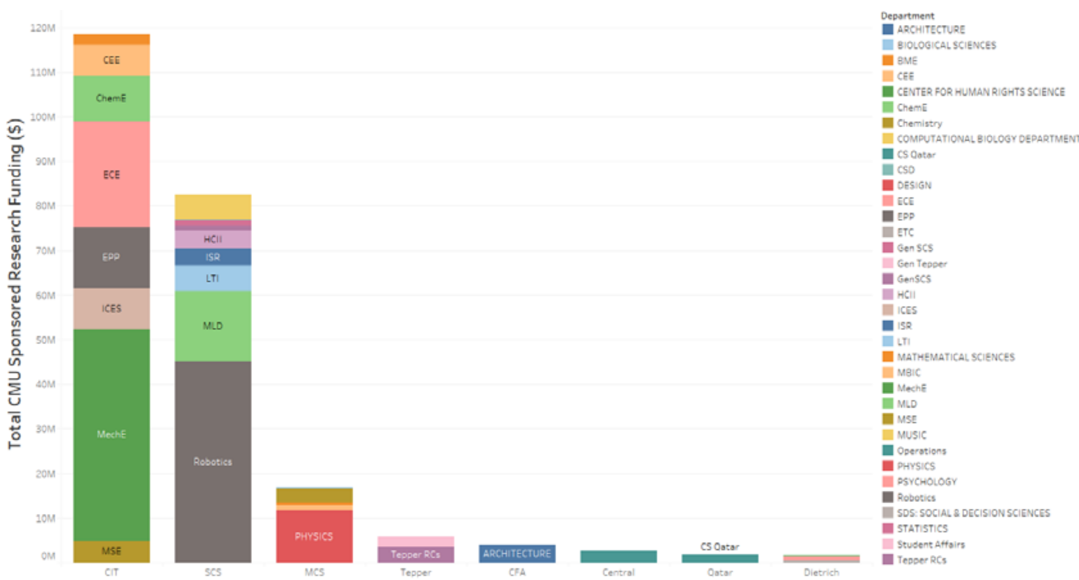

Figure 5.10 Distribution of Award Dollars ($) Across Colleges by Department

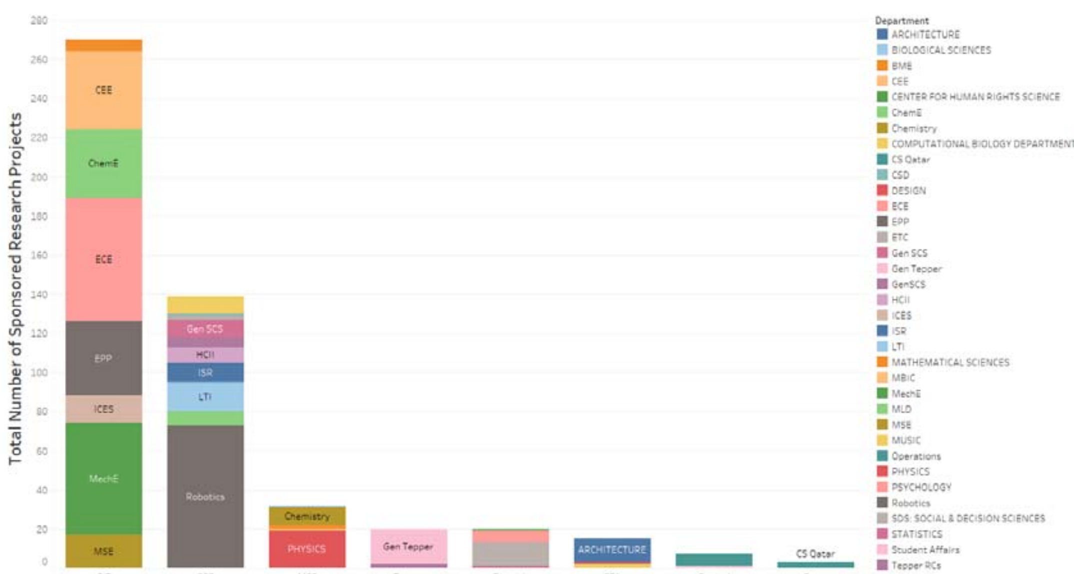

Figure 5.11 Distribution of Projects Across Colleges by Department

The analysis of sponsored research funds at CMU relating to sustainability shows that while the funding and number of projects have been increasing over the past ten years, the projects tend to be concentrated in only a few colleges, including CIT, SCS, and MCS. While these colleges have obvious links to sustainability (with perhaps the exception of SCS, though “smart city” and other computer-based initiatives might be part of these projects), it does suggest that there may be opportunities to engage some of the other colleges with obvious sustainability links, for example, Tepper given its strengths in economics, logistics, and organization, and Dietrich with its strengths in the social sciences and statistics.

5.4 Conclusions for Campus Education and Research

In this chapter, we analyzed educational and research activities within sustainability at CMU and its peer universities. Overall, CMU had programs that cover a wide range of sustainability focus areas. While courses, departments, and degrees included different sustainability-related keywords, there were specific topics that occurred more frequently among all programs, specifically ‘econ’ and ‘material.’ In comparison, some keywords, such as ‘infrastructure,’ ‘safe,’ ‘poverty,’ and ‘consume’ were less frequent among courses, and did not occur within other programs. Therefore, CMU could potentially expand upon the sustainability focus areas covered by educational programs. In addition, more frequently occurring words were concentrated within a few distinct colleges.

Interviews with several CMU faculty members indicated that there has been low interest in sustainability education among faculty and students, although such reports remain largely anecdotal in the absence of systematic survey data. Ongoing efforts to foster interest include transitioning from three separate minors to a new centralized minor in environmental and sustainability studies, and implementing sustainability modules into existing courses across the campus.

Sustainability research at CMU has expanded over the last ten years but has remained concentrated in few colleges. There is potential for CMU to expand its research in sustainability in its various colleges. Additionally, CMU’s research in sustainability is concentrated in a few specific focus areas. Such a concentration might be reasonable given the need to have a critical mass of researchers, but it also might suggest that funding opportunities in this area are not being fully pursued. To further this analysis, it would be useful to explore the “supply-side” of grants, that is, whether there are areas where funders are focusing resources in areas that match with CMU’s research strengths. In both education and research, a centralized effort or office to promote sustainability initiatives could substantially enhance current ad hoc effort across the campus.

Finally, from discussions with Green Practices Committee co-chair, Nina Baird, we learned that the CMU Green Practices Committee and CMU Libraries recently conducted a similar keyword search for published research at CMU relating to sustainability. This keyword search was performed on the Scopus database, and CMU projects were identified based on the faculty involved in the publications. A comparison between the analysis performed on sponsored research for this project and the analysis of published research could provide further insights into CMU’s involvement in sustainability research.

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Chapter 6: Societal and Behavioral Dimensions of Sustainability

A sustainable campus involves more than environmental sustainability. In order to be a truly sustainable campus, it is necessary to incorporate societal elements as well. Here we divide the societal elements of sustainability into social and behavioral sustainability. Social sustainability describes the impact of formal and informal systems, structures, processes and relationships on the current and future livability and health of communities (Barron and Gauntlett, 2002). According to Barron and Gauntlett (2002), the key elements of social sustainability are quality of life, equity, diversity, interconnectedness or social cohesion, and democracy and governance. Behavioral sustainability focuses on the environmental consequences of individual behavior.

6.1 Introduction

The objective of this chapter is to introduce and define the concept of social sustainability and ways to evaluate its current state. The chapter also seeks to deepen the understanding of sustainability not only as resource and energy saving measures, but also as an approach to shaping the consciousness of the school community. Finally, we explore the effects of human behavior on environmental sustainability.

6.1.1 Metrics of Sustainability

The main measure of social sustainability is the degree to which individuals and society are affected by sustainable actions. Actions impacting social sustainability can vary in both the number of people affected by a policy and the degree to which each individual is affected. There are a variety of metrics that can be applied to the various elements of social sustainability. For example, to measure diversity, the demographic distribution of a groups can be compared over time, with a focus on improvements in the proportion of underrepresented groups. Surveys and focus groups can also be used to measure some of the elements of social sustainability, such as the quality of life, equity, social cohesion, and democracy and governance.

The Western Australian Council of Social Service (WACOSS) developed the Social Sustainability Assessment Framework (SSAF) for the purpose of measuring social sustainability (Hodgson, 2018). The WACOSS SSAF is a series of questions that ask to what extent an action will promote aspects of social sustainability. Oxford Brookes University developed its own SSAF that collects quantitative, rather than qualitative, responses (Colatonio, 2009). The WACOSS SSAF has questions more easily related to the Carnegie Mellon University (CMU) context, but the Oxford Brookes University SSAF has a way of framing the questions quantitatively along with a numerical grading system.

Here we propose combining the two methods to create a survey to assess social sustainability at CMU (see Table 6.1). The answer options could be coded on a Likert scale from, say, -2 to +2, with -2 representing an answer of strongly disagree and +2 indicating a strongly agree. An adapted version of the Oxford Brookes grading system then could be used to represent the results as shown in Table 6.2 (Colantonio, 2009). The survey could be supplemented with other information, such as demographics, to help identify if the various needs are being met evenly across groups. Data would be collected from students, faculty and staff. Student group could be further divided into undergraduates, masters, and doctoral candidates because the needs across student groups can vary. This data should be collected at multiple time periods to assess the impact of any newly instituted policies.

Table 6.1 Proposed CMU Social Sustainability Survey developed from frameworks presented by Hodgson and Colantonio (2009)

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
To the best of their ability, CMU ensures my access to...					
Affordable and appropriate housing					
Physical health					
Mental health					
Education, training and skill development					
Employment					
Transportation					
My basic needs					
Safety and security					
Community amenities and facilities					
CMU works to the best of its ability to...					
Identify diverse groups within the CMU community and look at ways to meet their particular needs					
Recognize diversity within cultural, ethnic and racial groups					
Allow for diverse viewpoints, beliefs and values to be taken into consideration					
Promote understanding and acceptance within the broader community of diverse backgrounds, cultures and life circumstances					
Reduce my disadvantages					
Assist me to have more control over my life, socially and economically					

Identify the causes of disadvantage and inequality and look for ways to reduce them					
Identify and aim to meet the needs of any particularly disadvantaged and marginalized people within the CMU community					
Act without bias and promote fairness					
Help the members of the CMU community develop a sense of belonging in the broader community					
Increase participation in social activities by individuals in the CMU community					
Build links between the CMU community and other groups in the broader community					
Increase support to the CMU community by the broader community					
Encourage the CMU community to contribute towards the community or provide support for others					
Improve the target groups' understanding of and access to public and civic institutions					
Allow for a diverse range of people to participate and be represented in decision-making processes					
Make the processes of decision-making clear to and easily understood by stakeholders					
Provide sufficient support to ensure self-government support?					

Table 6.2 Social Sustainability Grading System developed from Colantonio (2009)

Assessment	**Lower Bound**	**Upper Bound**
Very Poor	-2	-1.5
Poor	-1.4	-0.5
Mediocre	-0.4	0.5
Good	0.6	1.5
Very Good	1.6	2

6.2 Social/Societal Dimensions of Sustainability

The key elements of social sustainability are quality of life, equity, diversity, interconnectedness or social cohesion, and democracy and governance. A socially sustainable campus requires that CMU ensures high levels of these dimensions across the campus community.

6.2.1 Quality of Life

CMU's 2025 Strategic Plan incorporates the societal goals of leadership in research and creativity, regional impact, and engaging and impacting the global community. Unfortunately, there are no explicit goals related to the CMU community itself. Quality of life measures how well the basic needs of of a population are met (Barron and Gauntlett, 2002). Elements of quality of life include affordable and appropriate housing opportunities, physical health, mental health, education, training and skill development, employment opportunities, and access to transport (Hodgson, 2018).

Students, staff, and faculty must have access to affordable housing that meets healthy living standards. The National Center for Healthy Housing of the American Public Health Association has released the National Healthy Housing Standard (National Center for Healthy Housing, 2016). The standard includes a minimum set of requirements for living arrangements to be considered healthy, with key categories tied to facilities, safety, lighting/electrical, thermal comfort, pest management, and chemical agents (National Center for Healthy Housing 2016). For a sustainable campus, the housing used by the campus community should be both affordable and meet the minimum healthy living standards. CMU provides guaranteed housing for all undergraduates on campus, provided that they do not opt to move off campus. For undergraduate students who choose to move off campus and graduate students, CMU offers information on local housing options and landlords (CMU Housing & Residential Education, 2018). Faculty and staff do not have direct access to housing from CMU, but CMU does facilitate real estate services and discounts in the form of access to the Coldwell Banker Real Estate Assistance and the Howard Hanna's Gold Advantage Program (CMU Human Resources, 2016).

Societal sustainability concerns are mentioned at the beginning of CMU's mission statement: "To create a transformative educational experience for students focused on deep disciplinary knowledge;

problem solving; leadership, communication, and interpersonal skills; and personal health and well-being.” The inclusion of “personal health and well-being” suggests that there should be access to information and resources for the campus community to improve their physical and mental health. Such access should include nutrition, exercise, and adequate care for both physical and mental health. CMU requires that all full-time students have adequate health insurance according to the university standards (CMU University Health Services, 2018). It also offers seven different health insurance programs to eligible faculty and staff (CMU Human Resources, 2018). The University provides mental health care for students in the form of Counseling and Psychological Services (CaPS) and for faculty and staff in the form of stress management services and informational services (CMU Human Resources, 2016). There are varied dining options available to the campus community, along with financial aid available to students to help them afford it. In October 2018, the university opened a food bank to address food insecurity among students (CMU Office of Dean of Students, 2018). CMU also has exercise facilities available for students, faculty, and staff to use, as well as access to group fitness classes (CMU Athletics, 2018). CMU hosts an annual benefits and fitness fair to inform faculty and staff of resources available to them (CMU Human Resources, 2018). Recently, CMU has begun a shift towards wellness, rooted in the idea that “our individual and collective well-being is rooted in healthy connections, to each other and to campus resources” (Lusk, 2018). In fall of 2018, it made the wellness application “headspace” freely available to campus members.

CMU’s mission directly emphasizes that students should reach their full potential, which means that the university has an interest in the education, training, skill development, and eventual employment opportunities of its students. CMU offers a wide range of academic degree programs that prepare students to enter high-paying fields when they graduate. Aside from the education and skill development provided from academic courses, the university also has Career and Professional Development Services (CPDC) to provide additional coaching and job placement services for students (CMU CPDC, 2018). The CPDC has resources available on researching and applying to companies, networking, interviewing, and evaluating and negotiating job offers (CMU CPDC, 2018). In addition to job placement services, CPDC helps host job fairs to connect employers and graduate schools to students. Post-graduation, only 6% of CMU students are unemployed. Students who choose to enter the workforce directly after graduation do so with salaries that are 66% higher than the national average (CMU CPDC, 2018). The university also has an interest in the education, training, and skill development of its own employees. CMU provides professional development and organizational development as well as other resources for faculty and staff (CMU Human Resources, 2018). Additionally, staff and faculty have access to further education, as well as skill and career development through the tuition assistance program (CMU Human Resources, 2018).

The last element of quality of life is access to transport. Students, faculty, and staff should have transportation options that are affordable, relatively fast, and safe. In order to participate in the school, community members must be able to get from their living accommodations to the campus in a reliable and safe manner. Students, faculty, and staff have unlimited access to the Pittsburgh public transportation system. For members of the campus community who drive, parking permits are available for spots located in and around campus (CMU Parking & Transportation Services, 2018). There are also bike racks located around campus. CMU offers shuttle and escort services for students, faculty, and staff to the neighborhoods surrounding the Pittsburgh campus at all hours (CMU Police 2018).

6.2.2 Diversity and Equity

Best practices in diversity and inclusion is also a part of CMU's Strategic Plan 2025 (CMU Board of Trustees, 2018). Diversity and equity describe the access that any member of the population has to resources, particularly the most vulnerable members (Barron and Gauntlett, 2002). Diversity requires that CMU employs and educates people from different ethnic, gender, ability, and socioeconomic groups. Equity requires identifying disadvantaged groups and working to remove their disadvantages (Hodgson, 2018). Here we define an underrepresented minority as a group on campus whose representation in the university community is significantly lower than their representation in the population as a whole. Table 6.3 lists the current demographics of CMU's student population as compared to the demographics of the US population. There are a number of categories where the CMU population is quite different than the nation as a whole, though this result is mitigated somewhat when the direct comparison is made to four-year research institutions rather than the US population.

Table 6.3 CMU Underrepresented Population Percentage (Velasco 2017, US Census Bureau 2017)

Category	**Undergraduates**	**Graduates**	**United States**
Women	45.5%	32.2%	50.8%
Hispanic	7.9%	N/A	18.1%
Black (Non-Hispanic)	4.3%	N/A	13.4%*
Native American (Non-Hispanic)	0.0045%	N/A	1.3%

*This value includes Hispanic Black people, making it larger than the true value

In the context of the university, questions of diversity and inclusion arise in multiple contexts. Hiring and admissions, for example, are notable areas that determine the membership of the university community. Diversity can also influence how decisions get made and, as a result, whose needs get served by the university. Currently, a number of CMU activities are tied to diversity and inclusion. To attract underrepresented students to the university, there are pipeline programs such as Girls of Steel Robotics and the Summer Academy for Math and Sciences. Carnegie Mellon also considers racial diversity in admissions and has actively sought to achieve gender diversity in admissions through programs like Women@SCS. CMU has made notable progress in reaching gender diversity, especially in STEM fields. In August 2017, the center for student diversity and inclusion was formed, bringing together campus resources for women, racial and ethnic minorities, LGBT, low income, and first generation students (CMU Center for Diversity and Inclusion). There is a diversity and inclusion roundtable for faculty, students, and staff held each semester to help bring different groups together to give them a voice. There are over 80 groups on campus such as SPIRIT, ALLIES, Latinx Alliance Network, and many more, all designed to amplify the voices of underrepresented groups on campus (CMU Student Government 2018).

CMU is an equal opportunity employer (CMU Human Resources, 2018). The committee on faculty diversity, inclusion and development, surveys effective methods to increase diversity in recruitment (CMU Vice Provost for Faculty 2018). The Vice Provost for Faculty website mentions pipeline issues, such as mentoring, access to role models, the degree of encouragement towards academia, and issues of climate as potential causes of under representation, but there is no mention of actions being taken to combat these concerns (2018). Instead, CMU's best practices for recruitment, adapted from the NSF ADVANCE programs, focus on reducing the under representation of women and ethnic minorities by the role of implicit bias (CMU Vice Provost of Faculty, 2018). Inclusivity training is also offered for faculty and staff (CMU Center for Diversity and Inclusion, 2018). The Office of Disability Resources handles accommodation issues for all members of the campus community in accordance with the Americans with Disabilities Act and section 504 of the Rehabilitation act of 1973 (CMU Disability Resources, 2018).

6.2.3 *Social Cohesion*

Social cohesion, or interconnectedness, is the informal, formal, and institutional support to advance a sense of community within the school and beyond (Barron and Gauntlett, 2002). Elements of social cohesion include a sense of belonging, participation in social activities, understanding and access to public institutions, and community support (Hodgson, 2018). At the university level, this means promoting a culture that encourages healthy relationships. The creation of such a culture begins during orientation week, during which incoming freshman students interact with each other in organized activities to build new social bonds. Community building for students also occurs through participation in over 300 different campus student groups (CMU Student Government, 2018). CMU Faculty have their own orientation to introduce them to the university and their peers (CMU Vice Provost for Faculty). The Vice Provost for faculty hosts small parties to encourage faculty to interact on a more personal level (2018), and there is also a guide for senior faculty members to develop mentoring relationships with junior faculty members (CMU Vice Provost for Faculty, 2018). The staff council promotes a sense of community with events such as the CMU community picnic and the ice cream social (CMU Staff Council, 2018). This variety of efforts exists to increase social cohesiveness among students, staff, and faculty separately.

There seems to be less direct effort to promote relationships across students, staff, and faculty. Events with the goal of encouraging relationships between students and the older adults around them are not common. Undergraduate student senate hosts a series of student-faculty lunches, but this was one of the few university-level activities we could find that was designed to create community among students and faculty (CMU Student Government, 2018). There appear to be no university-level events designed to directly bring students together with faculty and staff. Given CMU's decentralized model of academic governance, each department or unit has a lot of autonomy. Thus the level of activities designed to, for example, bring together students and faculty outside of the classroom, varies widely across campus.

6.2.4 Democracy and Governance

Strong democracy and governance means that the community has democratic processes and a transparent and accountable government structures (Barron and Gauntlett, 2002). The processes involved in governance must be understandable and accessible to all affected parties (Hodgson, 2018). Within the context of CMU, this means that students, faculty, and staff need to have a representative body to advocate for their interests. These bodies must be made up of members from the populations they represent and they must hold real power. There is an undergraduate senate, graduate student assembly, faculty senate, and a staff council where each respective group can bring forth their concerns (CMU Student Government, 2018; CMU Staff Council, 2018; CMU Faculty Senate, 2018). Within and under these broad legislative bodies, there are smaller councils where people can also get involved.

6.2.5 Current Activities

Tables 6.4 and 6.5 summarize the information above. A check indicates an area where CMU has taken some form of direct action designed to enhance the given category. Taking direct action does not necessarily indicate success in a given area -- such judgments would require the careful collection and analysis of data which to our knowledge has not yet occurred. CMU has taken action in many key areas of social sustainability for students, faculty, and staff. The university has taken action on every aspect of social sustainability for students, but may be lacking in action on diversity for faculty and staff and social cohesion across students, faculty, and staff. The Vice Provost for Faculty identified several aspects in the recruitment of more diverse faculty where it is not taking action (2018). There is no publicly available information on the recruitment of diverse staff. There is currently no publicly available information on the demographics of faculty and staff. Social cohesion requires efforts to ensure social cohesion within a given group, and across all groups. There are many groups dedicated to increasing social cohesion among students, and departments may take care of social cohesion within the department, but there is not much information to be found on direct activities to promote cohesion across students, faculty, and staff.

Table 6.5 CMU Social Sustainability Report

Category	**Students**	**Faculty**	**Staff**
Quality of Life	□	□	□
Equity	□	□	□
Diversity	□		
Social Cohesion (individually)	□	□	□
Social Cohesion (across groups)			
Democracy and Governance	□	□	□

□ = CMU is taking action in the specified category

6.2.6 Future Needs and Options

In the future, there needs to be a concerted effort to increase the amount of data collected on social sustainability in the campus community. While CMU is taking an active role in promoting many of the key dimensions of social sustainability, there is little publicly-available information on the efficacy of those efforts. To facilitate this effort, the survey model proposed in Tables 6.1 and 6.2 could be a potential analytical framework to begin quantifying CMU's current state of social sustainability.

During our research, we identified some potential gaps in CMU's support of social sustainability. In particular, direct programs to address diversity issues in faculty and staff hiring were not apparent. Also, the decentralized nature of CMU may be hampering efforts to build social cohesion within and across groups. Different departments take very different actions on these fronts, some likely quite successful and others less so, but under the current system it is difficult for one department to learn from another, plus programs that would benefit from centralized information or resources are difficult to implement.

6.3 Behavioral Aspects of Sustainability

Having buy-in and active participation from students and faculty is necessary for realizing campus-wide sustainable behavior. To achieve such buy-in it is important to understand how to productively influence sustainable behavior. Studies have shown that college students, for the most part, are increasingly interested in having a sustainable campus. For example, the Princeton Review's 2009 College Hopes & Worries Survey indicated that 66% of surveyed students consider an institution's environmental commitment when making college decisions, 3% higher than just the year before. An Investigation of University Students' Attitudes Toward Environmental Sustainability (Şahin, Hande, and Sibel Erkal 2017) found that over 86% of students are interested in being environmentally aware. A CMU survey conducted last year (Pittsburgh to Paris, 2018) found that the campus community's desire for a sustainable campus was far below their sense of its current state. The survey of students, faculty, and staff revealed that 67% of respondents expressed a strong concern for the effects of global climate change and an additional 21% expressed at least a slight concern. Over 90% of respondents strongly or somewhat strongly agreed that CMU should be a leader in green practices. Researchers have highlighted the importance of effectively altering sustainably-conscious behavior to achieve sustainability goals (Steg and Vlek, 2009; Rogerson et al., 2009).

6.3.1 Sustainable Behavior Literature Review

Human behavior often is difficult to change, and interventions such as telling members of the community to "act more sustainably" are not likely to be effective. Instead, for policies to be effective they must be carefully designed. Policies that can be deeply ingrained in campus culture have the potential to influence each new influx of students and faculty. For example, Western Michigan University established a strong environment of sustainability in 2009 using its Climate Action Plan and Talloires Declaration (WMU, 2009). This program was able to reduce net greenhouse gas emissions by 13% from 2008 to 2012, increase faculty engagement in sustainability research to 51%, and introduce 15 new sustainability related courses by 2014, all because of commitments made to sustainability in 2009 (WMU, 2014). Using this same thinking, CMU can lay the framework of sustainability now to make the university a leader in sustainability for years to come.

Various institutions have incorporated behavioral change tied to sustainability into their teaching. For example, Nanyang Technological University taught their students about sustainability using a phone app that used a game format to enhance learning. Western Michigan University held a Sustainability Leadership Summit, hosted a Community Sustainability Roundtable, and created a National Campus Sustainability Day (Boh, 2017; Drouet, 2017; and WMU, 2014). CMU can use similar engagement strategies to reach the campus population. With common networks already in place such as Canvas, Piazza, or even the CMU webpage, we can find similarly creative ways to reach the students. We could also incorporate some of these activities into Carnegie Mellon's extremely active orientation week.

Students make up over ninety percent of CMU's campus population, so changing their behavior should be prioritized. Ngaoka (2016) found that young people "learn best through active and reflective experiences." This insight may explain the effectiveness of the programs above that were implemented at Nanyang and Western Michigan Universities.

Behavior is also heavily influenced by immediate peers. Social comparison theory, proposed by Festinger (1954), suggests that people look towards peers to legitimize their own actions and opinions. Diffusion of Innovation Theory also suggests that people are more likely to participate after seeing other people take part (LaMorte, 2018). This suggest that the behavior of the campus community can be shaped indirectly through peers. Such a methodology was utilized in the reshaping of the University of Alberta's sustainability efforts. Instead of training the entire campus, the university implemented an ecoREPs program to train a few select student leaders in sustainability. These students then went on to start projects like waste reduction in art projects, a community conference on energy and climate change, a green living wall, and many other initiatives (Dietrich, 2015). Similarly, the University of Washington in Seattle was able to engage their large Greek community by enlisting the leadership of just a few members from each chapter. The UW Green Greek Representative Program gave these members from each chapter the role of Green Representative, and trained them in certain green practices. These members then influenced the rest of their community, allowing for subsequent initiatives like the Sustainable Fraternity Party Project, a community-wide street clean, and a sustainability pledge that was signed by nearly 200 students in the Greek community (Lyle, 2016; UW, 2018).

Behavioral Decision Theory suggests that behaviors often can be "nudged" in the intended direction. For example, Hansen (2014) discusses Google's attempts to have their employees eat healthier. Instead of asking or telling employees to eat healthier, Google reorganized its cafeterias so that the healthier options were presented first in the food line. This resulted in their employees choosing healthier options more than they had before the reorganization. CMU has implemented some nudges, for example, trash cans have been eliminated in newly renovated classrooms, encouraging students to take more responsibility for the generation and disposal of their waste. Similar initiatives throughout campus could have a significant impact on the population's behavior.

Habitual learning, whereby when something is done over and over it becomes a long-term habit, has long been recognized by psychologists. This suggests that by making sustainability an integrated and habitual part of the university, members of the campus community may become more inclined to behave more sustainably. For example, entering CMU students learn their dorm's laundry process and the school's computing practices through mandatory training at the beginning of their freshman year. After this training, these practices become habits for students. If the same thinking was applied to sustainability, and students and faculty were taught in the beginning of their time at CMU how to behave more sustainably, sustainable behaviors might become an integrated and habitual part of the CMU experience. The University of Maryland, College Park, found that integrating green lessons into student orientation is an effective way to transform campus culture (Stewart, 2010).

6.3.3 Benchmarking Other Universities

The Association for the Advancement of Sustainability in Higher Education (AASHE) is a widely recognized organization that scores universities on their sustainability efforts. Of our peer universities, nine have sought AASHE scoring. Figure 6.1 shows the community engagement scores for these peer institutions. Factors contributing to these scores include Student Educators Program, Student Orientation, Student Life, Outreach Materials and Publications, Outreach Campaign, Employee Educators Program, Employee Orientation, and Staff Professional Development. The average score among our participating peer institutions is 86%. CMU scored 67% in this category. Institutions achieve high engagement scores through a variety of means. For example, the Sustainable Food Program at Stanford University put in place organic teaching gardens and hydroponic farms in select dining and living areas, directly bringing sustainability into the lives of its students and encouraging them to take part in organic farming and sustainable food growth while simultaneously learning about the importance of such practices. Cornell University implemented a student-run energy conservation program called Lights Off Cornell that encourages students and faculty to reduce energy by shutting off the lights after hours during the school-week (Cornell University, 2005). CMU received no points in the Student Educator Program and Staff Professional Development categories. In an effort to match or exceed the progress of our peer institutions, CMU could start by working on these weak points in their engagement. Looking to some of the work other universities have done to excel in these categories we could also develop strong programs to for students and staff.

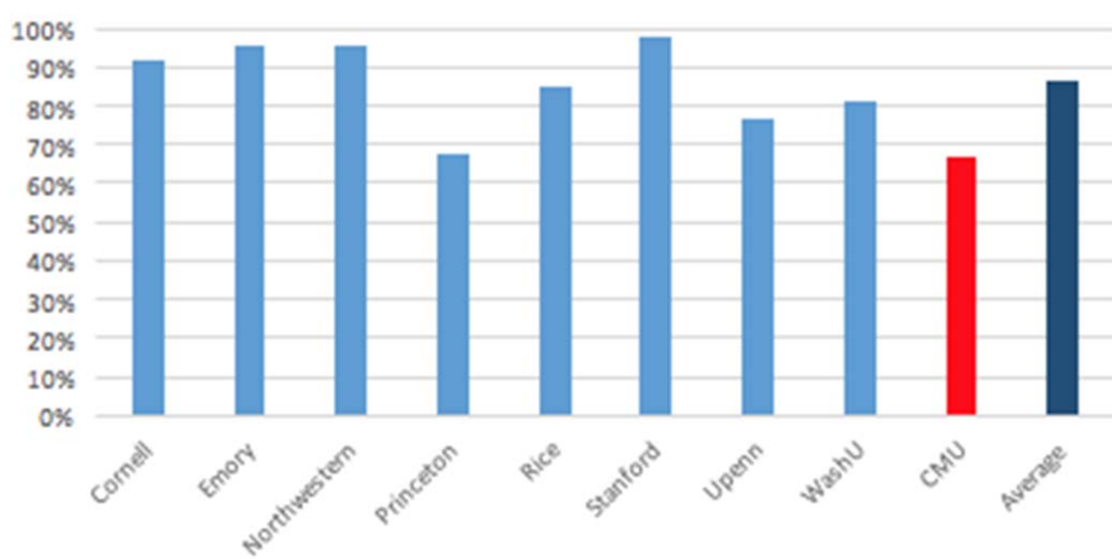

Figure 6.1 AASHE Engagement Scores of Peer Institutions

6.3.4 Current Sustainability Behaviors at Carnegie Mellon

CMU has been making efforts to increase sustainability engagement on campus. With student groups like Sustainable Earth that actively educate the campus community through talks, demonstrations, and signage, and Solar Racing that looks into powering vehicles using renewable energy sources, CMU students have a variety of opportunities to explore sustainability. CMU has also implemented various programs, like providing everyone in the campus community with access to the Pittsburgh bus system or creating a room in the Cohon University Center to make it easier for students to recycle a variety of materials.

While there are resources available for students to act sustainably, there is more that can be done to engage students. Currently, there are limited opportunities for the campus community to learn about sustainability initiatives. CMU's sustainability resources are scattered around different websites making it difficult for interested community members to get the needed information. Emory University, a school that has one of the highest AASHE engagement scores of our peer universities, has a detailed sustainability webpage that is only three clicks away from it's main webpage and classified under the major umbrella of "Life at Emory" (Emory University, 2018). CMU, on the other hand, does not include sustainability on their main website. Instead, the university has an entirely separate website for sustainability which then branches off into many other webpages. Thus, it is more difficult for students to find out information about ways they can get involved in sustainability in campus. Campus resources also have low visibility. Some of the efforts done by sustainability groups or the presence of sustainability resources like recycling bins go unnoticed because they are not advertised to students. For example, according to Facility Management Services, composting bins are only provided to departments that have requested them and that can closely monitor their use. This prevents such resources from becoming a habitual and integrated part of the daily lives of the campus community. Colorado State University created a campus-wide composting program that included instruction on appropriate use. This resulted in a substantial increase in composting at sporting events and in housing (Fleskes 2017, Fleskes 2018, Guiden 2018). An experiment on how people dispose of waste based on the convenience of bins (DiGiacomo 2018) revealed that "When recycling stations were placed just meters from suites in student residences, instead of in the basement, recycling increased by 147% (container), and 137% (paper), and composting increased by 139%." This shows that simply nudging the campus population's behavior and implementing more conveniently placed waste diverting bins instead of limiting them could increase the amount of waste people on campus recycle and compost. Suffolk County Community College introduced a behavior-based energy conservation program, resulting in a 25% reduction of energy by changing the way students interacted with the campus, including the temperature at which occupied classrooms would be set and how the energy would be used throughout the day.

6.4 Conclusions for Societal and Behavioral Dimensions

No sustainability movement on campus would be complete without considering the human, non-environmental dimensions of sustainability. CMU has taken actions to promote social sustainability in many domain, though there seems to be a lack of easily-accessible data, either because it is not collected or not distributed. While the educational mission of CMU provides number of opportunities to students, staff, and faculty to achieve some important social sustainability goals such as fulfilling employment, other areas such as diversity and social cohesion might require additional efforts.

There appear to be a number of behavioral changes that could enhance CMU's climate of sustainability. Given CMU's deep research strengths in behavioral science, promoting this area might create new and interesting opportunities for both theoretical and applied research on a topic that is important for both its research and social imperatives.

6.5 Chapter 6 References

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Chapter 7: Economic and Financial Dimensions of Sustainability

7.1 Introduction

The United Nations' Brundtland Report, "Our Common Future," described economic growth as one of the three basic components of sustainable development (Our Common Future, 1987). This report established a conceptual framework for sustainable development and has become the basis for many definitions of sustainability.

A commonly accepted model of sustainability is known as the "3 P's" or "Triple Bottom Line" model. This model incorporates three key tenets of sustainability: the planet (environment), people (social), and profits (economic) (James, 2018, and Savitz et al., 2006). Organizations beyond the United Nations have incorporated these tenets of into their own sustainability efforts and missions. For example, the Organisation for Economic Co-operation and Development (OECD) uses environment, society, and economy (Strange et al. 2008). The data analytics group B Lab uses the B Impact Assessment to measure environment, worker/community, and governance factors (Honeyman, 2016).

Here we focus on the economic component of sustainability. Traditionally, economists have focused on four factors of production: land, labor, capital, and entrepreneurship (Amadeo 2018). Environmental sustainability deals with land, social sustainability with labor, and economic sustainability with capital and entrepreneurship. More specifically, economic sustainability focuses on assets, growth, leadership, and innovation in order to best allocate resources and people in a sustainable way.

7.1.1 Categories of Economic/Financial Sustainability

Economic sustainability applied to higher education often includes leadership, culture, public relations, investment portfolios, innovation, and networking (Amos, 2015). The Sustainability Tracking, Assessment and Rating System (STARS) program by the Association for the Advancement of Sustainability in Higher Education (AASHE) uses the following categories for sustainability in higher education: institutional characteristics, academics, engagement, operations, planning and administration, and innovation. Financial sustainability touches mainly on engagement, planning and administration, and innovation. The analysis below refines these categories and focuses on Carnegie Mellon University's (CMU) portfolio management, leadership activities, networking, and innovation.

7.1.2 Portfolio Management

The Investment Office manages the CMU's portfolio and endowment. The Alumni Office and Advancement units raise money to supplement the CMU's financial resources. The careful management of CMU's long-term financial resources provides a sustainable base of financial resources for the University's operations and growth. Figure 7.1 shows CMU's revenues, expenses, and endowments from 2013-2017. Until recently, CMU's annual expenses and revenues have been roughly equal to its endowment, implying that a loss in revenues without an equal reduction in expenses could not be financed by the endowment (even if that was legally allowed) for very long.

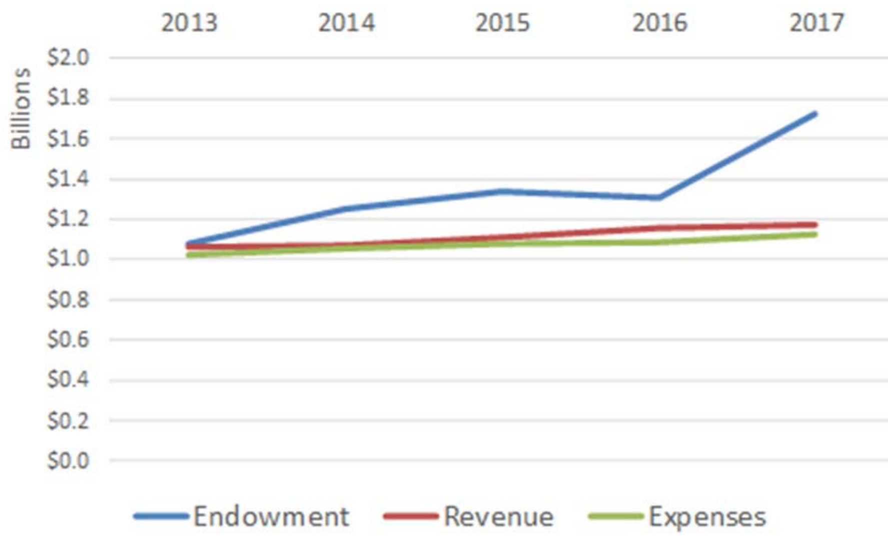


Figure 7.1 Financial Overview for Carnegie Mellon University

Figure 7.2 shows the 2017 endowments for CMU and its self-defined peer institutions. CMU's endowment is ranked 12th out of the thirteen schools in this pool. Figures 7.3 and 7.4 show the number of full-time students at these institutions and the endowment per full-time student. CMU's ranking, 12th, remains unchanged when considering endowment per full-time student. Indeed, the overall rankings of the schools remain fairly static on this latter metric, with the exception of the California Institute of Technology, which given its low number of full-time students, rises from 11th to 4th.

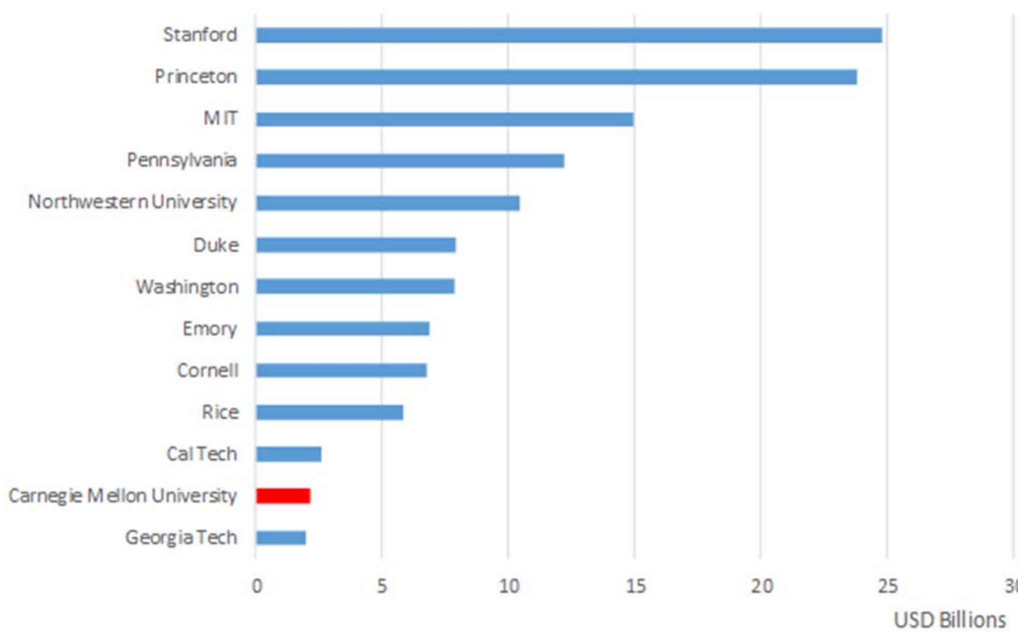


Figure 7.2 Total Endowment (as of 2017) for CMU and Its Peer Institutions

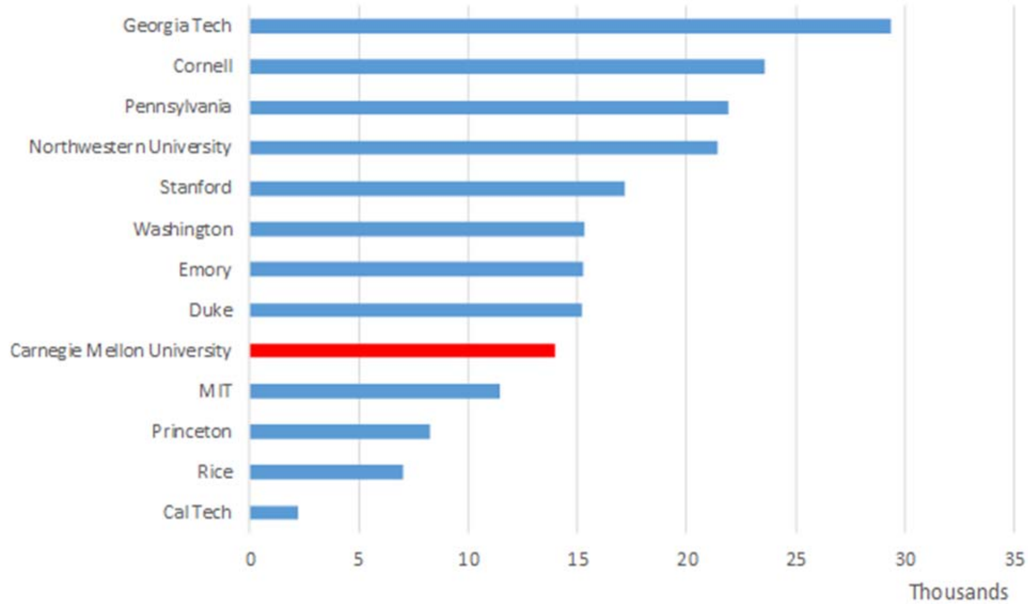


Figure 7.3 Full-time Students (as of 2017) for CMU and Its Peer Institutions

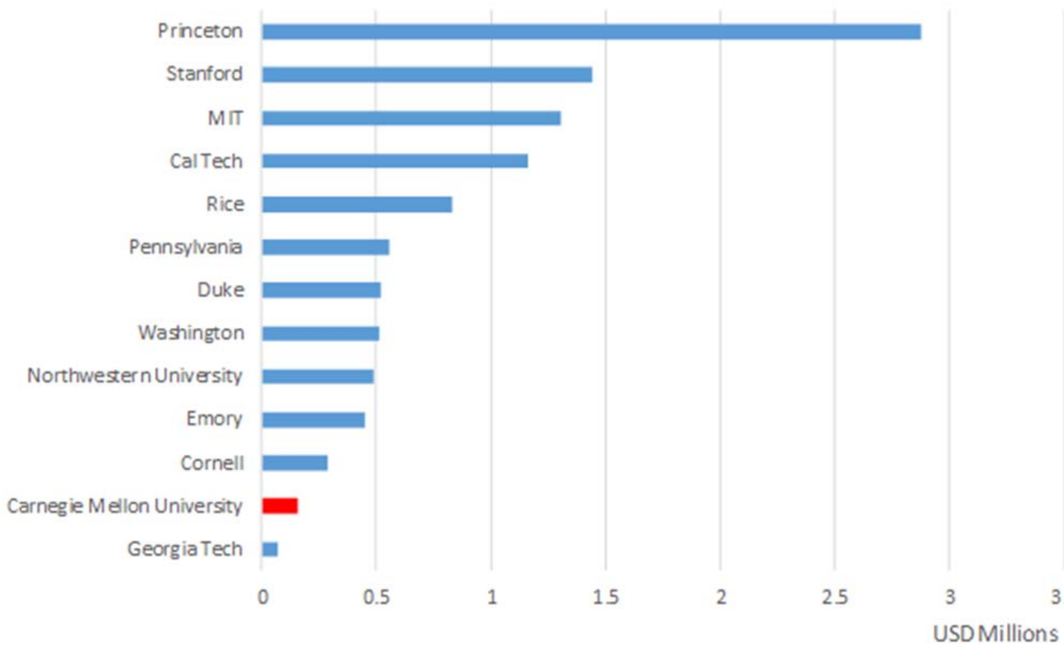


Figure 7.4 Endowment Per Full-Time Student (as of 2017) for CMU and Its Peer Institutions

In order to gain more context for CMU's financial standing, we analyzed a larger set of US universities and colleges, namely, those with endowments above one billion dollars in 2017. The 97 US institutions that meet this threshold are shown in Figure 7.5. CMU (shown in red) is ranked 45th. If we include all of the 1,993 4-year nonprofit US universities, CMU's endowment would place it in the top 3% of these schools (National Center for Education Statistics).

Some key financial indicators are outlined in Figure 7.6. Endowment per student is an important metric because the higher this ratio, the less dependent the institution is on streams of current revenue. The equity ratio provides a measure of the liquidity of an institution's assets as well as its potential to earn returns on its assets. Finally, the expense ratio provides a notion of an institution's dependency on current revenues. Figure 7.7 provides a comparison of CMU to its peer institutions based on these metrics (where the size of the circle is tied to the institution's endowment per student ratio). Relative to its peers, CMU has experienced only moderate growth of its expense ratio during the five-year period captured in the figure, while being at the high-end of changes in its equity ratio (Denneen & Dretler, IPEDS et al).

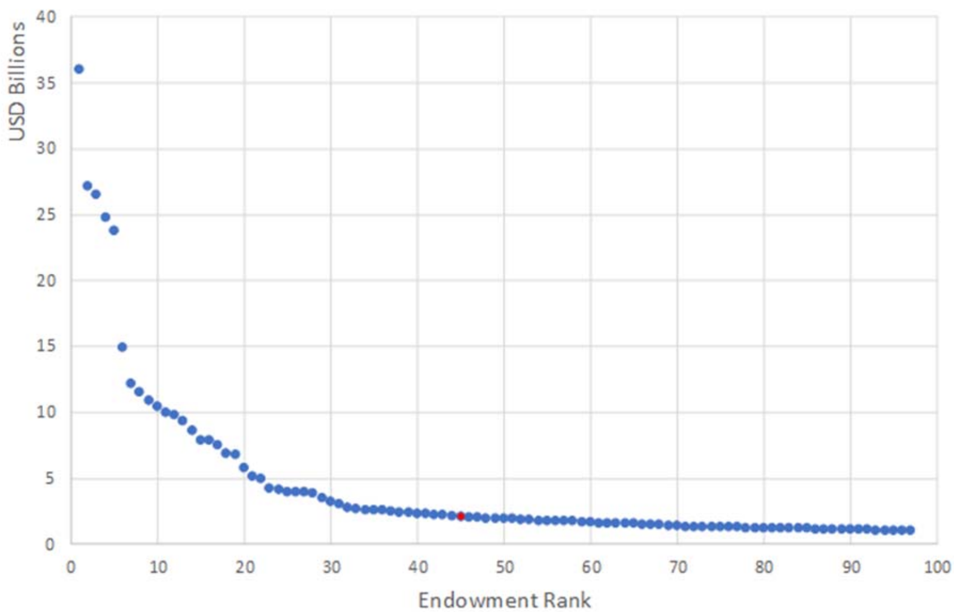


Figure 7.5 Endowment Comparison for Billion Dollar Endowment Universities

$$\boldsymbol{Endowment\ per\ FTE} = \frac{Total\ Endowment}{Full\ Time\ Student\ Equivalent}$$

$$\boldsymbol{Equity\ Ratio} = \frac{Equity}{Assets}$$

$$\boldsymbol{Expense\ Ratio} = \frac{Expenses}{Revenue}$$

Figure 7.6 Portfolio Management Equations for Metrics

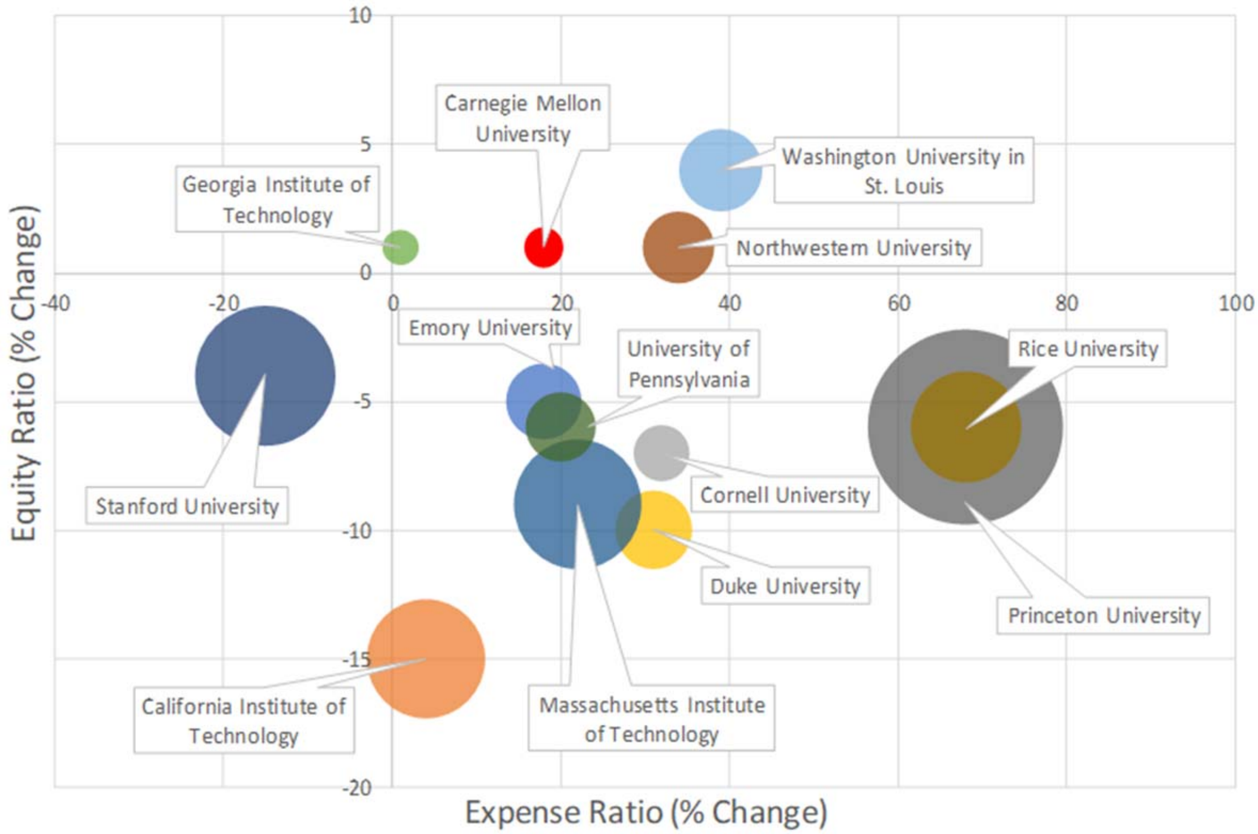


Figure 7.7 Financial Overview Comparison for Carnegie Mellon University and its Peer Institutions

7.1.3 Leadership Activities

Leadership within higher education depends on organizational structure and leadership development. The administrative structure of CMU as it pertains to sustainability will be discussed in Chapter 8. Leadership development on college campuses is a crucial concern, especially for the student body. Given the relatively short time students spend on campus--an undergraduate degree routinely requires four years and a master's degree two years to complete--it is difficult to develop good, long-term student leaders or maintain the needed level of institutional memory in student groups. The tenure of staff and faculty is much longer, and thus these groups can often develop organizations with effective leadership (Martin, 2012).

7.1.4 Networking

Networking involves defining the relationship between Carnegie Mellon and various external entities: alumni, corporations, government organizations, non-profits, other universities, and so on. The Alumni Office and Career & Professional Development Center manage many of these relationships. The strength of an alumni network is often measured by the number of alumni in management positions. Figure 7.8 shows CMU compared to those peer institutions that had available data. CMU is ranked ninth out of twelve on this dimension. An alternative metric, provided by Best College Values (2016), reports that CMU had the 31st most powerful alumni network in the US. Data for alumni giving, a measure of the strength of a university's alumni network, is given in Figure 7.9. CMU is ranked 10th out of 12 institutions on this measure.

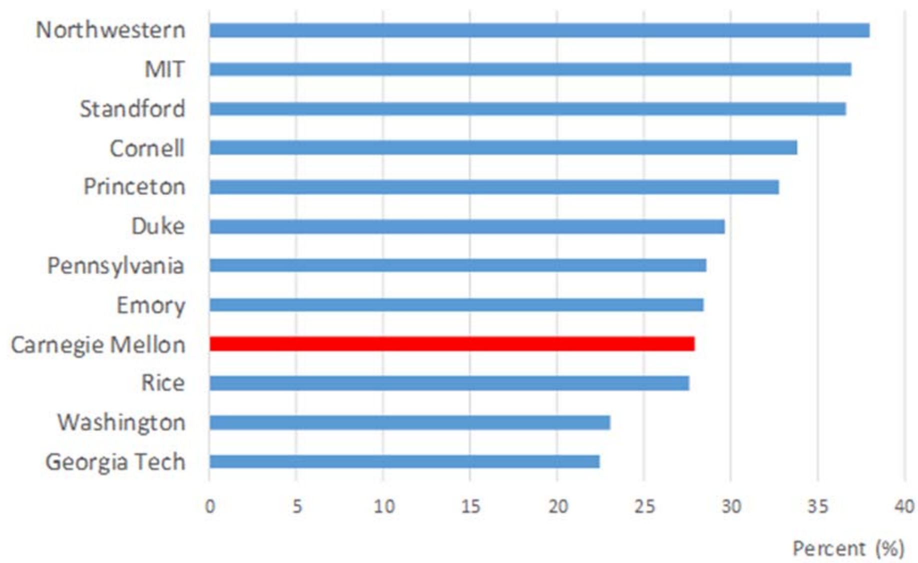


Figure 7.8 Alumni in Management for Carnegie Mellon University and its peer institutions

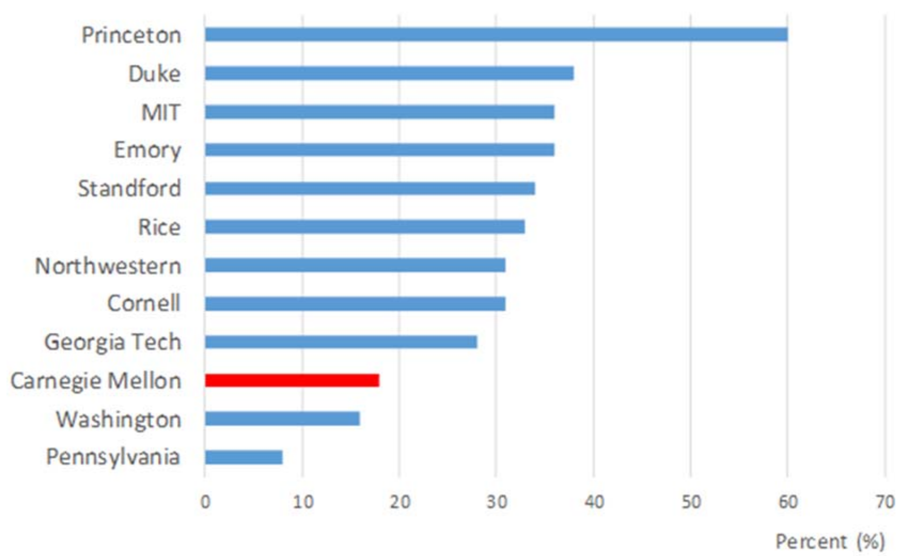


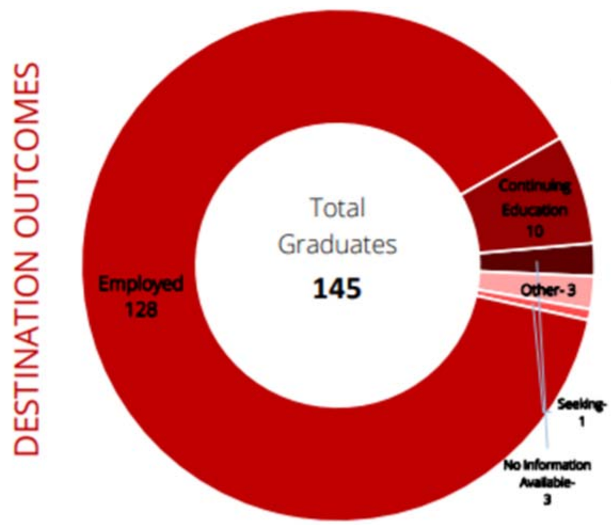
Figure 7.9 Alumni Donation Activity for Carnegie Mellon University and its peer institutions

The Career and Professional Development Center at Carnegie Mellon has two separate offices. The employee relations office organizes career fairs and fosters recruiter relationships. The success of our external professional network is measured by recruiter emails, corporate sponsorship, and number of interviews. CMU uses the career service platform *Handshake*. This online service allows students and alumni to apply for on-campus and off-campus positions. *Handshake* has all of the Fortune 500 Companies, over 9 million users, and access to over a quarter million employers ("Employer"). The site provides analytical tools to CMU career services. These metrics are not made public, but managed by the employee relations office.

The main career office at CMU provides major-specific consulting, interview preparation, and skill/personality assessments to students and alumni (CPDC, “Welcome”). This office collects and publicizes professional data in the form of salaries and destinations. An example of this is shown in figure 7.10 (CPDC, “2017 Post-Graduation Salaries & Destination Information”).

2017 CMU FIRST DESTINATION OUTCOMES

School of Computer Science: Computer Science-Bachelor’s



SALARIES

AVERAGE SALARY =
$108,532

MEDIAN SALARY =
$109,000

SALARY RANGE =
$48,000 – 150,000

*Other = volunteer, military, return to home country, seeking graduate school, or delay in post graduate search.

EMPLOYMENT DESTINATIONS

EMPLOYER	JOB TITLE	CITY	STATE/COUNTRY
Affirm (3)	Software Engineer	San Francisco	California
Airbnb	Software Engineer	San Francisco	California
Alarm.com	Software Developer	Tysons	Virginia
Amazon (8)	Software Engineer (2)	Seattle	Washington
		Boston	Massachusetts
	Software Development Engineer (4)	Seattle	Washington
	Software Developer	Sunnyvale	California
	Software Development Engineer	Herndon	Virginia
Applied Predictive Technologies (3)	Software Engineer	Arlington	Virginia
	Database Analyst (2)	Arlington	Virginia
Asana	Software Engineer	San Francisco	California
B12	Software Engineer	New York City	New York
Bank of America Merrill Lynch	Technology Analyst	New York City	New York
Belvedere Trading	Software Engineer	Chicago	Illinois

Carnegie Mellon University
Career & Professional
Development Center

School of Computer Science: Computer Science—Bachelor’s [Page **1** of **4**]

Figure 7.10 Salaries & Destinations Example for Career & Professional Development Center

7.1.5 Innovation

The innovative activities at CMU occur in a variety of venues on campus. For example, the Swartz Center for Entrepreneurship and the Integrated Innovation Institute coordinate a lot of the activity in this space. There is also an on-campus center for technology transfer that facilitates the commercialization of CMU-linked innovations. CMU has also spawned a lot of start-ups, particularly in the areas of computer science and engineering. Table 7.1 shows the US News 2018 rankings for Most Innovative Schools ("The 10 Most Innovative Universities in America"). CMU is ranked seventh nationally and fourth against its peer group.

Table 7.1 Most Innovative Schools Rank 2018 For Carnegie Mellon University and Its Peer Institutions

Peer Institutions in Top 58	US Most Innovative Schools Rank (2018)
Massachusetts Institute of Technology	3
Georgia Institute of Technology	4
Stanford University	5
Carnegie Mellon University	7
California Institute of Technology	11
Princeton University	15
Duke University	16
Cornell University	21
Rice University	28
University of Pennsylvania	32

7.2 Current Activities

CMU currently practices economic and financial sustainability in its engagement with portfolio management, leadership activities, networking, and innovation. These programs, directed by various entities and departments, make up an essential part of the CMU experience.

7.2.1 Portfolio Management

At CMU, both the Finance Division and Investment Office take part in key financial planning. While separate offices, these two entities collaborate heavily, with the Finance Division focusing on internal financial sustainability and the investment office focusing on long-term, external financial sustainability. Each sets targets, engages other units, and tracks progress.

The Finance Division is run by the vice president for finance and chief financial officer, and has a five-person leadership team. This group manages budget and financial planning, the controller's office, business systems and services, the treasurer's office, procurement services, and the university audit services. The Finance Division focuses on internal management of funds to support the educational, research, and strategic goals of the University (Eberly Center, "Chief Financial Officer"). Major cash flows are tracked and summarized yearly in the annual financial report (Eberly Center, "Financial Reporting and Incoming Funds"). A finance bulletin is released monthly for internal, campus-wide communications, providing a greater degree of financial awareness across campus (Eberly Center, “Finance Division”). The Finance Division also provides budget and financial planning resources to departments and other units (Reichard). This information is tracked internally, but not made publicly available.

The Investment Office works closely with the Finance Division and helps to release the annual financial report. The mission of the Investment Office is to focus on the longer-term goals of financial viability. This mainly consists of the portfolio composed of investments that form CMU’s endowments (Eberly Center, “Investment Office”). This group determines CMU’s investment strategy, implements these decisions, and tracks the portfolio. The degree to which investment activities are directed to companies that embrace sustainability as part of their missions is unknown. Figure 7.11 shows the 2017 asset allocations. Figure 7.12 shows the total value of the endowment from 2008-2017 as well as the annual rates of return.

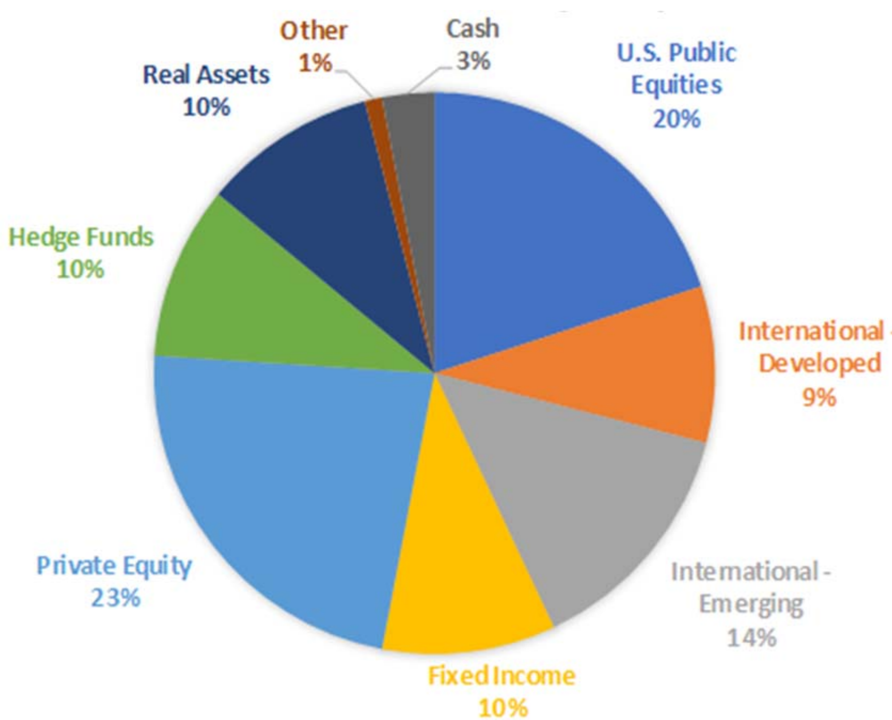


Figure 7.11 Actual Asset Allocation by Carnegie Mellon University Investment Office for 2017

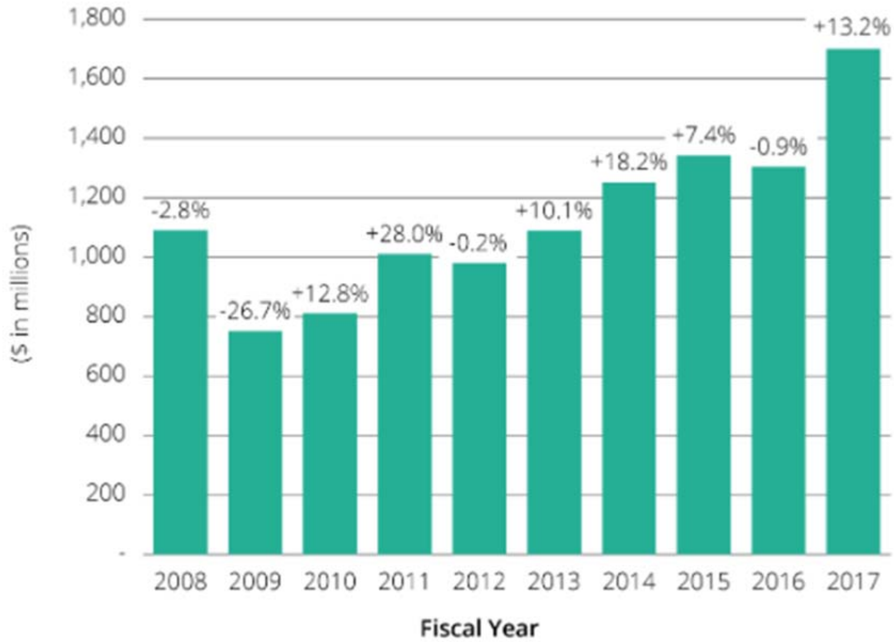


Figure 7.12 Endowment Ending Value and Annual Investment Return

7.2.2 Leadership Activities

Current leadership activities are focused on developing student leaders and maintaining institutional memory within campus organizations. Most of these activities are managed by the Division of Student Affairs, which houses a myriad of offices (Eberly Center, "Division of Student Affairs"). The various departments are listed below. The Division of Student Affairs aims to improve and coordinate diverse activities across campus. The data they collect is not publicly available, but their resources and initiatives are. Insight can be gained from these efforts.

Departments of the Division of Student Affairs

1. Athletics, Physical Education and Recreation
2. Career & Professional Development Center
3. Center for Student Diversity and Inclusion
4. Cohon University Center
5. Conference & Event Services
6. Counseling and Psychological Services
7. Dining Services
8. Housing Services
9. Office of Community Standards & Integrity
10. Office of Residential Education
11. Orientation and First Year Programs
12. Pre-College Summer Studies
13. Student Leadership, Involvement, and Civic Engagement
14. University Health Services

As discussed in section 7.1.3, leadership development and transition is most challenging for student-run organizations. This issue is often tackled by the office of Student Leadership, Involvement, and Civic Engagement (SLICE). SLICE engages in several projects with aspects of financial sustainability. Some of these services are outlined below.

SLICE provides resources for student-run organizations at CMU. The *Officer Transition Guide* is one example (SLICE, "Office Transition Guide"). This guide provides various checklists on how to run elections and maintain institutional memory for a given student organization. The Tartan Leadership Conference provides financial and leadership training for student organization leaders (Eberly Center, "Tartan Leadership Conference"). This training provides foundation information for organizations on how to operate the organization's bank account and run campus events. The Bridge serves as an online repository for all student organizations at CMU (SLICE, "The Bridge"). This site provides club descriptions and contact information. It also contains a database for organization membership, account information, and mission statements. These examples show economic sustainability in action at CMU. Deliverables, training, and websites provide the foundations of these efforts.

7.2.3 Networking

The Alumni Office and Career and Professional Development Center develop internal and external relationships for CMU. The major services and resources of the alumni office are shown in Table 7.2. The services offered by the career center are organized by stakeholder: students and alumni, employers, parents, faculty, and staff. Table 7.3 shows the major offerings.

Table 7.2 Current Activities for CMU Alumni Association

CMU Alumni Association - Current Activities		
Attend Event	**Involvement**	**Benefits & Resources**
Network/Group Calendar	Networks	Professional Development
Spring Carnival	Volunteers	Alumni Career/Executive Coaching
Homecoming	Reunions	University Employment
Reunions	Students	Diplomas & Transcripts
CMUConnect	Alumni Awards	Campus Visits
CMUThink		Insurance
Virtual Events		

Table 7.3 Current Activities for CMU Career Center

CMU Career Center - Current Activities		
Students & Alumni	**Employers**	**Parents**
Career Exploration	Recruit/Post Jobs	Student Support Guide
Resume/Cover Letter	Attend Career Events	Graduation Statistics
Job or Internship Search	Host Information Sessions	Student Recruitment
Career Event Preparation	Career Partners	Student Testimonials
Resources	Hiring & Offer Policy	Volunteer Opportunities
Early Engagment Events		
Ethical Job Search Policy	**Faculty & Staff**	**Handshake Access**
Olitsky Career Readiness	On-Campus Employment	Students, Faculty, Staff, Alumni, Employers

7.2.4 Innovation

The Swartz Center for Entrepreneurship and the Integrated Innovation Institute manage various innovative activities at CMU. The resources and engagement activities of the Swartz Center are shown in Table 7.4. Table 7.5 shows the degrees, projects, resources, and outreach programs provided by the CMU Integrated Innovation Institute.

Table 7.4 Current Activities for CMU Swartz Center for Entrepreneurship

CMU Swartz Center - Current Activities		
Education & Resources		**Involvement**
Courses & Degrees	Mentorship & Funding	Learn
Incubator Program	Startup Job Resources	Mentor
VentureBridge	Student Clubs	Invest
ITIC Fund	Corporate Startup Lab	Donate
CONNECTS	News Archives	Events
Experiential Learning		
Extracurricular & Networking		

Table 7.5 Current Activities for CMU Integrated Innovation Institute

CMU Innovation Institute - Current Activities		
Master's Degrees	**Projects & Research**	**Our Innovators**
Admissions	For Industry	Faculty & Staff
Products & Services (MIIPS)	For Society	Our Students
Software Management (MSSM)	Internet of Things	Alumni
Technology Ventures (MSTV)	CMU-Emirates iLab	Partners

7.3 Future Needs and Options

Based on our review of CMU’s current activities and its US rankings, there is still the potential for improving its positions in leadership, innovation, and networking. The specific options for these categories are outlined below. Currently, there is no single entity that connects these different initiatives.

7.3.1 Portfolio Management

The current activities of the Investment Office and Division of Finance allow Carnegie Mellon University to effectively track and allocate funds and investments. The Annual Financial Report and departmental resources provide financial awareness to campus entities and the greater community. One potential area for improvement here is to directly incorporate sustainability considerations in CMU’s investment decisions.

7.3.2 Leadership Activities

Specific colleges within the University have their own leadership development activities. For example, the College of Engineering has both requirements and opportunities for leadership exposure. Experiential learning is a graduation requirement for undergraduate engineering majors. In fall 2017, the College of Engineering started a leadership development seminar for its students. These two programs and potential areas of improvement are discussed below.

Experiential learning is an initiative that asks students to participate in lectures, seminars, workshops, and club positions outside of the required curriculum. Involvement in these activities encourages students to develop skills and perspectives not normally presented in classes and contributes to shaping the overall character of the student body. Students are currently required partake in two lectures/seminars, or in one elected leadership position per semester for three semester. This program is assessed through essay reflections. Students write about the event or position and how it has affected them. These assignments are graded by advisors with thresholds required to obtain a passing grade. This program presents a unique opportunity to quantify student exposure to leadership development across the University. While currently it improves engagement for the College of Engineering, such a program could be expanded to the other colleges on campus.

In fall 2017 the College of Engineering began to offer a leadership development seminar for undergraduate students within the college. This course provides a conceptual understanding of human interactions and management (The HUB). Currently this seminar resides in the College of Engineering as an interdisciplinary course. Replicating this course for all students, faculty, and staff could enable a broader understanding of leadership structures, skills, and tactics across the CMU community..

7.3.3 Networking

Many financially sustainable efforts exist at CMU and are managed by the Career Center and Alumni Office. Currently the data from the Alumni Office and Career Center is inaccessible, and while privacy and strategic concerns are reasonable, there is the potential for opening up some of this data to analysis in order to improve these programs.

7.3.4 Innovation

The Swartz Center for Entrepreneurship and the Integrated Innovation Institute have many resources and services that can be utilized by the greater campus community. The current activities discussed in section 7.2.4 provide useful models for university curricula, organizations, departments, and research efforts. These internal campus resources can help to further define and strengthen the entrepreneurial spirit and therefore the financial sustainability of Carnegie Mellon.

7.4 Conclusions for Economic Sustainability

Economic sustainability within higher education capitalizes on the comparative advantage of an institution. Strategic capital allocation and an underlying entrepreneurial spirit can allow a University to prosper and fulfill its core goals. For CMU, the pursuit of educational, research, and professional excellence depends on its financial viability. Progress towards financial sustainability can be tracked through portfolio management, leadership activities, networking, and innovation.

Leadership, networking, and innovative activities need standardization and expansion across the CMU community. Existing resources and events can provide the baseline for a more centralized effort. Portfolio management and internal financial planning have appropriate representation within the University hierarchy. Figure 7.13 shows the Senior Leadership at Carnegie Mellon University ("Senior Leadership"). The four members outlined in red oversee various aspects of financial sustainability as of Novemberf 2018. Table 7.6 outlines the specific departments that manage this form of sustainability on campus.

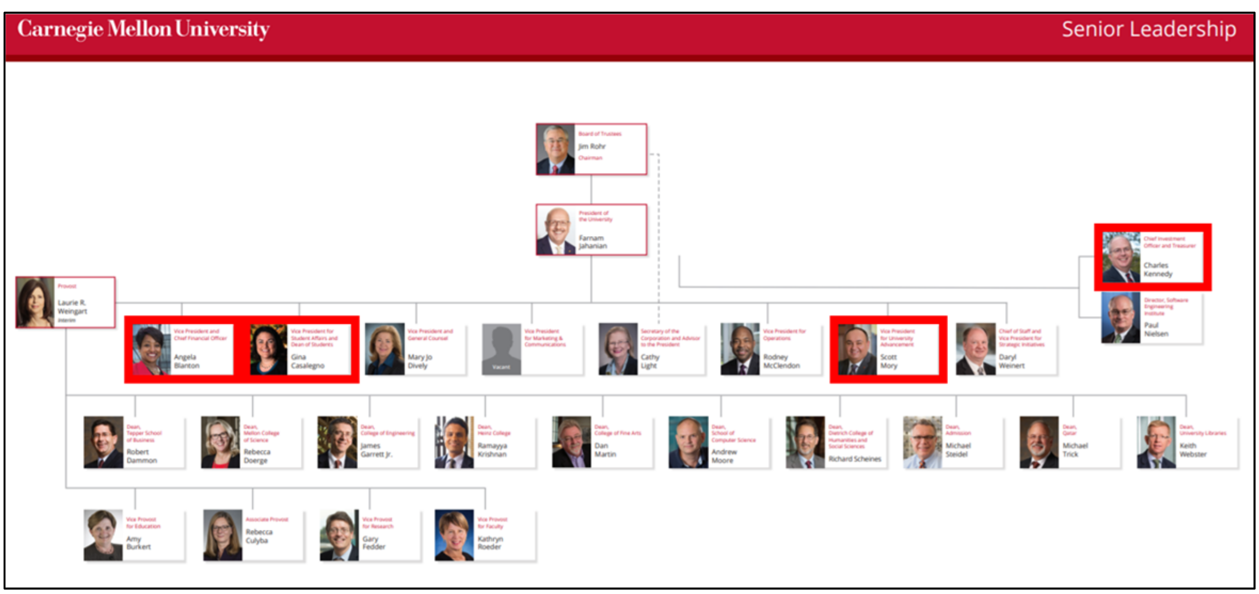


Figure 7.13 Carnegie Mellon Leadership Chart for Financial Sustainability

Table 7.6 Financially Sustainable Departments under Senior Leadership for Carnegie Mellon University

 Vice President and Chief Financial Officer Angela Blanton	 Vice President for Student Affairs and Dean of Students Gina Casalegno	 Vice President for University Advancement Scott Mory	 Chief Investment Officer and Treasurer Charles Kennedy
Budget and Financial Planning Controller's Office Business Systems and Services The Treasurer's Office Procurement Services University Audit Services	Athletics, Physical Education and Recreation Career & Professional Development Center Center for Student Diversity and Inclusion Cohon University Center Conference & Event Services Counseling and Psychological Services Dining Services Housing Services Office of Community Standards & Integrity Office of Residential Education Orientation and First Year Programs Pre-College Summer Studies SLICE Office University Health Services	Advancement Communications and Marketing Alumni Relations Annual Giving Gift Offices Donor Relations, Stewardship and Events Information Systems and Research Institutional Partnerships	Investment Portfolio

A wide range of offices and individuals take part in this component of CMU's sustainability. While key structures and some innovative programs are in place, they are often isolated from one another and implemented in local units. Such efforts could benefit from having a more unified vision of economic sustainability and a higher degree of cross-campus collaboration.

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Chapter 8: Organizational Structures for Sustainability

The previous chapters of this report have looked at the different dimensions of sustainability in the context of Carnegie Mellon University and identified a broad set of needs and potential measures to foster sustainability going forward. In this chapter we examine the institutional and organizational structures needed to effectively achieve sustainability goals.

8.1 Summary of Organizational Structures at Peer Institutions

Centrally organized sustainability efforts are a common feature in many of Carnegie Mellon University's peer institutions. The configuration of a sustainability office within the existing hierarchy of a university may have a large impact on the scope, influence, and effectiveness of sustainability efforts. To better understand alternative structures for instituting university-level sustainability efforts, we investigated sustainability offices at other institutions, both online and through interviews. We interviewed high-level officials at CMU's twelve peer institutions along with the University of Pittsburgh.

As shown in Table 8.1, sustainability offices range in size from 1 to 21 people, with a median of 5. All of our peer institutions have at least one full-time employee, and some of them also rely on (typically paid) student interns. The count of full-time employees does not include student interns. Sustainability offices tend to be in relatively close proximity to the highest level of university leadership, with four offices having one level in the hierarchy between the sustainability director and the university head, seven having two, and one having three. Seven of the thirteen peer institutions place their sustainability offices under the direction of their facilities management group, with the second most common location being under a vice president for administration (sometimes, joint with the provost, combining both academic and administrative foci).

Conversations with peer universities emphasized the breadth of the typical mission for the sustainability office and the importance of working with campus culture rather than against it. Several representatives of these sustainability offices characterized the office's role as centralizing cross-campus sustainability initiatives. Additionally, the sustainability office typically has a part in distributing sustainability-related grants to individuals and groups on campus.

Peer institutions also have sustainability dashboards where they have centralized sustainability resources and information. The nature of the information contained on the sites is summarized in Figure 6.something. Most peer institutions have resources available on water, energy, transportation, waste, buildings, landscape, food, education, research, purchasing, and campus involvement.

Table 8.1 Sustainability Departments in Peer Institutions as of Fall 2018

Institution	**# Full Time Employees**	**Sustainability Department Head Reports to:** ***(# of levels between top level of leadership)***
California Institute of Technology	3	Associate VP for Facilities → VP of Administration → President (2)
Cornell University	21	VP for Facilities and Campus Services → Executive Vice President → President (2)
Duke University	8	Executive Vice President → President (1)
Emory University	4	Provost AND Executive VP for Business Administration → President (1)
Georgia Institute of Technology	3	Associate VP of Institute Planning and Resource Management → Executive VP of Administration and Finance → President (2)
Massachusetts Institute of Technology	8	Executive Vice President → President (1)
Northwestern University	2	VP of Facilities → Executive Vice President → President (2)
Princeton University	6	VP for Facilities → Executive Vice President → President (2)
Rice University	6	Associate VP for Facilities Engineering and Planning → VP of Administration → President (2)
Stanford University	5	Associate VP for Land, Buildings, and Real Estate → VP for Land, Buildings, and Real Estate → President (2)
University of Pennsylvania	4	University Architect → VP of Facilities → Executive Vice President → President (3)
University of Pittsburgh	1	Senior Vice Chancellor of Business and Operations → Chancellor and CEO (1)
Washington University in St. Louis	6	Executive Vice Chancellor for Administration → Chancellor (1)

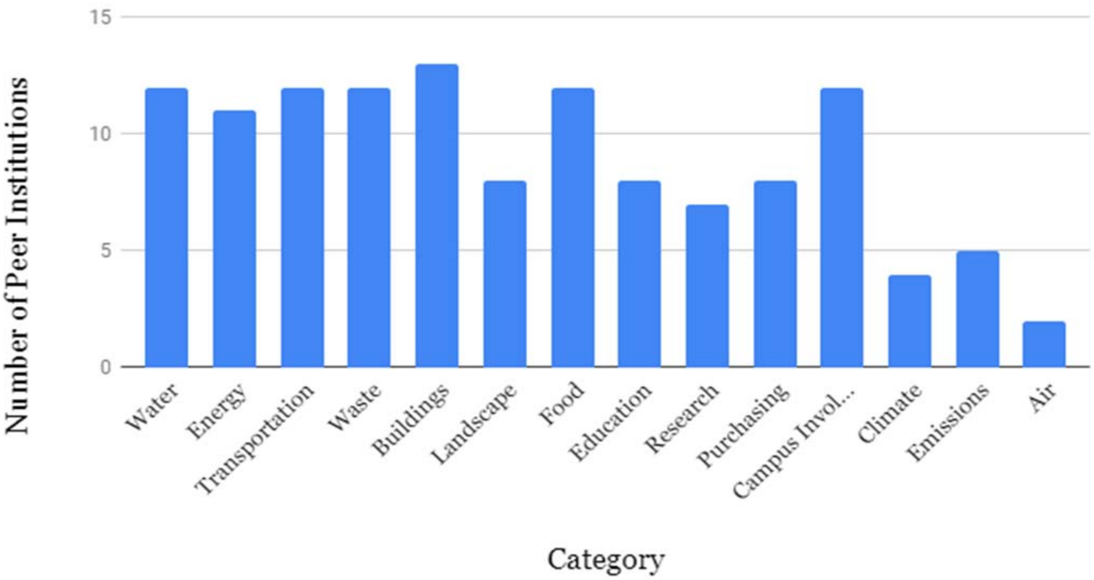

Figure 8.1 Sustainability Dashboard Benchmarking Among Peer Institutions

8.2 Current Organization at Carnegie Mellon

CMU does not presently have a centralized office of sustainability. The Facilities Management Services (FMS) offers some initiatives promoting sustainability on campus, which include installing light occupancy sensors, providing recycling bins, and incorporating environmental language into purchasing contracts. Additionally, FMS has an Environmental Coordinator who is co-chair of the Green Practices Committee (GPC), an initiative that was started in 1999 at the direction of CMU's president. The Green Practices Committee "strive[s] to improve environmental quality, decrease waste and conserve natural resources and energy" and currently holds bi-monthly meetings (CMU GPC, 2018). Members of the GPC include faculty, staff, and students. On the academic side, the Steinbrenner Institute for Environmental Education and Research (SEER), established in 2004, provides support for environmental education and research (CMU SEER, 2016). The SEER provides fellowships and small grants to qualified individuals and projects. The Sustainable Earth Club, run by CMU students, focuses on educating the campus community and campaigning for sustainable options. In addition, a large number of CMU faculty are involved in sustainability-related activities in education and research, as indicated earlier in Chapter 5. However, these diverse activities are not currently coordinated across the campus or even well documented (prior to the data collected for this report).

Regarding university structure, the FMS office, led by the Associate Vice President for Facilities Management and Campus Services (currently Donald Coffelt), is under the Vice President of Operations (currently Rodney McClendon) who reports to the President of the University (currently Farnam Jahanian). Figure 8.2 shows the upper-level management team of CMU. Notably, no upper-level CMU official currently has "Sustainability" in his or her title.

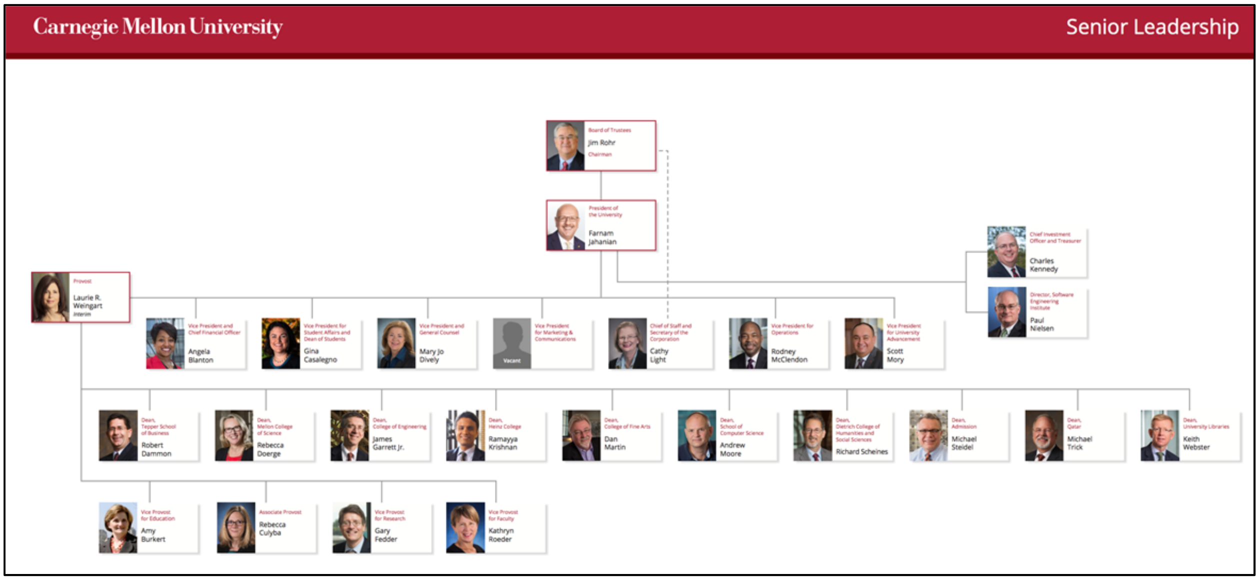

Figure 8.2 Carnegie Mellon Leadership Chart

CMU has an environmental dashboard as well, with information about sustainability groups on the front page and tabs recycling and waste management, energy and water management, campus green design, transportation, getting involved, and university commitments (Environment at CMU 2018). The recycling and waste management tab presents data on recycling and total waste over the years and resources on which materials can be recycled on campus and how. The energy and water management tab has information on campus solar projects, greenhouse gas inventories, conservation, renewable electricity data, and stormwater management. The campus green design tab gives information on current sustainable building goals, sustainable landscapes, green buildings, green roofs, and solar installations. The transportation tab features transportation alternatives. The get involved tab lists many of the different grassroots sustainability efforts that campus community members could join. The university commitments tab lists CMU's sustainability goals and a timeline of environmental activism on campus. This dashboard represents a good start toward increasing sustainability transparency at CMU. The topics highlighted in the sustainability dashboard are on par with peer institutions, but based on the information in this paper, there is vastly more information which could be made available.

8.3 Discussion of Change Agents

A change agent is an individual, office, or department with the ability to accomplish change within the organization. The first category of CMU-relevant change agents includes key players in the upper administration of CMU, such as the VP for Operations, the Provost, and the President. These individuals may have the largest power to instigate change due to their position and access to resources. The second category of change agents includes administrative offices on campus such as the Facilities Management Services (FMS). FMS impacts campus attitudes and initiatives for sustainability, as evidenced by its leadership of the Green Practices Committee and its broad range of campus activities tied to energy and infrastructure. Another category of change agents includes academic departments such as Engineering and Public Policy and Civil and Environmental Engineering. Departmental coursework and research related to sustainability could assist in enacting goals set forth by the future sustainability organizers at Carnegie Mellon.

Finally, individual students, staff, and faculty who value sustainability and wish to take action are also change agents. These individuals can engage the campus community in various ways and also participate in governing bodies such as the Staff Council or Faculty Senate. In the past, students have mobilized amongst themselves to promote sustainability agendas to the campus community and administration. Student organizations such as Sustainable Earth exemplify the potential power and impact of students working together to promote sustainability on campus.

8.4 Proposed Organizational Structure for Carnegie Mellon

All of CMU's peer institutions have a dedicated office of sustainability, many of which have access to substantial human and financial resources. Currently, CMU's sustainability activities are widely dispersed across campus and not well coordinated with one another. Moreover, many of the change agents on campus who want to increase CMU's sustainability efforts do so with limited access to resources and often on their own time given the other priorities of their positions. Based on the above observations, CMU should seriously consider the formation of a dedicated office of sustainability, one that is carefully designed to work within the context and constraints of the institution. By coordinating campus-wide sustainability efforts, new efficiencies and scale-economies can be realized in CMU's sustainability efforts. Moreover, having a high-level representative of sustainability in the administrative hierarchy will ensure that key decisions take into account their implications for sustainability, and by doing so embrace the high-level ideals promoted as part of CMU's vision, mission, and strategic plans. Finally, such an office can likely garner new resources in its activities, allow current efforts to be better leveraged and enhanced.

8.4.1 Distribution of Roles

While the final details of an office of sustainability will need to be carefully considered, here we describe a "median" (among peers) office in order to evaluate that office's potential cost. Such an office could have a director, and a few other full-time employees, such as, an Assistant Director, Programs Director, and Administrative Assistant. This structure would place CMU around the median size of sustainability offices at peer institutions, while still allowing the needed flexibility for future growth. Table 8.2 describes the potential responsibilities associated with the roles of an office of this type at other universities. The office could use these traditional office roles or could develop a unique office structure to fit CMU's unique campus environment.

Table 8.2 “Average” Office Positions among Peer Institutions

Title	Responsibilities
Director	Oversees all sustainability actions and identifies needs
Assistant Director	Assists the Director in overseeing actions and identifying needs
Programs Director	Oversees projects (i.e. initiatives, grants)
Administrative Assistant	Supports office functions

8.4.2 Office Hierarchy

Although most of our peer institutions house their sustainability office in the operations unit of the campus, our vision for Carnegie Mellon is a campus-wide office that materially includes the educational and research activities of the university as well as campus operations. Thus, one potential location for this new office would be to place it so that it is jointly owned by both the administrative and educational portions of the university. Having this office jointly under the Provost and VP for Operations might meet these various criteria. Alternatively, the office could be placed under the President’s Chief of Staff.

8.4.3 Cost and Funding

Estimating the cost of establishing this new office was beyond the scope of the present study, although we did attempt to look at other recently-established offices on campus such as the Title IX Initiatives office directed by Holly Hippensteel, which includes four full-time employees. However, a sustainability office could require a higher level of funding given the scope of its mission. That funding, however, along with many activities of the office, might also be funded, either wholly or in part, via projects tied to its mission. For example, cost savings from new sustainability efforts could be funneled back into the program, or receipts from a campus-wide sustainability “tax” (perhaps tied to carbon generation, thereby accomplishing multiple goals) could be used to help support the office. Further study is needed to better estimate the costs, funding mechanisms, and economic payoffs of a new Office of Sustainability at Carnegie Mellon University.

8.5 Chapter 8 References

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Chapter 9: Conclusions and Recommendations

9.1 Summary of Conclusions

We expanded on a previous analysis of CMU's carbon footprint by providing a more comprehensive analysis of CMU's environmental impacts beyond carbon emissions, incorporating non-environmental aspects of sustainability, and analyzing and recommending a more general set of actions to enhance CMU's sustainability. Our objectives were to define sustainability in the context of all university activities, including education, research and campus operations; to characterize the current state of activities and needs related to sustainability; and to suggest sustainability goals for these various activities at Carnegie Mellon. Our analysis evaluated the sustainability of the following areas: Campus Buildings, Water and Waste Management, Transportation, Education and Research, and Social and Financial Dimensions.

We evaluated the sustainability of CMU's buildings based on their certifications, standards, energy use, and emissions. We first found that the "Design and Construction Standards" for the university are outdated with respect to modern sustainability goals and objectives for university buildings. We also found that CMU has signed on to the Pittsburgh 2030 District Goals, which aim to significantly reduce energy consumption, water use, and transportation emissions. However, we found no plan or program to achieve those goals. In addition, we found that while new buildings are successfully meeting LEED Silver standards, they are under-performing in the LEED categories of 'water efficiency' and 'energy and atmosphere' relative to other LEED categories, based on the percentage of total points available in each category. Furthermore, we observed that electricity and steam use from buildings are rising. We suggest that the university improves its metering of electricity and steam use by and within campus buildings in order to identify best opportunities for reducing energy use and associated emissions. We also recommend that the university again investigate implementing a cogeneration plant at CMU to help reduce emissions (and costs) from electricity and steam usage.

We evaluated the sustainability of CMU's water use and waste generation based on the current university's management of water, solid waste, and hazardous waste. We found that water use is poorly tracked in most academic buildings. Furthermore, we identified that the current water use index falls far short of the 2030 District goals. In regard to campus waste, we found that solid waste recycling is increasing, but post-consumption composting is poor. Lastly, we found that improving the campus purchasing system to track the flow of purchased materials could help improve solid waste management.

We evaluated the sustainability of CMU's transportation based on the goals of lowering greenhouse gas emissions, conserving resources, and facilitating mobility. We found that indirect emissions from CMU-related travel are significant, especially from air travel. In addition, we found that total air travel emissions vary greatly among colleges and other university units. In regard to minimizing the number of people who commute by driving, we found that the existing carpool program is underutilized and not effectively reducing the number of commuter cars on campus. Lastly, we found that the existing bike infrastructure on campus is underutilized and bike education is lacking in the community. Measures for addressing these issues are discussed later under recommendations.

We also analyzed sustainability-related educational and research activities at CMU. The university currently has programs that cover a wide range of sustainability focus areas. However, based on the frequency of sustainability-related keywords in university programs, we found that CMU's sustainability-related courses are concentrated in just a few focus areas. Thus, CMU could potentially expand upon the sustainability focus areas covered by educational programs. However, through interviews with key faculty members, we found that there has been low interest in sustainability education among faculty and students. There have been ongoing efforts to foster interest by transitioning from three separate minors to a new centralized minor in environmental and sustainability studies and implementing sustainability modules into courses. Lastly, through a keyword search of the university database on funded research projects, we found that sustainability research has been concentrated in few colleges and a few specific focus areas. While such concentrations are reasonable given the need to have a critical mass of researchers, it might suggest that funding in this area is not being fully pursued. We suggest exploring the "supply-side" of grants to determine whether there are areas where funders are focusing their resources in areas that match with CMU's research strengths. The CMU Green Practices Committee also just conducted a keyword analysis on sustainability-related published research. A potential area of future work could involve studying how this analysis compares with our sponsored research analysis.

To examine societal elements of sustainability along with environmental sustainability, we also evaluated several dimensions of CMU's social and behavioral sustainability. The key elements of social sustainability included quality of life, equity, diversity, interconnectedness or social cohesion, and democracy and governance, while the key elements of behavioral sustainability focused on the environmental consequences of individual behavior. First, we saw that there is currently a limited amount of information on social sustainability. Therefore, in order to promote social sustainability, more data is needed. Currently, CMU provides a number of opportunities to students, staff, and faculty to achieve important social sustainability goals such as fulfilling employment. However, other areas such as diversity and social cohesion need improvement. Compared to most of our peer institutions, CMU also has a lower endowment per student. However, the university seems to perform better on other metrics of financial sustainability. Ultimately, we suggest the university assess investment strategies with regard to sustainability and seek opportunities for improvement.

Organizationally, we found that the current sustainability structure of CMU is highly decentralized and fragmented. There are separate groups and individuals on campus working independently on particular aspects of sustainability with no coordination from the top. There are currently sustainability goals for the university, but there is not currently anyone in the university administrative structure who is accountable for reaching these goals. With the structure as scattered as it is, small-scale goals can be achieved, but university-wide goals tend to fall through the cracks.

9.2 Recommendations of this Study

Current sustainability efforts at CMU, because of their fragmented and decentralized nature, have not sufficiently advanced sustainable policies to make CMU a visible leader in the field of sustainability. To achieve this goal, the campus would need to prioritize and coordinate efforts across campus, which is difficult in the absence of a centralized sustainability office and high-level leadership. Establishing more specific university-wide sustainability goals and appointing individuals to ensure community follow-through would help move the university forward in this direction. Based on the analysis in this report, we recommend the university create a high-level sustainability office that can facilitate coordination among different groups and achieve campus sustainability through the following three activities.

First, the office would be able to keep better records of relevant sustainability metrics. In some cases, this would involve expanding the coverage of existing data collection. In other cases, we would suggest that the office initiate data collection that has not previously been compiled at CMU, or not at the campus level. Some of these metrics include building energy and water consumption, current state of rainwater collection systems, purchases and waste production from different campus units, and social sustainability factors including quality of life and equity.

Second, the office would be able to better support academic departments and other campus units in implementing changes to enhance sustainability. For example, to improve sustainability in campus buildings, the office could assist FMS to improve data acquisition on building water and energy use, and to identify and implement cost-saving measures that support sustainability goals, such as the Pittsburgh 2030 District goals. To track and reduce solid wastes, the office could work with the procurement office to upgrade the campus accounting system to collect needed data on purchased materials. To reduce food waste, more composting stations are needed along with compost education on campus. To progress towards more sustainable transportation, a carbon offset program might be implemented for university business air travel. Meanwhile, developing carpool programs and expanding bicycling parking would help reduce the current impacts of daily commuting. A sustainability office could facilitate such projects by assisting a variety of campus personnel and monitoring progress.

Third, the office could improve sustainability-related goal-setting for the university, and better perform analyses on different available options. The establishment of an office would elevate the sustainability conversation at CMU, making it a higher priority. More available data, implementation potential, and sustainability expertise will help CMU innovate in this space and become a leader in sustainability. Research in behavior and education can also help improve sustainability awareness within the campus community and better foster a culture of sustainable behavior. With additional metrics and projects there will be greater potential to integrate campus practices with ongoing research and educational efforts.

9.2.1 Organizational Structure of Office

We recommend that the proposed sustainability office be jointly sponsored by the Office of the Provost and the Division of Operations. The Division of Operations contains Facilities Management Services (FMS) and Campus Design and Facility Development (CDFD), both of which play a leading role in establishing and promoting sustainability metrics across the university, and in collecting the data necessary to monitor and track progress. FMS and CDFD, along with the sustainability office, could thus help establish sustainability goals and standards across campus.

The provost is the chief academic officer of the university, so we propose that the provost’s office be actively and prominently involved in campus leadership on sustainability. One aspect of that leadership should be to increase the depth and breadth of sustainability activities and expertise on campus, both by attracting expert faculty and encouraging and supporting sustainability research and education.

Most of our peer institutions have created a central sustainability office with the traditional structure of a director, assistant director, program director and administrative assistant as the basic staffing. Adopting that type of structure would put us on par with peer institutions. But a more board-like structure could help CMU bridge the gaps between different departments, both academic and operational. CMU needs an office that will be effective at bringing together independent entities on campus.

Based on these needs, the office we envision would have a director and a minimum staff of four people, for a total of five full time employees. The director would lead the office as well as help develop goals and sustainability standards for the university. Staff members of the office would act as liaisons with specific sets of people in the campus community. Among the four staff members, a facilities liaison could work with facilities management to collect and maintain sustainability information about the campus and expand data collection where needed. An education liaison could help increase the sustainability education available to the campus community through academic courses, degree programs, and other initiatives such as the student and faculty orientation programs. A research and entrepreneurship coordinator could help connect the campus community to resources for both research and entrepreneurship purposes. Finally, a living laboratory coordinator could help bring new sustainability initiatives to the campus community and help collect data on the outcomes. An advisory committee of other relevant campus units would support the central office and its director. This structure would work naturally and synergistically with the current decentralized system to help bridge gaps, foster communication, and achieve higher-level goals for the university. Office members in these positions would be able to elevate the efforts of separate groups who deal in sustainability issues while collaborating to promote university-wide sustainability goals across campus.

9.2.2 Justifications for an Office

According to Carnegie Mellon's Strategic Plan 2025, one of our core values is "sustainability, reflected in our shared commitment to lead by example in preserving and protecting our natural resources, and in our approach to responsible financial planning" (CMU Board of Trustees 2018). Sustainability is therefore already a part of the university's vision. Establishing a high-level Office of Sustainability would operationalize this "core value" and demonstrate further commitment. Thus, while the strategic plan includes sustainability, there is an absence of high-level leadership. In practice, sustainability activities on campus are extremely decentralized, with a number of individuals and groups operating independently and voluntarily to pursue a more sustainable CMU. A centralized sustainability office would allow the university to plan more comprehensive projects, realize greater results, and maintain accountability.

More focused efforts in the area of sustainability would help the university promote many of the goals and strategic recommendations made by the Board of Trustees in its *Strategic Plan 2025* (see Table 9.1 below). For example, a sustainability office would be a space to help spark collaboration across disciplines, and allow students, staff and faculty to work together on projects. This could also provide an avenue for apprenticeship and mentoring relationships across departments. Interdisciplinary collaboration and project implementation would help develop skills and knowledge among participants, while simultaneously creating a cross-department community space and improving social sustainability.

Table 9.1 Strategic recommendations of the Strategic Plan 2025 (CMU Board of Trustees 2018)

Apprenticeship and Mentorship	The Innovation Corridor
Catalyzing Interdisciplinary Encounters	Innovation in Teaching
Collaborative Culture and Climate	Innovative Experiences for Students
Crafting an International Strategy	An Integrated Graduate Education
An "Ecology" of Infrastructure and Support	Learning Science
Engaging Alumni	Professional Development for Staff
Foundational Research and Creativity	Recruiting and Retaining World-Class Faculty
Grand Challenges	Scholarships and Fellowships
Holistic Health and Wellness	Shaping the Research Agenda
Incubating Emerging Areas	Support for Entrepreneurial Activities

A sustainability office would also help CMU attract talent. Creating an office would demonstrate serious commitment from CMU to promoting sustainability, which could attract more professionals committed to tenets of sustainability. A sustainability office could also help the university acquire new funding by connecting donor sources with research activities or campus projects. The office would also be able to aggregate information about sustainability related scholarships and fellowships to make available for students, staff, and faculty.

A sustainability office would also help create sustainable standards for new construction. Building standards have not been updated at CMU since 1998. More effective standards could include, for example, information about sourcing of building materials, specifications for energy use and targeted emissions, and LEED certifications, all of which could ultimately improve CMU's sustainability and promote innovation in campus construction.

A sustainability office also would help improve educational outcomes by incorporating sustainability into the CMU experience. Under the current structure, sustainability education in the CMU curriculum is highly fragmented and done on an individual department or college basis. This is not efficient because sustainability is interdisciplinary—it requires collaboration across departments. This type of cooperation would be best facilitated by a centralized high-level office.

Carnegie Mellon is focused on innovation and fostering a cutting-edge academic community. There are thirteen universities that CMU considers to be its peers, and twelve of these thirteen universities have a sustainability office. Therefore, in terms of organized campus efforts on sustainability, CMU lags behind.

A sustainability office is in line with the goals that CMU has already set forth. It would help the university concentrate resources to implement the established strategic plan. The evidence in this report demonstrates why a centralized sustainability office would be advantageous to the campus community and future university development. We believe the university would do well to prioritize this initiative, and would realize a range of benefits including a cleaner environment, economic gain, and expanded academic options. As CMU continues to grow, the potential advantages of creating an office of sustainability only increase.

9.3 Chapter 9 References

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Appendices

This section includes some of the data used in analyses in previous chapters. The first digit of the appendix number denotes the chapter where these data were used or developed.

Appendix 2-1: Keywords in Building Standards

The following appendix displays the keywords that were searched for when completing building standard comparison.

Keyword
Sustainable
Sustainability
Emissions
Efficient
Recycling
LEED
Environmental
Green
Waste

Appendix 2-2: Peer Institutions and Document Length

The following appendix lists the peer institutions that building standard analysis was completed on. The appendix also contains the length of the compiled documents for each university.

University	**Page Count**
California Institute of Technology	364
Duke University	583
Emory University	310
Georgia Institute of Technology	348
Massachusetts Institute of Technology	581
Northwestern University	510
University of Pennsylvania	496
Rice University	141
Stanford University	1,777
Washington University in St. Louis	402

Appendix 2-3: LEED Certification by Net Square Footage

This appendix contains data related to the percentage of net square footage that is LEED certified in Carnegie Mellon University buildings.

Total Gold Square Footage	**Total Silver Square Footage**	**LEED Certified Buildings**	**Awaiting LEED Certification**	**Total LEED Square Footage**	**Total Square Footage at Carnegie Mellon**	**Total Non-LEED Square Footage**
361,800	295,710	11,400	662,000	1,330,910	5,179,186	3,848,276
Percentage of LEED Buildings by Square Footage	**Percentage of Non-LEED Square Footage**	**Percentage of Total Certified LEED Gold Square Footage**	**Percentage of Total Certified LEED Silver Square Footage**	**Percentage of Total Certified LEED Square Footage**	**Percentage of Total Square Footage Awaiting LEED Certification**	
25.7%	74.3%	7.0%	5.7%	0.2%	12.8%	

Building	Year Certified	Square Footage
LEED Gold		
Mehrabian Collaborative Innovation Center	2005	136,000
Carnegie Mellon Café	2008	9,400
GSIA West Entry Addition	2010	5,000
Gates and Hillman Centers	2011	208,000
Hamburg Hall Auditorium	2017	3,400
LEED Silver		
Stever House	2003	71,140
Henderson House	2004	15,770
300 South Craig Street	2007	68,000

407 South Craig Street	2007	12,000
Porter Hall 100	2009	6,800
Doherty Hall Phase II	2010	91,200
Mellon Institute Renovations	2012	12,000
GSIA First Floor	2013	7,800
Doherty Hall Renovation MSE	2015	11,000
LEED Certified		
Posner Center	2005	11,400
LEED Registered (Awaiting Rating by USGBC)		
Scott Hall		107,000
Cohon University Center Addition		68,000
Hamerschlag Maker Wing		32,000
4721 Fifth Avenue		24,000
Tepper Building		300,000
Tata Consultancy Services Building		50,000
Ansys Building		25,000
Almono		56,000
LEED Certified Total (All Ratings)		668,910
LEED Registered Total		662,000

Fiscal Year	Net Usable Square Feet
1990	3,564,793
1991	3,453,918
1992	3,306,193
1993	3,373,530
1994	3,382,777
1995	3,426,743
1996	3,447,904
1997	3,627,256
1998	3,881,591
1999	3,892,439
2000	3,957,237
2001	4,121,863
2002	4,234,338
2003	4,217,146
2004	4,406,153
2005	4,510,270
2006	4,679,157
2007	4,740,770
2008	4,724,720
2009	4,752,084
2010	4,754,805
2011	4,986,790
2012	5,002,209
2013	5,115,149

2014	5,147,812
2015	5,222,854
2016	5,174,236
2017	5,365,986
2018	5,625,986
2019	5,658,486
2020	5,993,236
2021	6,071,236
2022	6,071,236

Appendix 2-4: LEED Scorecards for Buildings & Renovations at Carnegie Mellon University

0010003760, PITTSBURGH, PA

RESNIK DINING HALL

LEED ID+C: Commercial Interiors (v2.0) — GOLD, AWARDED DEC 2008

SUSTAINABLE SITES		AWARDED: 4 / 7
SSc1	Site selection	0 / 3
SSc2	Development density and community connectivity	1 / 1
SSc3.1	Alternative transportation - public transportation access	1 / 1
SSc3.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc3.3	Alternative transportation - parking availability	1 / 1

WATER EFFICIENCY		AWARDED: 0 / 2
WEc1.1	Water use reduction - 20% reduction	0 / 1
WEc1.2	Water use reduction - 30% reduction	0 / 1

ENERGY & ATMOSPHERE		AWARDED: 2 / 12
EAc1.1	Optimize energy performance - lighting power	0 / 3
EAc1.2	Optimize energy performance - lighting controls	1 / 1
EAc1.3	Optimize energy performance - HVAC	0 / 2
EAc1.4	Optimize energy performance - equipment and appliances	0 / 2
EAc2	Enhanced commissioning	0 / 1
EAc3	Energy use, measurement and payment accountability	0 / 2
EAc4	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 10 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain 40% of interior non-structural components	1 / 1
MRc1.3	Building reuse - maintain 60% of interior non-structural components	1 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	1 / 1
MRc3.1	Resource reuse - 5%	0 / 1
MRc3.2	Resource reuse - 10%	0 / 1
MRc3.3	Resource reuse - 30% furniture and furnishings	1 / 1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 10% extracted and manufactured regionally	0 / 1
MRc6	Rapidly renewable materials	1 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 14 / 17
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and laminate adhesives	1 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	0 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	0 / 1
EQc6.2	Controllability of systems - temperature and ventilation	1 / 1
EQc7.1	Thermal comfort - compliance	1 / 1
EQc7.2	Thermal comfort - monitoring	1 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	1 / 1
EQc8.2	Daylight and views - daylight 90% of spaces	1 / 1
EQc8.3	Daylight and views - views for 90% of seated spaces	1 / 1

INNOVATION		AWARDED: 3 / 5
IDc1	Innovation in design	2 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	33 / 57

0010034321, Pittsburgh, PA

CMU Doherty Hall Phase II

LEED ID+C: Commercial Interiors (v2.0)

SILVER, AWARDED MAR 2010

SUSTAINABLE SITES		AWARDED: 4 / 7
SSc1	Site selection	1 / 3
SSc2	Development density and community connectivity	1 / 1
SSc3.1	Alternative transportation - public transportation access	1 / 1
SSc3.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc3.3	Alternative transportation - parking availability	0 / 1

WATER EFFICIENCY		AWARDED: 0 / 2
WEc1.1	Water use reduction - 20% reduction	0 / 1
WEc1.2	Water use reduction - 30% reduction	0 / 1

ENERGY & ATMOSPHERE		AWARDED: 3 / 12
EAc1.1	Optimize energy performance - lighting power	0 / 3
EAc1.2	Optimize energy performance - lighting controls	0 / 1
EAc1.3	Optimize energy performance - HVAC	0 / 2
EAc1.4	Optimize energy performance - equipment and appliances	0 / 2
EAc2	Enhanced commissioning	1 / 1
EAc3	Energy use, measurement and payment accountability	1 / 2
EAc4	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 8 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain 40% of interior non-structural components	1 / 1
MRc1.3	Building reuse - maintain 60% of interior non-structural components	0 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	1 / 1
MRc3.1	Resource reuse - 5%	0 / 1
MRc3.2	Resource reuse - 10%	0 / 1
MRc3.3	Resource reuse - 30% furniture and furnishings	0 / 1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 10% extracted and manufactured regionally	1 / 1
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 8 / 17
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	0 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and laminate adhesives	0 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	0 / 1
EQc5	Indoor chemical and pollutant source control	0 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - temperature and ventilation	1 / 1
EQc7.1	Thermal comfort - compliance	1 / 1
EQc7.2	Thermal comfort - monitoring	0 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	0 / 1
EQc8.2	Daylight and views - daylight 90% of spaces	0 / 1
EQc8.3	Daylight and views - views for 90% of seated spaces	0 / 1

INNOVATION		AWARDED: 5 / 5
IDc1	Innovation in design	4 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	28 / 57

1000018800, Pittsburgh, PA

CMU Doherty Hall Renovation

LEED ID+C: Commercial Interiors (v2009) SILVER, AWARDED MAR 2016

SUSTAINABLE SITES		AWARDED: 18 / 21
SSc1	Site selection	4 / 5
SSc2	Development density and community connectivity	6 / 6
SSc3.1	Alternative transportation - public transportation access	6 / 6
SSc3.2	Alternative transportation - bicycle storage and changing rooms	0 / 2
SSc3.3	Alternative transportation - parking availability	2 / 2

WATER EFFICIENCY		AWARDED: 0 / 11
WEc1	Water use reduction	0 / 11

ENERGY & ATMOSPHERE		AWARDED: 16 / 37
EAc1.1	Optimize energy performance - lighting power	2 / 5
EAc1.2	Optimize energy performance - lighting controls	2 / 3
EAc1.3	Optimize energy performance - HVAC	5 / 10
EAc1.4	Optimize energy performance - equipment and appliances	2 / 4
EAc2	Enhanced commissioning	5 / 5
EAc3	Measurement and verification	0 / 5
EAc4	Green power	0 / 5

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 2
MRc2	Construction waste Mgmt	2 / 2
MRc3.1	Materials reuse	0 / 2
MRc3.2	Materials reuse - furniture and furnishings	0 / 1
MRc4	Recycled content	1 / 2
MRc5	Regional materials	2 / 2
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 6 / 25
EQc1	Outdoor air delivery monitoring	0 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	0 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	0 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	0 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - thermal comfort	0 / 1
EQc7.1	Thermal comfort - design	0 / 1
EQc7.2	Thermal comfort - verification	0 / 1
EQc8.1	Daylight and views - daylight	0 / 2
EQc8.2	Daylight and views - views	0 / 1
EQpc123	Designing with Nature, Biophilic Design for the Indoor Environment	REQUIRED
EQpc124	Performance-based IAQ design and assessment	REQUIRED

INNOVATION		AWARDED: 2 / 6
IDc1	Innovation in design	1 / 5
IDc2	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY		AWARDED: 2 / 4
EQc2	Increased ventilation	1 / 1
MRc3.1	Materials reuse	0 / 1
MRc5	Regional materials	1 / 1
SSc1	Site selection	0 / 1

TOTAL	50 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

0010003447, PITTSBURGH, PA

School of Computer Science Complex

LEED BD+C: New Construction (v2.1)

GOLD, AWARDED OCT 2011

SUSTAINABLE SITES		AWARDED: 12 / 14
SSc1	Site selection	1 / 1
SSc2	Development density	1 / 1
SSc3	Brownfield redevelopment	1 / 1
SSc4.1	Alternative transportation - public transportation access	1 / 1
SSc4.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc4.3	Alternative transportation - alternative fuel vehicles	0 / 1
SSc4.4	Alternative transportation - parking capacity	0 / 1
SSc5.1	Reduced site disturbance - protect or restore open space	1 / 1
SSc5.2	Reduced site disturbance - development footprint	1 / 1
SSc6.1	Stormwater Mgmt - rate and quantity	1 / 1
SSc6.2	Stormwater Mgmt - treatment	1 / 1
SSc7.1	Heat island effect - non-roof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 2 / 5
WEc1.1	Water efficient landscaping - reduce by 50%	0 / 1
WEc1.2	Water efficient landscaping - no potable water use or no irrigation	0 / 1
WEc2	Innovative wastewater technologies	0 / 1
WEc3.1	Water use reduction - 20% reduction	1 / 1
WEc3.2	Water use reduction - 30% reduction	1 / 1

ENERGY & ATMOSPHERE		AWARDED: 3 / 17
EAc1	Optimize energy performance	0 / 10
EAc2.1	Renewable energy - 5%	0 / 1
EAc2.2	Renewable energy - 10%	0 / 1
EAc2.3	Renewable energy - 20%	0 / 1
EAc3	Additional commissioning	0 / 1
EAc4	Ozone protection	1 / 1
EAc5	Measurement and verification	1 / 1
EAc6	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 7 / 13
MRc1.1	Building reuse - maintain 75% of existing walls, floors and roof	0 / 1
MRc1.2	Building reuse - maintain 100% of existing walls, floors and roof	0 / 1
MRc1.3	Building reuse - maintain 100% of shell/structure and 50% of non-shell/non-structure	0 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	1 / 1
MRc3.1	Resource reuse - 5%	0 / 1

MATERIAL & RESOURCES		CONTINUED
MRc3.2	Resource reuse - 10%	0 / 1
MRc4.1	Recycled content - 5% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 50% extracted regionally	1 / 1
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	1 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 12 / 15
EQc1	Carbon dioxide (CO2) monitoring	1 / 1
EQc2	Ventilation effectiveness	0 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - after construction	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet	1 / 1
EQc4.4	Low-emitting materials - composite wood	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - perimeter spaces	1 / 1
EQc6.2	Controllability of systems - non-perimeter spaces	1 / 1
EQc7.1	Thermal comfort - compliance with ASHRAE 55-1992	1 / 1
EQc7.2	Thermal comfort - permanent monitoring system	1 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	0 / 1
EQc8.2	Daylight and views - views for 90% of spaces	0 / 1

INNOVATION		AWARDED: 4 / 5
IDc1	Innovation in design	3 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	40 / 69

0010300745, Pittsburgh, PA

GSIA 1st Floor Renovation

LEED ID+C: Commercial Interiors (v2.0)

SILVER, AWARDED AUG 2013

SUSTAINABLE SITES		AWARDED: 5 / 7
SSc1	Site selection	1 / 3
SSc2	Development density and community connectivity	1 / 1
SSc3.1	Alternative transportation - public transportation access	1 / 1
SSc3.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc3.3	Alternative transportation - parking availability	1 / 1

WATER EFFICIENCY		AWARDED: 2 / 2
WEc1.1	Water use reduction - 20% reduction	1 / 1
WEc1.2	Water use reduction - 30% reduction	1 / 1

ENERGY & ATMOSPHERE		AWARDED: 3 / 12
EAc1.1	Optimize energy performance - lighting power	0 / 3
EAc1.2	Optimize energy performance - lighting controls	0 / 1
EAc1.3	Optimize energy performance - HVAC	0 / 2
EAc1.4	Optimize energy performance - equipment and appliances	2 / 2
EAc2	Enhanced commissioning	0 / 1
EAc3	Energy use, measurement and payment accountability	0 / 2
EAc4	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain 40% of interior non-structural components	0 / 1
MRc1.3	Building reuse - maintain 60% of interior non-structural components	0 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	1 / 1
MRc3.1	Resource reuse - 5%	0 / 1
MRc3.2	Resource reuse - 10%	0 / 1
MRc3.3	Resource reuse - 30% furniture and furnishings	1 / 1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	0 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 10% extracted and manufactured regionally	0 / 1
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 11 / 17
EQc1	Outdoor air delivery monitoring	0 / 1
EQc2	Increased ventilation	0 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and laminate adhesives	1 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	0 / 1
EQc5	Indoor chemical and pollutant source control	0 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - temperature and ventilation	1 / 1
EQc7.1	Thermal comfort - compliance	1 / 1
EQc7.2	Thermal comfort - monitoring	0 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	1 / 1
EQc8.2	Daylight and views - daylight 90% of spaces	1 / 1
EQc8.3	Daylight and views - views for 90% of seated spaces	1 / 1

INNOVATION		AWARDED: 4 / 5
IDc1	Innovation in design	3 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	31 / 57

0010300754, Pittsburgh, PA

GSIA West Entry Addition

LEED ID+C: Commercial Interiors (v2.0)

GOLD, AWARDED JUL 2010

SUSTAINABLE SITES		AWARDED: 6 / 7
SSc1	Site selection	2 / 3
SSc2	Development density and community connectivity	1 / 1
SSc3.1	Alternative transportation - public transportation access	1 / 1
SSc3.2	Alternative transportation - bicycle storage and changing rooms	1 / 1
SSc3.3	Alternative transportation - parking availability	1 / 1

WATER EFFICIENCY		AWARDED: 0 / 2
WEc1.1	Water use reduction - 20% reduction	0 / 1
WEc1.2	Water use reduction - 30% reduction	0 / 1

ENERGY & ATMOSPHERE		AWARDED: 4 / 12
EAc1.1	Optimize energy performance - lighting power	0 / 3
EAc1.2	Optimize energy performance - lighting controls	0 / 1
EAc1.3	Optimize energy performance - HVAC	0 / 2
EAc1.4	Optimize energy performance - equipment and appliances	2 / 2
EAc2	Enhanced commissioning	1 / 1
EAc3	Energy use, measurement and payment accountability	0 / 2
EAc4	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 5 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain 40% of interior non-structural components	0 / 1
MRc1.3	Building reuse - maintain 60% of interior non-structural components	0 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	0 / 1
MRc3.1	Resource reuse - 5%	0 / 1
MRc3.2	Resource reuse - 10%	0 / 1
MRc3.3	Resource reuse - 30% furniture and furnishings	0 / 1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	0 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 10% extracted and manufactured regionally	1 / 1
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 14 / 17
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and laminate adhesives	1 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	0 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - temperature and ventilation	1 / 1
EQc7.1	Thermal comfort - compliance	1 / 1
EQc7.2	Thermal comfort - monitoring	1 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	0 / 1
EQc8.2	Daylight and views - daylight 90% of spaces	0 / 1
EQc8.3	Daylight and views - views for 90% of seated spaces	1 / 1

INNOVATION		AWARDED: 5 / 5
IDc1	Innovation in design	4 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	34 / 57

1000048574, Pittsburgh, PA

CMU Heinz College Lecture Hall Addition

LEED BD+C: New Construction (v2009)

GOLD, AWARDED AUG 2016

SUSTAINABLE SITES		AWARDED: 16 / 26
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	5 / 5
SSc3	Brownfield redevelopment	0 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	0 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	0 / 3
SSc4.4	Alternative transportation - parking capacity	2 / 2
SSc5.1	Site development - protect or restore habitat	0 / 1
SSc5.2	Site development - maximize open space	0 / 1
SSc6.1	Stormwater design - quantity control	0 / 1
SSc6.2	Stormwater design - quality control	0 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	0 / 1
SSc8	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 6 / 10
WEc1	Water efficient landscaping	2 / 4
WEc2	Innovative wastewater technologies	0 / 2
WEc3	Water use reduction	4 / 4

ENERGY & ATMOSPHERE		AWARDED: 15 / 35
EAc1	Optimize energy performance	10 / 19
EAc2	On-site renewable energy	0 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	0 / 2
EAc5	Measurement and verification	1 / 3
EAc6	Green power	2 / 2

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	1 / 2
MRc5	Regional materials	2 / 2

MATERIAL & RESOURCES		CONTINUED
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	1 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 12 / 23
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - thermal comfort	1 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	0 / 1
EQc8.2	Daylight and views - views	0 / 1
EQpc123	Designing with Nature, Biophilic Design for the Indoor Environment	REQUIRED
EQpc124	Performance-based IAQ design and assessment	REQUIRED

INNOVATION		AWARDED: 6 / 6
IDc1	Innovation in design	5 / 5
IDc2	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY		AWARDED: 1 / 4
EQc2	Increased ventilation	1 / 1
SSc6.1	Stormwater design - quantity control	0 / 1
SSc6.2	Stormwater design - quality control	0 / 1
SSc7.2	Heat island effect - roof	0 / 1

TOTAL 62 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

0010299402, Pittsburgh, PA

Porter Hall 100, Carnegie Mellon Univ.

LEED ID+C: Commercial Interiors (v2.0)

SILVER, AWARDED OCT 2009

SUSTAINABLE SITES		AWARDED: 2 / 7
SSc1	Site selection	0 / 3
SSc2	Development density and community connectivity	1 / 1
SSc3.1	Alternative transportation - public transportation access	1 / 1
SSc3.2	Alternative transportation - bicycle storage and changing rooms	0 / 1
SSc3.3	Alternative transportation - parking availability	0 / 1

WATER EFFICIENCY		AWARDED: 0 / 2
WEc1.1	Water use reduction - 20% reduction	0 / 1
WEc1.2	Water use reduction - 30% reduction	0 / 1

ENERGY & ATMOSPHERE		AWARDED: 3 / 12
EAc1.1	Optimize energy performance - lighting power	1 / 3
EAc1.2	Optimize energy performance - lighting controls	0 / 1
EAc1.3	Optimize energy performance - HVAC	0 / 2
EAc1.4	Optimize energy performance - equipment and appliances	1 / 2
EAc2	Enhanced commissioning	0 / 1
EAc3	Energy use, measurement and payment accountability	0 / 2
EAc4	Green power	1 / 1

MATERIAL & RESOURCES		AWARDED: 5 / 14
MRc1.1	Tenant space - long-term commitment	1 / 1
MRc1.2	Building reuse - maintain 40% of interior non-structural components	0 / 1
MRc1.3	Building reuse - maintain 60% of interior non-structural components	0 / 1
MRc2.1	Construction waste Mgmt - divert 50% from landfill	1 / 1
MRc2.2	Construction waste Mgmt - divert 75% from landfill	0 / 1
MRc3.1	Resource reuse - 5%	0 / 1
MRc3.2	Resource reuse - 10%	0 / 1
MRc3.3	Resource reuse - 30% furniture and furnishings	0 / 1
MRc4.1	Recycled content - 10% (post-consumer + 1/2 pre-consumer)	1 / 1
MRc4.2	Recycled content - 20% (post-consumer + 1/2 pre-consumer)	0 / 1
MRc5.1	Regional materials - 20% manufactured regionally	1 / 1
MRc5.2	Regional materials - 10% extracted and manufactured regionally	1 / 1
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 12 / 17
EQc1	Outdoor air delivery monitoring	0 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	1 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - carpet systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and laminate adhesives	1 / 1
EQc4.5	Low-emitting materials - systems furniture and seating	1 / 1
EQc5	Indoor chemical and pollutant source control	0 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - temperature and ventilation	1 / 1
EQc7.1	Thermal comfort - compliance	1 / 1
EQc7.2	Thermal comfort - monitoring	0 / 1
EQc8.1	Daylight and views - daylight 75% of spaces	0 / 1
EQc8.2	Daylight and views - daylight 90% of spaces	0 / 1
EQc8.3	Daylight and views - views for 90% of seated spaces	1 / 1

INNOVATION		AWARDED: 5 / 5
IDc1	Innovation in design	4 / 4
IDc2	LEED Accredited Professional	1 / 1

TOTAL	27 / 57

1000020222, Pittsburgh, PA

Scott Hall

LEED BD+C: New Construction (v2009)

GOLD, AWARDED OCT 2017

SUSTAINABLE SITES		AWARDED: 23 / 26
SSc1	Site selection	1 / 1
SSc2	Development density and community connectivity	5 / 5
SSc3	Brownfield redevelopment	0 / 1
SSc4.1	Alternative transportation - public transportation access	6 / 6
SSc4.2	Alternative transportation - bicycle storage and changing rooms	0 / 1
SSc4.3	Alternative transportation - low-emitting and fuel-efficient vehicles	3 / 3
SSc4.4	Alternative transportation - parking capacity	2 / 2
SSc5.1	Site development - protect or restore habitat	0 / 1
SSc5.2	Site development - maximize open space	1 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.1	Heat island effect - nonroof	1 / 1
SSc7.2	Heat island effect - roof	1 / 1
SSc8	Light pollution reduction	1 / 1

WATER EFFICIENCY		AWARDED: 6 / 10
WEc1	Water efficient landscaping	4 / 4
WEc2	Innovative wastewater technologies	0 / 2
WEc3	Water use reduction	2 / 4

ENERGY & ATMOSPHERE		AWARDED: 10 / 35
EAc1	Optimize energy performance	3 / 19
EAc2	On-site renewable energy	0 / 7
EAc3	Enhanced commissioning	2 / 2
EAc4	Enhanced refrigerant Mgmt	2 / 2
EAc5	Measurement and verification	1 / 3
EAc6	Green power	2 / 2

MATERIAL & RESOURCES		AWARDED: 6 / 14
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 3
MRc1.2	Building reuse - maintain interior nonstructural elements	0 / 1
MRc2	Construction waste Mgmt	2 / 2
MRc3	Materials reuse	0 / 2
MRc4	Recycled content	2 / 2
MRc5	Regional materials	2 / 2

MATERIAL & RESOURCES		CONTINUED
MRc6	Rapidly renewable materials	0 / 1
MRc7	Certified wood	0 / 1

INDOOR ENVIRONMENTAL QUALITY		AWARDED: 11 / 23
EQc1	Outdoor air delivery monitoring	1 / 1
EQc2	Increased ventilation	1 / 1
EQc3.1	Construction IAQ Mgmt plan - during construction	1 / 1
EQc3.2	Construction IAQ Mgmt plan - before occupancy	0 / 1
EQc4.1	Low-emitting materials - adhesives and sealants	1 / 1
EQc4.2	Low-emitting materials - paints and coatings	1 / 1
EQc4.3	Low-emitting materials - flooring systems	1 / 1
EQc4.4	Low-emitting materials - composite wood and agrifiber products	1 / 1
EQc5	Indoor chemical and pollutant source control	1 / 1
EQc6.1	Controllability of systems - lighting	1 / 1
EQc6.2	Controllability of systems - thermal comfort	0 / 1
EQc7.1	Thermal comfort - design	1 / 1
EQc7.2	Thermal comfort - verification	1 / 1
EQc8.1	Daylight and views - daylight	0 / 1
EQc8.2	Daylight and views - views	0 / 1
EQpc123	Designing with Nature, Biophilic Design for the Indoor Environment	REQUIRED
EQpc124	Performance-based IAQ design and assessment	REQUIRED

INNOVATION		AWARDED: 6 / 6
IDc1	Innovation in design	5 / 5
IDc2	LEED Accredited Professional	1 / 1

REGIONAL PRIORITY		AWARDED: 4 / 4
EQc2	Increased ventilation	1 / 1
MRc1.1	Building reuse - maintain existing walls, floors and roof	0 / 1
SSc6.1	Stormwater design - quantity control	1 / 1
SSc6.2	Stormwater design - quality control	1 / 1
SSc7.2	Heat island effect - roof	1 / 1

TOTAL 66 / 110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Appendix 2-5: CMU Electricity Usage

The following table identifies total electricity usage for CMU's Pittsburgh Campus from 2003-2018. *(Source: "Pittsburgh to Paris" report, 2018 and FMS)*

Year	MWh
2003	97,268
2004	98,594
2005	96,874
2006	100,942
2007	105,620
2008	108,613
2009	108,618
2010	114,867
2011	117,741
2012	118,925
2013	119,745
2014	117,450
2015	122,871
2016	131,472
2017	126,269
2018	135,108

Appendix 2-6: Campus Building Electricity Usage

The following table contains data for electricity usage for academic and residential buildings in 2017. *(Source: "Pittsburgh to Paris" report, 2018)*

Building	Usage (kWh)
1055 Morewood	176,320
1057 Morewood	139,440
300 S Craig	1,833,840
4700 Fifth	446,700
5170 MM	2,280
Baker Porter	4,784,068
Boss	97,194
CFA	2,518,682
CIC	3,264,464
Doherty A	190,800
Doherty B	6,438,335
Donner	368,730
Gates	9,418,184
Hamburg	2,482,422
Hamerschlag A	271,064
Hamerschlag B	4,255,988
Henderson	291,235
Industrial Admin	5,258,215
Margaret Morrison	2,370,682
McGill	115,378
MM A	154,905
MM B	63,906

MM C and Plaza	211,420
Morewood Gardens A-D	1,427,651
Morewood Gardens E	495,600
Mudge	370,080
Neville	27,084
NREC	2,660,400
NSH	5,133,515
PTC	3,777,000
Resnik	2,046,331
Roberts	3,306,147
Roselawn 1,3,5,7	21,850
Roselawn 10,12,14	24,490
Roselawn 12,4,6,8	29,840
Scaife	853,251
Scobell	87,028
SEI	5,592,489
Shirley	65,880
Smith	512,969
Stever	945,149
Wean	12,312,362
Welch	249,318
West Wing	543,196
Woodlawn	41,600

Appendix 2-7: CO_2 Emissions Due to Heating

The following table contains data for CO_2 emissions related to natural gas and steam for the years 2003-2018. *(Source: "Pittsburgh to Paris" report, 2018)*

Fiscal Year	Natural Gas (Metric Tons CO_2)	Steam (Metric Tons CO_2)	Total
2003	2,519	36,106	38,626
2004	2,644	38,571	41,215
2005	2,388	34,020	36,408
2006	2,876	32,025	34,901
2007	2,707	34,508	37,215
2008	3,044	37,515	40,559
2009	3,154	37,218	40,372
2010	3,048	27,929	30,977
2011	3,599	27,451	31,051
2012	2,981	22,633	25,614
2013	3,413	26,334	29,747
2014	3,946	28,467	32,413
2015	4,770	28,537	33,308
2016	3,681	25,542	29,222
2017	3,520	25,660	29,180
2018	3,597	28,769	32,366

Appendix 2-8: Emission Rates Based on Zip Code

The following appendix is the data from EPA emissions factors on the average amount of emissions based on zip code.

ZIP CODE	Grid Subregion	CO_2 (lb/MWh)	CH_4 (lb/MWh)	N_2O (lb/MWh)	CO_2e (lb/MWh)	NO_X (lb/MWh)	SO_2 (lb/MWh)
15217	RFCW	1,243	0.108	0.019	1,251	0.945	1.199

Appendix 2-9: RECs Pricing and CMU RECs Cost

This table displays the cost of RECs nationally between years 2013-2017 along with the cost of RECs for CMU. *(Source: "Pittsburgh to Paris" report, 2018)*

Year	Price ($/REC)	CMU Cost for RECs ($)
2013	0.75	89,808
2014	0.68	79,866
2015	0.56	68,808
2016	0.49	64,421
2017	0.41	51,770

Appendix 3-1: Metering in Academic Buildings

This appendix displays the metering status in academic buildings.

Building	Metering	Building	Metering	Building	Metering	Building	Metering
Alumni House	Yes	III	Yes	CIC	Yes	WQED Building	No
BH -PH	No	UC	Yes	Scaife	No	300 S. Craig	Yes
Bakery Square	No	MMCH	Yes	Scott	Yes	311S. Craig	No
Bramer House	Yes	MI	Yes	Skibo	Yes	407 S. Craig	Yes
CFA	No	REI	Yes	Smith	Yes	417 S. Craig	No
Cyert	Yes	Newell Simon	Yes	SEI	Yes	4516 Henry	Yes
DH	No	PPG 6	No	Solar House	No	4609 Henry	Yes
FMS	No	Posner Center	No	FMS R&G	No	4615 Forbes	Yes
Gates - Hillman	Yes	Posner Hall	No	Tepper Quad	Yes	4616 Henry	Yes
HBH	Yes	Purnell	Yes	Warner	Yes	4721 Fifth	Yes
HH	No	Rand Building	No	Wean	Yes	6555 Penn	Yes
Hunt	No	Roberts Hall	Yes	Whitfield Hall	Yes	ANSYS	No

Appendix 3-2: Water Use in Academic and Administrative Buildings

This appendix displays the annual total water use and water use intensity (WUI) for academic and administrative buildings from October 2016 to September 2018.

$$WUI = \frac{Annual\ Total\ Water\ Use}{Area}$$

Buildings	Total 16-17 (M gal)	Total 17-18 (M gal)	Area 2017 sq ft)	Area 2018 (sq ft)	WUI 16-17 (gal/sq ft-yr)	WUI 17-18 (gal/sq ft-yr)
Alumni House	0.1	0.1	7,960	7,960	15.6	7.4
Bramer House	0.0	0.0	4,768	4,768	9.6	8.8
Cyert	0.9	0.7	64,372	64,372	14.2	10.7
HBH	1.3	1.3	105,376	105,376	12.3	12.1
MMCH	2.4	1.7	108,683	108,664	22.0	15.5
MI	18.3	15.1	355,079	355,394	51.5	42.5
Skib	0.5	0.3	63,307	63,307	8.5	4.0
Whitfield	0.1	0.1	12,352	12,352	6.9	5.6
300 S. Craig	1.2	1.4	85,388	85,383	14.4	16.7
407 S. Craig	0.1	0.2	10,935	10,935	12.5	13.8
4516 Henry	0.5	0.3	34,263	40,954	13.5	8.0
4615 Forbes	0.1	0.1	40,976	40,954	2.8	2.6
4616 Henry	0.1	0.1	25,249	25,605	5.1	3.7
4721 Fifth	0.1	0.1	18,019	18,456	4.2	5.5
6555 Penn	0.1	0.2	114,591	114,591	1.2	2.0

Appendix 3-3: Water Use in Residential Halls and Greek Houses

This appendix displays the annual total water use and daily water use per capita for residential halls and Greek houses from October 2016 to September 2018.

$$Daily\ Water\ Use\ = \frac{Annual\ Total\ Water\ Use}{Capacity * 365\ Days}$$

Buildings	**Total 16-17 (M gal)**	**Total 17-18 (M gal)**	**Capacity**	**Daily Water Use 16-17 (gal/day-capita)**	**Daily Water Use 17-18 (gal/day-capita)**
Boss	2.6	2.1	72	134.4	105.2
McGill	2.5	3.3	71	126.5	171.8
Scobell	2.8	2.0	88	118.3	83.1
Doherty	2.7	1.9	152	63.7	44.8
MW Garden	9.1	6.9	451	73.7	55.7
Donner	3.2	2.7	239	48.6	41.3
Mudge	4.0	3.1	310	47.1	36.0
Rez	1.7	1.3	150	41.9	31.5
Woodlawn	0.3	0.2	35	29.1	22.1
1063 MW	0.8	0.3	36	79.2	28.4
1069 MW	0.4	0.3	36	42.4	31.5
1071 MW	0.1	0.1	36	15.1	13.1
1077 MW	0.4	0.3	36	41.7	26.3
1079 MW	0.1	0.1	36	14.4	11.6
1085 MW	0.4	0.3	36	43.2	26.8
1091 MW	0.2	0.2	36	16.4	17.3
5031 Forbes	0.4	0.3	36	37.7	29.5
5033 Forbes	0.2	0.2	36	20.8	17.7

Appendix 3-4: Waste Data

This appendix displays data from the years 2004 to 2017 for waste calculations. CMU population includes all students, faculty, and staff on campus.

Year	CMU Population	Total Landfill Waste (Tons)	Total Recycled Waste (Tons)
2004	13,834	2906	671.97
2005	13,951	3006	642.75
2006	14,072	3145	709.98
2007	14,383	3106	682.86
2008	14,866	3066	699.19
2009	15,559	3089	835.83
2010	15,898	3139	994.12
2011	16,214	3090	1090.38
2012	16,734	3234	1150.4
2013	17,384	3124	1196.67
2014	17,831	3293	1311.96
2015	18,013	3038	1367.6
2016	18,327	2941	1473.71
2017	20,605	3107	1475.9

Appendix 4-1: Faculty and Staff Air Travel Costs and Emissions Sorted by College

This appendix compiles university sponsored air travel data from FY 2012-2017. The original data was provided by Procurement Services. Departments from the original data were grouped by college to give the following results.

Codebook:
$: sum of dollar amount spent on air travel for each college
Mi: sum of number of air miles traveled, Mi = $/0.24
E: sum of CO_2 emissions, E = Mi*0.000188117
F: number of faculty with primary appointment to that college in that year
S: number of staff with primary appointment to that college in that year
E/F: CO_2 emissions per faculty for that year
E/(F+S): CO_2 emissions per faculty and staff combined for that year

College	FY	$	Mi	E	F	S	E/F	E/(F+S)
CFA	2012	112,754	469,808	88.38	163	230	0.54	0.22
CFA	2013	120,711	502,964	94.62	159	236	0.60	0.24
CFA	2014	117,812	490,882	92.34	168	236	0.55	0.23
CFA	2015	294,938	1,228,909	231.18	183	256	1.26	0.53
CFA	2016	305,389	1,272,455	239.37	182	250	1.32	0.55
CFA	2017	307,212	1,280,051	240.80	181	269	1.33	0.54
CIT	2012	697,194	2,904,974	546.47	181	310	3.02	1.11
CIT	2013	716,436	2,985,150	561.56	200	324	2.81	1.07
CIT	2014	867,289	3,613,705	679.80	211	361	3.22	1.19
CIT	2015	1,417,263	5,905,262	1110.88	216	392	5.14	1.83
CIT	2016	1,449,639	6,040,161	1136.26	214	421	5.31	1.79
CIT	2017	1,205,606	5,023,357	944.98	217	488	4.35	1.34
DC	2012	229,666	956,940	180.02	251	169	0.72	0.43
DC	2013	232,026	966,776	181.87	246	179	0.74	0.43
DC	2014	249,049	1,037,703	195.21	243	176	0.80	0.47
DC	2016	338224.69	1409269.54	265.11	207	236	1.28	0.60
DC	2017	326881.13	1362004.71	256.22	213	267	1.20	0.53

HC	2012	85,643	773,514	145.51	58	150	2.51	0.70
HC	2013	53,513	1,056,305	198.71	67	146	2.97	0.93
HC	2014	73,324	1,138,849	214.24	69	143	3.10	1.01
HC	2015	39,930	2,249,707	423.21	59	184	7.17	1.74
HC	2016	46,527	1,860,531	350.00	59	183	5.93	1.45
HC	2017	473,417	1,972,571	371.07	62	215	5.99	1.34
MCS	2012	273,295	1,138,730	214.21	248	174	0.86	0.51
MCS	2013	77,915	1,157,979	217.84	231	172	0.94	0.54
MCS	2014	328,287	1,367,862	257.32	220	167	1.17	0.66
MCS	2015	88,107	2,033,778	382.59	217	167	1.76	1.00
MCS	2016	483,557	2,014,823	379.02	212	170	1.79	0.99
MCS	2017	06,576	1,694,065	318.68	210	164	1.52	0.85
SCS	2012	29,008	3,870,866	728.18	282	514	2.58	0.91
SCS	2013	1,025,989	4,274,952	804.19	281	501	2.86	1.03
SCS	2014	1,020,453	4,251,888	799.85	275	496	2.91	1.04
SCS	2015	1,481,558	6,173,159	1161.28	267	507	4.35	1.50
SCS	2016	1,528,839	6,370,164	1198.34	282	519	4.25	1.50
SCS	2017	1,743,708	7,265,450	1366.75	293	538	4.66	1.64
TSB	2012	239,608	998,368	187.81	107	134	1.76	0.78
TSB	2013	313,212	1,305,050	245.50	110	141	2.23	0.98
TSB	2014	353,716	1,473,817	277.25	106	143	2.62	1.11
TSB	2015	400,076	1,666,985	313.59	111	139	2.83	1.25
TSB	2016	455,316	1,897,149	356.89	109	152	3.27	1.37
TSB	2017	559,998	2,333,326	438.94	106	176	4.14	1.56

Appendix 4-2: Faculty and Staff Car Rental Costs and Emissions

This appendix includes the data required to calculate carbon emissions from faculty and staff car rentals. The data for car rentals was sourced from a record provided by Procurement Services. To inform the estimates of carbon emissions based on cost, this analysis draws on a set of reports from the Direct Travel agency which includes total travel expenditures and estimated carbon emissions for air travel in fiscal years 2012-2015.

Fiscal Year	Total car rental spending	Estimated car rental spending	Estimated lbs. CO_2	Estimated metric tons CO_2
2012	$6,923,796	$291,667	319,613	145.0
2013	$8,098,100	$440,306	520,623	236.2
2014	$9,325,468	$459,440	565,080	256.3
2015	$13,369,591	$799,276	959,825	435.4
2016	$13,599,977	$698,859	822,737	373.2
2017	$13,549,044	$696,242	819,655	371.8

Appendix 4-3: Student Organization Air Travel Costs and Emissions

This appendix includes the data required to calculate carbon emissions from student organization air travel. The main source of raw data for analysis was a record of student organization travel expenses, including foreign and domestic air travel. This was obtained from Student Leadership, Involvement, and Civic Engagement (SLICE), with the help of the Finance Assistant to the Student Body Vice President of Finance. As with the faculty and staff car rental analysis, this analysis also draws on the Direct Travel reports.

Fiscal Year	Air travel spending	Air travel spending, 2018 dollars	Lbs. CO_2 per 2018 dollar	Lbs. CO_2	Metric tons CO_2
2010	$37,604	$43,015	1.44	61,984	28.1
2011	$102,099	$114,916	1.44	165,591	75.1
2012	$94,604	$103,453	1.16	120,146	54.5
2013	$79,667	$85,751	1.54	131,664	59.7
2014	$80,685	$85,497	1.52	130,265	59.1
2015	$87,638	$92,948	1.54	143,467	65.1
2016	$134,994	$141,233	1.44	203,514	92.3
2017	$123,544	$126,103	1.44	181,711	82.4
2018	$107,688	$107,688	1.44	155,176	70.4

Appendix 4-4: Student Organization Gas Purchase Costs and Emissions

This appendix includes the data and analysis assumptions required to calculate carbon emissions from student organization gas purchases. This analysis uses US annual average gas prices, obtained from the Statista database, along with the Energy Information Agency's value for carbon emissions per gallon.

Fiscal Year	Gas spending	Gas price $ per gallon	Gallons purchased	Lbs. CO_2/ gallon	Total lbs. CO_2	Metric tons CO_2
2010	$12,274	2.78	4,415	19.6	86,539	39.3
2011	$12,674	3.52	3,601	19.6	70,571	32.0
2012	$1,639	3.62	453	19.6	8,874	4.0
2013	$821	3.51	234	19.6	4,584	2.1
2014	$16,509	3.36	4,913	19.6	96,300	43.7
2015	$25,183	2.43	10,363	19.6	203,119	92.1
2016	$14,672	2.14	6,856	19.6	134,376	61.0
2017	$17,535	2.42	7,246	19.6	142,017	64.4
2018	$26,383	2.72	9,685	19.6	189,831	86.1

Appendix 4-5: Student Organization Car Rental Costs and Emissions

This appendix includes the data and analysis assumptions required to calculate carbon emissions from student organization car rentals. As with air travel costs, the data for car rentals was sourced from the record of student organization travel expenses, and the carbon emissions conversions are based on the Direct Travel Reports. The total expenditures were adjusted to 2018 dollar equivalents using an inflation calculator from the US Bureau of Labor Statistics.

Fiscal Year	Car rental spending	Car rental spending, 2018 dollars	Lbs. CO_2/2018 dollar	Lbs. CO_2	Metric tons CO_2
2010	$22,430	$25,658	1.10	28,182	12.8
2011	$23,998	$27,011	1.10	29,669	13.5
2012	$28,387	$31,042	1.00	31,106	14.1
2013	$37,361	$40,214	1.10	44,176	20.0
2014	$42,551	$45,089	1.16	52,335	23.7
2015	$46,612	$49,437	1.13	55,975	25.4
2016	$41,387	$43,299	1.10	47,560	21.6
2017	$48,385	$49,387	1.10	54,246	24.6
2018	$72,037	$72,037	1.10	79,125	35.9

Appendix 4-6: Faculty and Staff Residence Zip Code Tally, 2018-2019

Staff Count	Staff Zip Code	Faculty Count	Faculty Zip Code
10	15001	1	15015
5	15003	3	15024
9	15005	1	15035
1	15006	7	15044
4	15009	1	15049
5	15012	1	15056
2	15014	1	15057
15	15017	1	15065
2	15018	1	15068
16	15024	21	15090
20	15025	13	15101
3	15026	1	15102
1	15027	4	15106
1	15030	5	15108
3	15034	1	15110
3	15035	9	15116
6	15037	2	15120
1	15042	1	15133
57	15044	2	15135
3	15045	2	15136
2	15049	4	15139
1	15050	18	15143
1	15051	3	15145
1	15052	4	15146
2	15054	1	15147
1	15056	23	15201

7	15057	5	15202
4	15061	13	15203
4	15063	1	15204
9	15065	3	15205
2	15066	135	15206
40	15068	6	15207
4	15071	53	15208
2	15074	1	15209
1	15083	2	15210
8	15084	2	15211
12	15085	14	15212
2	15089	73	15213
73	15090	2	15214
50	15101	30	15215
52	15102	13	15216
14	15104	388	15217
18	15106	43	15218
35	15108	15	15219
8	15110	2	15220
4	15112	43	15221
35	15116	6	15222
52	15120	38	15224
39	15122	1	15226
4	15126	1	15227
1	15127	25	15228
12	15129	6	15229
18	15131	99	15232
14	15132	5	15234
7	15133	17	15235

4	15135	1	15236
17	15136	28	15237
18	15137	46	15238
25	15139	1	15239
4	15140	17	15241
4	15142	14	15243
55	15143	1	15260
4	15144	13	15289
7	15145	1	15301
72	15146	1	15317
42	15147	1	15332
2	15148	2	15367
107	15201	1	15501
53	15202	1	15610
44	15203	2	15632
5	15204	2	15642
34	15205	1	15658
256	15206	2	15668
46	15207	1	15935
68	15208	4	16046
39	15209	1	16053
31	15210	4	16066
29	15211	1	16648
56	15212	1	19096
132	15213	1	19146
18	15214	1	43920
67	15215	1	44236
83	15216	1	45238
373	15217		

123	15218		
20	15219		
31	15220		
176	15221		
21	15222		
20	15223		
71	15224		
1	15225		
28	15226		
58	15227		
83	15228		
32	15229		
127	15232		
6	15233		
36	15234		
92	15235		
60	15236		
144	15237		
50	15238		
28	15239		
44	15241		
1	15242		
32	15243		
1	15277		
11	15289		
4	15301		
37	15317		
3	15330		
3	15332		

1	15342		
1	15347		
9	15367		
1	15427		
1	15473		
1	15482		
1	15501		
10	15601		
1	15610		
4	15613		
2	15626		
7	15632		
4	15636		
1	15637		
1	15641		
74	15642		
12	15644		
5	15650		
8	15656		
6	15658		
1	15663		
1	15665		
5	15666		
28	15668		
2	15683		
5	15690		
1	15692		
1	15701		
1	15748		

1	15857		
2	15904		
2	15905		
1	15931		
4	16001		
4	16002		
1	16023		
1	16024		
2	16025		
1	16028		
1	16033		
1	16034		
4	16037		
14	16046		
1	16049		
1	16053		
7	16055		
3	16056		
2	16057		
5	16059		
4	16063		
49	16066		
2	16101		
1	16105		
1	16115		
1	16116		
1	16117		
1	16127		
1	16142		

1	16148		
4	16201		
1	16210		
1	16214		
3	16229		
1	16238		
1	16259		
1	16335		
1	16627		
1	16803		
1	17050		
1	17545		
1	18062		
1	18612		
1	19006		
1	19129		
1	19343		
1	19422		
1	26003		
1	26035		
1	26047		
1	26059		
2	26062		
1	26505		
1	26508		
1	43026		
1	43221		
1	43952		
2	43953		

1	44041		
1	44114		
1	44406		
1	44413		
2	44512		
1	44514		
1	45206		
1	45243		
1	45434		

Appendix 4-7: CMU Parking Permit Holders' Residence Zip Code Tally, 2018-2019

Staff Zip Code	Staff Count	Faculty Zip Code	Faculty Count	Student Zip Code	Student Count
8817	1	15015	1	1720	1
15001	8	15024	1	1867	1
15003	1	15035	1	2478	1
15005	4	15044	6	6488	1
15009	3	15057	1	6840	1
15012	4	15090	19	6853	1
15017	4	15101	9	7083	1
15018	2	15106	3	7652	1
15024	8	15108	2	7882	1
15025	13	15110	2	7960	1
15026	2	15116	9	8534	2
15027	1	15120	2	10514	1
15030	1	15122	1	10591	1
15034	1	15133	1	10598	1
15037	2	15139	2	11377	1
15042	2	15143	8	11507	1
15044	31	15145	1	11746	1
15049	2	15146	4	11766	1
15050	1	15201	10	15025	1
15051	1	15202	2	15043	1
15057	4	15203	3	15044	1
15061	2	15205	1	15090	1

15063	1	15206	60	15101	1
15065	5	15207	2	15143	2
15066	1	15208	30	15147	1
15068	22	15209	1	15203	3
15071	1	15211	2	15206	5
15074	2	15212	5	15207	1
15084	4	15213	24	15208	2
15085	5	15214	1	15213	28
15090	37	15215	23	15214	1
15101	23	15216	6	15215	3
15102	15	15217	131	15217	5
15104	6	15218	19	15219	1
15106	8	15219	1	15221	3
15108	19	15221	19	15224	2
15110	2	15222	4	15232	6
15112	1	15224	13	15234	1
15116	21	15226	1	15235	3
15120	31	15228	13	15236	1
15122	16	15229	5	15237	1
15126	1	15232	27	15238	1
15129	8	15234	1	15241	1
15131	8	15235	13	15289	1
15132	8	15237	17	15317	1
15133	1	15238	36	15632	1
15135	1	15239	1	15644	1

15136	7	15241	9	15905	1
15137	13	15243	11	16142	1
15139	19	15286	1	19073	1
15140	2	15301	1	19153	1
15142	2	15317	2	20015	1
15143	23	15332	1	20170	1
15144	3	15367	1	20171	1
15145	4	15632	2	20850	1
15146	43	15642	2	20878	1
15147	19	15668	1	20904	2
15148	1	16046	4	21093	1
15201	21	16053	1	21784	1
15202	24	16066	3	22124	1
15203	8	16648	1	28217	1
15204	1	22209	1	29585	1
15205	15	29631	1	29650	1
15206	42	55112	1	30327	1
15207	12			33326	1
15208	11			33811	1
15209	22			37918	1
15210	7			40502	1
15211	7			43545	1
15212	28			43623	1
15213	381			44022	1
15214	8			44094	1

15215	30			44718	1
15216	27			53097	1
15217	51			55309	1
15218	36			59802	1
15219	3			60523	1
15220	10			60657	1
15221	54			61822	1
15222	5			66212	1
15223	10			75206	1
15224	10			77479	1
15226	17			78726	1
15227	27			78739	1
15228	26			80134	1
15229	12			90272	1
15232	15			91107	1
15233	4			93940	1
15234	18			94720	1
15235	42			95129	1
15236	34			97035	1
15237	77			98198	1
15238	24				
15239	15				
15241	18				
15243	18				
15301	1				

15317	14				
15330	2				
15332	3				
15342	1				
15367	5				
15601	2				
15610	1				
15613	3				
15626	2				
15632	4				
15636	4				
15637	1				
15641	1				
15642	33				
15644	3				
15647	1				
15650	3				
15656	3				
15658	1				
15666	3				
15668	15				
15683	1				
15690	1				
15904	2				
16002	1				

16024	1				
16025	1				
16028	1				
16033	2				
16034	1				
16037	1				
16046	7				
16049	1				
16055	5				
16056	2				
16059	2				
16063	3				
16066	29				
16101	1				
16115	1				
16116	1				
16201	2				
16229	3				
16238	1				
16259	1				
16803	1				
20011	1				
20147	1				
20165	1				
20170	1				

20171	1				
20744	1				
20772	1				
22025	1				
22039	1				
22046	1				
22101	2				
22124	1				
22153	2				
22191	1				
22193	1				
22206	1				
22207	1				
22309	1				
22310	1				
22314	1				
22315	1				
22405	1				
26003	1				
26035	2				
26062	1				
26505	1				
26508	2				
32608	1				
43026	1				

43221	1				
43952	1				
43953	1				
44514	2				
15227-3988	1				
15238-1817	1				
15243-2023	1				

Appendix 4-8: Bike Thefts Reported to CMU Police Department (2/6/2016 - 10/3/2018)

The following table shows all reported bike thefts from February 6, 2016 to October 3, 2018 given by Sergeant Nello Bruno of the Carnegie Mellon Police Department.

Location	Street #	Street Name	Frequency
Hamerschlag Hall	425	Hamerschlag Drive	5
Doherty Hall	281	Hamerschlag Drive	4
Gates/Hillman Center	4902	Forbes Ave.	4
Morewood Gardens (A-D)	1060	Morewood Ave.	4
Stever House	1030	Morewood Ave.	4
Baker Hall	4825	Frew St.	3
College Of Fine Arts	4919	FREW ST.	3
Margaret Morrison Apartments	5134-5140	Margaret Morrison St.	3
Porter Hall	4815	Frew St.	3
Morewood Gardens (E)	4921	Forbes Ave.	2
Newell-Simon Hall	4804	Forbes Ave.	2
Posner Hall	4999	Frew Street	2
Purnell Center	4908	Forbes Ave.	2
Resnik House (East Dorm)	5125	Margaret Morrison St.	2
Webster Hall	101	N. Dithridge St.	2
West Wing	5125	Margaret Morrison St.	2
300 South Craig Street	300	S. Craig St.	1
407 South Craig St	407	S. Craig St.	1
Area #10 - Sei/Dithridge Gar Gated	4500	Fifth Ave.	1
Boss House	5126	Margaret Morrison St.	1
Cohon University Center	5034	Forbes Ave.	1
Cyert Hall	4910	Forbes Ave.	1

Delta Gamma	5031	Forbes Ave.	1
East Campus Garage Area 5		Morewood Ave.	1
Fairfax Annex	4630	Fifth Ave.	1
Hamerschlag Hall	346	Hamerschlag Drive	1
Hornbosel Mall Area		Frew St.	1
Hunt Library	4909	Frew St.	1
Mudge House	1000	Morewood Ave.	1
Off Campus Location	201	South Craig	1
Posner Hall	151	Tech St.	1
Purnell Center		Pausch Bridge	1
Residence On Fifth	4700	Fifth Avenue	1
Roberts Hall	364	Hamerschlag Drive	1
Scaife Hall	4805	Frew St.	1
Shady Oak Apts.	601	Clyde St.	1
Shirley Apartments	133	N. Dithridge St.	1
Smith Hall - Elliot Dunlop Smith	4802	Forbes Ave.	1
Tech Street		Tech St.	1
Wean Hall	311	Hamerschlag Drive	1
Webster Hall	4415	Fifth Avenue	1

Appendix 4-9: Bicycle Advocacy Committee Survey Response

Carnegie Mellon University's Bicycle Advocacy Committee conducted a survey at their events throughout 2015. The following tables show the results of their survey questions.

1. What factors would keep you from commuting to campus by bicycle?

Averages days biked per week	Count
0	26
1	13
2	9
3	17
4	18
5	39
6	19
7	14

2. When you come to CMU's main campus, how frequently do you commute by a bicycle in an average week? (Check all that apply)

Factors	Count
Weather	97
Safety	52
Distance	30
Other	41

3. What outdoor conditions (if any) will prevent you from riding your bicycle to campus? (Check all that apply)

Outdoor conditions	Count
Rain	82
Snow	110
Chilly (below 40)	24
Cold (below 25)	77
Heat / Humidity	12
Nighttime	34
None	16
Other	21

4. How safe do you feel biking on campus? (1 = Very Safe, 4 = Unsafe)

Response	Count
1 - Strong & Fearless	22
2 - Enthused & Confident	62
3 - Interested but Concerned	58
4.- No Way No How	13

5. How safe do you feel biking in the city? (1 = Very Safe, 4 = Unsafe)

Response	Count
1 - Strong & Fearless	22
2 - Enthused & Confident	62
3 - Interested but Concerned	58
4.- No Way No How	13

6. What street do you primarily enter CMU's main campus from?

Street	Count
Morewood	58
Forbes (Squirrel Hill)	32
Forbes (Oakland)	18
Frew St. (Schenley Park)	23
Junction Hollow Trail (Neville)	9
Other	15

7. On the main campus, how should we prioritize bicycle infrastructure? [Bicycle Paths]

Ranking (1 = Highest Priority, 7 = Lowest Priority)	Count
1	40
2	22
3	29
4	17
5	26
6	13
7	0

8. On the main campus, how should we prioritize bicycle infrastructure? [Bicycle Racks]

Ranking (1 = Highest Priority, 7 = Lowest Priority)	Count
1	24
2	34
3	37
4	29
5	12
6	6
7	0

9. On the main campus, how should we prioritize bicycle infrastructure? [Bicycle Racks (Covered)]

Ranking (1 = Highest Priority, 7 = Lowest Priority)	Count
1	53
2	29
3	22
4	12
5	11
6	19
7	0

10. On the main campus, how should we prioritize bicycle infrastructure? [Bicycle Parking Areas in Parking Garages]

Ranking (1 = Highest Priority, 7 = Lowest Priority)	**Count**
1	18
2	18
3	31
4	26
5	33
6	19
7	0

11. On the main campus, how should we prioritize bicycle infrastructure? [Fix-It Stations]

Ranking (1 = Highest Priority, 7 = Lowest Priority)	**Count**
1	19
2	39
3	30
4	33
5	14
6	9
7	0

12. On campus, where do you usually park your bicycle?

Options	Count
A Bicycle Rack	61
A covered Bike Rack (Under a Building / Bridge)	34
A Parking Garage	2
Bring it into the classroom / office (no racks provided)	23
Bring it into the classroom / office (racks provided)	9
Whatever is closest to my destination (tree, fence, light post, etc.)	12

13. Do you ever utilize the bicycle parking areas in the parking garages?

Options	Count
Yes, and it is the only place I will park my bicycle.	3
Yes, but I wish there were other options.	7
No, it is too far from my on-campus destination.	72
No, I didn't know there were bicycle parking areas in the parking garages, but I still wouldn't use them.	38
No, I didn't know there were bicycle parking areas in the parking garages, and I am interested in using them now.	12

14. On campus, what characterizes your bicycle usage the best?

Options	Count
I lock my bicycle up and walk everywhere.	101
I mostly ride my bicycle to get across campus.	38
Other	16

Appendix 5-1: Sustainability-Related Keywords

This appendix displays keywords used to search for sustainability educational programs (courses, departments, and degrees). Keywords were sourced from sustainability definitions at CMU peer institutions and the UN sustainable development goals.

Econ	Material	Carbon	Utilities	Perception
Health	Energy	GHG	Recycling	Innovation
Building	Climate	Purchasing	Facilities	Implement
Community	Sustainable	Procurement	Ground	Industry
Water	Education	Awareness	Emissions	Production
Engage	Sustainability	Preparedness	Consume	
Operations	Food	Emergency	Waste	
Justice	Natural	Hunger	Transport	
People	Well-being	Sanitation	Land	
Equal	Peace	Equity	Academics	
Outreach	Infrastructure	Partnerships	Research	
Safe	Poverty	Connection	Learn	

Appendix 5-2: Sustainability-Related Courses at Carnegie Mellon

This appendix displays all courses found in the 2017-2018 CMU catalog with sustainability-related keywords.

Keyword	Course Number	Course Name	College	Department
Sustainability	09-510	Chemistry and Sustainability	MCS	Chemistry
Sustainability	67-353	IT & Environmental Sustainability	DC	IS
Sustainability	67-354	Information Systems and Sustainability	DC	IS
Sustainability	67-361	Big Data and Sustainability	DC	IS
Sustainable	79-318	Sustainable Social Change: History and Practice	DC	History
Sustainable	12-712/19-717	Introduction to Sustainable Engineering	CIT	CEE
Sustainable	19-425	Sustainable Energy for the Developing World	CIT	EPP
Sustainable	90-789	Sustainable Community Development	Heinz	Heinz
Sustainable	48-448	History of Sustainable Architecture	CFA	Architecture
Energy	99-245	Energy: Science, Society and Communication	CMU	CMU
Energy	99-238	Materials, Energy and Environment	CMU	CMU
Energy	88-412	Energy, Climate Change, and Economic Growth in the 21st Century	DC	Decision Science
Energy	19-424/24-424	Energy and the Environment	CIT	EPP
Energy	90-808	Energy Policy	Heinz	Heinz
Energy	79-381	Energy and Empire: How Fossil Fuels Changed the World	DC	History
Energy	48-315	Environment I: Climate & Energy	CFA	Architecture
Energy	19-421	Emerging Energy Policies	CIT	EPP
Energy	19-666	Energy Policy and Economics	CIT	EPP
Energy	24-292	Renewable Energy Engineering	CIT	MECHE
Energy	24-628	Energy Transport and Conversion at the Nanoscale	CIT	MECHE
Energy	48-752	Zero Energy Housing	CFA	Architecture

Operations	70-371	Operations Management	Tepper	Business Administration
Operations	21-292	Operations Research I	MCS	Mathematical Sciences
Operations	21-393	Operations Research II	MCS	Mathematical Sciences
Building	48-116	Building Physics	CFA	Architecture
Building	48-432	Environment II: Design Integration of Active Building Systems	CFA	Architecture
Building	48-722	Building Performance Modeling	CFA	Architecture
Building	48-795	LEED, Green Design and Building Rating in Global Context	CFA	Architecture
Building	48-721	Building Controls and Diagnostics	CFA	Architecture
Building	48-723	Performance of Advanced Building Systems	CFA	Architecture
Building	48-729	Productivity, Health and the Quality of Buildings	CFA	Architecture
Water	79-315	The Politics of Water: Global Controversies, Past and Present	DC	History
Water	79-336	Oil & Water: Middle East Perspectives	DC	History
Water	12-702	Fundamentals of Water Quality Engineering	CIT	CEE
Water	12-657	Water Resource Systems Engineering	CIT	CEE
Water	06-365/19-365	Water Technology Innovation and Policy	CIT	CHEME
Food	79-311	Paleo Kitchen: Food and Cooking in the Ancient World	DC	History
Food	79-377	Food, Culture, and Power: A History of Eating	DC	History
Food	79-283	Hungry World: Food and Famine in Global Perspective	DC	History
Health	80-348	Health Development and Human Rights	DC	Philosophy
Health	94-705	Health Economics	Heinz	Heinz
Health	90-836	Health Systems	Heinz	Heinz
Health	90-861	Health Policy	Heinz	Heinz
Health	90-721	Healthcare Management	Heinz	Heinz
Health	90-818	Health Care Quality & Performance Improvement	Heinz	Heinz

Health	90-831	Advanced Financial Management of Health Care	Heinz	Heinz
Health	90-706	Healthcare Information Systems	Heinz	Heinz
Health	90-832	Health Law	Heinz	Heinz
Health	76-494	Healthcare Communications	DC	English
Health	85-442	Health Psychology	DC	Psychology
Health	79-331	Body Politics: Women and Health in America	DC	History
Health	67-308	Innovation Studio: Health Care Information Systems	DC	IS
Health	90-834	Health Care Geographical Information Systems	Heinz	Heinz
Health	03-451	Advanced Developmental Biology and Human Health	MCS	Biological Sciences
Health	67-357	Healthcare Analytics and Big Data	DC	IS
Econ	73-102	Principles of Microeconomics	Tepper	Economics
Econ	73-103	Principles of Macroeconomics	Tepper	Economics
Econ	73-240	Intermediate Macroeconomics	Tepper	Economics
Econ	94-705	Health Economics	Heinz	Heinz
Econ	80-247	Ethics and Global Economics	DC	Philosophy
Econ	80-324	Philosophy of Economics	DC	Philosophy
Econ	73-160	Foundations of Microeconomics: Applications and Theory	Tepper	Economics
Econ	88-360	Behavioral Economics	DC	Decision Sciences
Econ	88-367	Behavioral Economics in the Wild	DC	Decision Sciences
Econ	88-365	Behavioral Economics and Public Policy	DC	Decision Sciences
Econ	88-406	Behavioral Economics in Organizations	DC	Decision Sciences
Econ	88-409	Behavioral Economics Perspectives on Ethical Issues	DC	Decision Sciences
Econ	80-337	Philosophy, Politics, & Economics	DC	Philosophy
Econ	88-366	Behavioral Economics of Poverty and Development	DC	Decision Sciences
Econ	88-412	Energy, Climate Change, and Economic Growth in the 21st Century	DC	Decision Sciences
Econ	76-265	Economics and Data Science	DC	English
Econ	73-148	Environmental Economics	Tepper	Economics
Econ	73-352	Public Economics	Tepper	Economics

Econ	73-358	Economics of the Environment and Natural Resources	Tepper	Economics
Econ	73-408	Law and Economics	Tepper	Economics
Econ	73-476	American Economic History	Tepper	Economics
Econ	88-387	Social Norms and Economics	DC	Decision Sciences
Econ	73-394	Development Economics	Tepper	Economics
Econ	88-257	Experimental Economics	DC	Decision Sciences
Econ	19-666	Energy Policy and Economics	CIT	EPP
Econ	62-714	Galleries & Auction Houses:Economics of the Art Market	CFA	Interdisciplinary
Econ	73-210	Economics: Colloquium I	Tepper	Economics
Econ	88-453	Behavioral Economics, Policy, and Organizations Capstone	DC	Decision Sciences
Econ	70-449	Social, Economic and Information Networks	Tepper	Business Administration
Econ	84-310	International Political Economy and Organizations	DC	Institute for Politics and Strategy
Econ	73-347	Game Theory for Economists	Tepper	Economics
Econ	88-411	Rise of the Asian Economies	DC	Decision Sciences
Econ	73-331	Political Economy of Inequality and Redistribution	Tepper	Economics
Econ	73-270	Strategic Professional Communication for Economists	Tepper	Economics
Econ	51-388	Sharing Economies	CFA	Design
Econ	73-274	Econometric I	Tepper	Economics
Econ	73-374	Econometrics II	Tepper	Economics
Infrastructure	12-750	Infrastructure Management	CIT	CEE
Natural	73-358	Economics of the Environment and Natural Resources	Tepper	Economics
Natural	09-716	Bioactive Natural Products	MCS	Chemistry
Education	05-418	Design Educational Games	SCS	HCI
Education	79-338	History of Education in America	DC	History
Education	76-378	Literacy: Educational Theory and Community Practice	DC	English

Education	57-331	Principles of Education	CFA	Music
Education	85-418	Contributions of Psychological Research to Education	DC	Psychology
Climate	88-412	Energy, Climate Change, and Economic Growth in the 21st Century	DC	Decision Sciences
Climate	48-315	Environment I: Climate & Energy	CFA	Architecture
Climate	19-653	Climate Change Mitigation	CIT	EPP
Climate	39-109	Grand Challenge Interdisciplinary Freshman Seminar: Climate Change	CIT	Interdisciplinary
Climate	19-443	Special Topics in EPP: Climate Change Science and Adaptation	CIT	EPP
Climate	66-109	DC Freshman Seminar: Climate Change	DC	Interdisciplinary
Climate	09-225	Climate Change: Chemistry, Physics and Planetary Science	MCS	Chemistry
Engage	38-110	ENGAGE in Service	MCS	All departments (MCS)
Engage	38-230	ENGAGE in Wellness: Looking Inward	MCS	All departments (MCS)
Engage	38-330	ENGAGE in Wellness: Looking Outward	MCS	All departments (MCS)
Engage	38-430	ENGAGE in Wellness: Looking Forward	MCS	All departments (MCS)
Engage	38-220	ENGAGE in the Arts	MCS	All departments (MCS)
People	79-289	Animal Planet: An Environmental History of People and Animals	DC	History
People	51-271	How People Work	CFA	Design
Community	82-281	Tutoring for Community Outreach	DC	Modern Languages
Community	82-282	Community Service Learning	DC	Modern Languages
Community	76-378	Literacy: Educational Theory and Community Practice	DC	English
Community	51-334	Photography, Community & Change	CFA	Design
Community	62-483	Growing Theatre Community Outreach	CFA	Interdisciplinary
Community	67-319/67-	Global Technology Consulting Groundwork - Technology Consulting in the Global	DC	IS

	331	Community		
Community	67-330	Technology Consulting in the Community	DC	IS
Outreach	82-281	Tutoring for Community Outreach	DC	Modern Languages
Outreach	62-483	Growing Theatre Community Outreach	CFA	Design
Peace	79-230	Arab-Israeli Conflict and Peace Process since 1948	DC	History
Peace	84-323	War and Peace	DC	Institute for Politics and Strategy
Equal	73-331	Political Economy of Inequality and Redistribution	Tepper	Economics
Equal	66-110	DC Grand Challenge Freshman Seminar: Inequality	DC	Interdisciplinary
Justice	80-447	Global Justice	DC	Philosophy
Justice	79-340	Juvenile Delinquency and Juvenile Justice	DC	History
Justice	76-312	Crime and Justice in American Film	DC	English
Consume	70-385	Consumer Behavior	Tepper	Business Administration
Well-Being	85-501	Stress, Coping and Well-Being	DC	Psychology
Well-Being	85-443	Social Factors and Well-Being	DC	Psychology
Safe	09-202	Undergraduate Seminar II: Safety and Environmental Issues for Chemists	MCS	Chemistry
Poverty	88-366	Behavioral Economics of Poverty and Development	DC	Decision Sciences
Material	99-238	Materials, Energy and Environment	CMU	CMU
Material	27-100	Engineering the Materials of the Future	CIT	MSE
Material	39-602	Materials Science for Additive Manufacturing	CIT	Additive Manufacturing
Material	27-215	Thermodynamics of Materials	CIT	MSE
Material	27-201	Structure of Materials	CIT	MSE
Material	27-202	Defects in Materials	CIT	MSE
Material	27-433	Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices	CIT	MSE
Material	27-367	Selection and Performance of Materials	CIT	MSE

Material	27-311	Polymeric Biomaterials	CIT	MSE
Material	27-323	Powder Processing of Materials	CIT	MSE
Material	27-357	Introduction to Materials Selection	CIT	MSE
Material	27-445	Structure, Properties and Performance Relationships in Magnetic Materials	CIT	MSE
Material	27-591	Mechanical Behavior of Materials	CIT	MSE
Material	27-555	Materials Project I	CIT	MSE
Material	27-565	Nanostructured Materials	CIT	MSE
Material	42-411	Engineering Biomaterials	CIT	BME
Material	42-670	Special Topics: Biomaterials Host Interactions in Regenerative Medicine	CIT	BME
Material	42-613	Molecular and Micro-scale Polymeric Biomaterials in Medicine	CIT	BME
Material	12-358	Materials Lab	CIT	CEE
Material	12-686	Special Topics: Computational Materials Modeling for Structures	CIT	CEE
Material	27-210	Materials Engineering Essentials	CIT	MSE
Material	27-205	Introduction to Materials Characterization	CIT	MSE
Material	27-216	Transport in Materials	CIT	MSE
Material	24-651	Material Selection for Mechanical Engineers	CIT	MECHE
Material	24-623	Molecular Simulation of Materials	CIT	MECHE
Material	48-215	Materials and Assembly	CFA	Architecture
Learn	39-210	Experiential Learning I	CIT	All departments (CIT)
Learn	39-220	Experiential Learning II	CIT	All departments (CIT)
Learn	39-310	Experiential Learning III	CIT	All departments (CIT)
Learn	03-365	Neural Correlates of Learning and Memory	MCS	Biological Sciences
Learn	03-765	Advanced Neural Correlates of Learning and Memory	MCS	Biological Sciences
Learn	70-437	Organizational Learning and Strategic Management	Tepper	Business Administration
Learn	05-	Machine Learning in Practice	SCS	HCI

	434/11-344			
Learn	05-432	Personalized Online Learning	SCS	HCI
Learn	05-291	Learning Media Design	SCS	HCI
Learn	05-292	Learning Media Methods	SCS	HCI
Learn	05-823	E-Learning Design Principles and Methods	SCS	HCI
Learn	11-441	Machine Learning for Text Mining	SCS	Language Technologies Institute
Learn	10-601	Introduction to Machine Learning (Master's)	SCS	Machine Learning
Learn	10-401	Introduction to Machine Learning (Undergrad)	SCS	Machine Learning
Learn	10-605	Machine Learning with Large Datasets	SCS	Machine Learning
Learn	10-703	Deep Reinforcement Learning & Control	SCS	Machine Learning
Learn	82-280	Learning about Language Learning	DC	Modern Languages
Learn	82-282	Community Service Learning	DC	Modern Languages
Learn	80-516	Casualty and Learning	DC	Philosophy
Learn	80-292	Learning Science Principles	DC	Philosophy
Learn	85-426	Learning in Humans and Machines	DC	Psychology
Perception	86-375	Computational Perception	SCS	Center for Neural Basis and Cognition
Perception	15-387	Computational Perception	SCS	CS
Perception	88-355	Social Brains: Neural Bases of Social Perception and Cognition	DC	Decision Sciences
Perception	88-405	Risk Perception and Communication	DC	Decision Sciences
Perception	51-379	Information + Interaction + Perception	CFA	Design
Perception	51-374	Understanding Perception through Design	CFA	Design
Perception	11-752	Speech II: Phonetics, Prosody, Perception and Synthesis	SCS	Language Technologies Institute

Perception	80-371	Philosophy of Perception	DC	Philosophy
Perception	85-370	Perception	DC	Psychology
Perception	85-385	Auditory Perception: Sense of Sound	DC	Psychology
Innovation	70-438	Commercialization and Innovation	Tepper	Business Administration
Innovation	06/19-365	Water Technology Innovation and Policy	CIT	CHEME
Innovation	15-300	Research and Innovation in Computer Science	SCS	CS
Innovation	51-423	Pieces 2.0: Social Innovation: Desis Lab	CFA	Design
Innovation	51-455	Design the Future: Human Centered Innovation for Exponential Times	CFA	Design
Innovation	51-490	Design Capstone Project: Social Innovation	CFA	Design
Innovation	54-360	Leadership Workshop: Ethics & Innovation	CFA	Drama
Innovation	67-475	Innovation in Information Systems	DC	IS
Innovation	67-308	Innovation Studio: Health Care Information Systems	DC	IS
Innovation	67-324	Accelerating Innovation and Entrepreneurship	DC	IS
Implement	84-336	Implementing Public Policy: From Good Idea to Reality	DC	Institute of Politics and Strategy
Implement	67-304	Database Design and Implementation	DC	IS
Implement	67-318	Business Process Modeling and Implementation	DC	IS
Implement	94-700	Organizational Design & Implementation	Heinz	Heinz
Implement	15-410	Operating System Design and Implementation	SCS	CS

Appendix 5-3: Sustainability-Related Programs at Carnegie Mellon

This appendix displays all departments and degrees (minors, bachelors, masters, and PhD's) found in the 2017-2018 CMU catalog with sustainability-related keywords.

Departments

Keyword	Department/ Program	College
Econ	Undergraduate Economics Program	DC
Material	Department of Material Science and Engineering	CIT
Learn	Machine Learning	SCS
Innovation	Integrated Innovation Institute	University-Wide

Minors

Keyword	Minor	College	Department
Buildings	Building Science	CFA	Architecture
Econ	Economics	Tepper	Economics
Education	Music Education	CFA	Music
Health	Healthcare Policy and Management	Interdisciplinary (Heinz, DC, MCS)	
Innovation	Innovation and Entrepreneurship	Tepper	IDEATE
Learn	Machine Learning	SCS	Machine Learning
Material	Electronic Materials	CIT	All departments (CIT)
Material	Material Science and Engineering	CIT	MSE
Material	Mechanical Behavior of Materials	CIT	All departments (CIT)
Operation	Operations and Supply Chain Management	Tepper	Business Administration
Sustainability	Environmental Engineering and Sustainability	CIT	All departments (CIT)

Bachelor's degrees

Keyword	Bachelors	College	Department
Econ	Bachelor of Science in Economics and Mathematical Sciences	DC/Tepper/MCS	Economics/Mathematical Sciences
Econ	Bachelor of Science in Economics and Statistics	DC/ Tepper	Economics/ Statistics and Data Science
Econ	Bachelor of Arts in Economics	Tepper	Economics
Econ	Bachelor of Science in Economics	DC/Tepper	Economics
Econ	Bachelor of Arts in Behavioral Economics, Policy, and Organizations	DC	
Material	Materials Science and Engineering	CIT	MSE
Learn	Bachelor of Science in Statistics and Machine Learning	DC/SCS	Department of Statistics and Data Science/ SCS

Master's degrees

Keyword	Masters	College	Department
Building	Master of Science in Building Performance and Diagnostics	CFA	Architecture
Education	Master of Music in Music Education	CFA	Music
Education	Master of Educational Technology & Applied Learning Sciences	SCS/DC	HCI
Energy	Master of Science in Energy Science, Technology and Policy	CIT	Interdepartmental
Health	Master of Science in Health Care Policy and Management	Heinz	Public Policy & Management
Industry	Master of Entertainment Industry Management	Heinz/CFA	Public Policy & Management (Heinz)
Infrastructure	Master of Science in Advanced Infrastructure Systems	CIT	CEE
Innovation	Engineering Technology and Innovation Management	CIT	Interdisciplinary
Innovation	Master of Arts Management and Graduate Degree in Innovation and Organization of Culture and the Arts	Heinz	Public Policy & Management

Innovation	Biotechnology Innovation and Computation	SCS	Computational Biology/Language Technologies Institute
Innovation	Master of Integrated Innovation for Products and Services	Integrated Innovation Institute	
Learn	Master of Educational Technology & Applied Learning Sciences	SCS/DC	HCI
Learn	Machine Learning	SCS	Machine Learning
Material	Materials Science	CIT	MSE
Material	Materials Science and Engineering	CIT	MSE
Sustainable	Master of Science in Sustainable Design	CFA	Architecture

Doctoral Degrees

Keyword	PhD	College	Department
Building	Building Performance and Diagnostics	CFA	Architecture
Econ	Economics	Tepper	
Econ	Economics and Public Policy	Tepper and Heinz	
Infrastructure	Advanced Infrastructure Systems	CIT	CEE
Learn	Neural Computation and Machine Learning	DC/SCS	Center for Neural Basis of Cognition/ Machine Learning
Learn	Statistics and Machine Learning	DC/SCS	Statistics and Data Science/Department of Machine Learning
Learn	Machine Learning and Public Policy	Heinz/SCS	Machine Learning
Learn	Machine Learning	SCS	Machine Learning
Material	Materials Science	CIT	MSE
Operation	Operations Management and Manufacturing	Tepper	
Operation	Operations Research	Tepper	

Appendix 5-4: Peer Universities' Sustainability Research Websites

The comprehensiveness of our peer institutions' sustainability research websites were evaluated. The information gathered is recorded in this appendix.

California Institute of Technology	Information provided on focus areas and research professors involved
Cornell University	Search engine with focus area, department and faculty
Duke University	Not as comprehensive, some focus areas found
Emory University	Not as comprehensive
Georgia Institute of Technology	Provides list of research centers
Massachusetts Institute of Technology	Provides information on focus areas, projects and faculty involved
Northwestern University	Focus areas provided
Princeton University	Research centers and focus areas provided
Rice University	Research centers provided
Stanford University	Research centers provided
University of Pennsylvania	Not as comprehensive, some focus areas found within a research center
Washington University in St. Louis	Research centers provided

Appendix 5-5: Peer universities' keywords and focus areas

This appendix presents the focus areas and keywords found from peer universities' sustainability research websites.

Institution	Keywords/Focus Areas
California Institute Of Technology	Department Of Environmental Science And Engineering: 1. Atmospheric Chemistry And Air Pollution 2. Environmental Chemistry And Technology 3. Dynamics Of Climate 4. Biogeochemistry And Climates Of The Past 5. Environmental Microbiology 6. Landscape Evolution Resnick Sustainability Institute: 1. Electricity Production 2. Fuel Production 3. Storage 4. Distribution 5. Energy Efficiency 6. Greening Industry
Cornell University, David R Atkinson Center For A Sustainable Future	1. Agricultural Development 2. Battery Research And Technology 3. Behavioral Adaptation And Response 4. Biodiversity 5. Biofuels 6. Biogeochemistry 7. Built Environment 8. Carbon Footprint 9. Carbon Sequestration 10. Citizen Science 11. Climate Change 12. Combustion Engineering 13. Communication 14. Community-based Approaches 15. Computation And Modeling 16. Computational Sustainability 17. Conservation Genetics 18. Crop And Livestock Improvement 19. Economic Development 20. Ecosystem Protection And Revitalization 21. Ecosystem Services 22. Energy 23. Energy Demand Management 24. Energy Efficiency 25. Energy Storage 26. Energy Transitions 27. Environment

	28. Environmentalism 29. Extreme Weather 30. Forest Ecology 31. Fossil Fuels 32. Fuel Cells 33. Geothermal 34. Global Public Health 35. Human Health 36. Inequality And Development 37. Inequity And Social Justice 38. Invasive Species 39. Jobs And The Workforce 40. Landscape Restoration 41. Measurement And Indicators 42. New Materials 43. Nitrogen Pollution 44. Nutrition 45. One Health 46. Politics Of Sustainability 47. Population 48. Poverty Reduction 49. Pro-poor Financial Systems 50. Renewable Energy 51. Risk Communication 52. Rural Development 53. Smart And Local Electric Grids 54. Social Entrepreneurship 55. Solar Energy 56. Sustainable Agriculture And Food Systems 57. Sustainable Architecture 58. Sustainable Communities 59. Sustainable Enterprise 60. Urban Ecologies 61. Value Chains 62. Waste Conversion 63. Water Management 64. Wildlife Conservation 65. Wind Energy
Duke University	1. Conservation 2. Ecology 3. Oceanography 4. Restoration 5. Agriculture 6. Biology 7. Climate 8. Topography & Soils 9. Biodiversity 10. Smart Homes

Emory University	Not Listed
Georgia Institute Of Technology	1. Clean And Sustainable Fuels 2. Combustion Process Optimization And Pollution Control 3. Carbon Capture And Mitigation 4. Next Generation Water Purification Technology 5. Solar Power And Photovoltaics 6. Sustainable Urban Infrastructure Systems 7. Energy Management Programs 8. Power Grid Management 9. Electrical Testing 10. Water-energy-transportation Nexus
Massachusetts Institute Of Technology	MIT Energy Initiative: 1. Basic Energy Science 2. Built Environment & Infrastructure 3. Climate & Environment 4. Conventional Energy 5. Developing World 6. Energy Efficiency 7. Nuclear Energy 8. Policy & Economics 9. Power Distribution & Energy Storage 10. Renewable Energy 11. Transportation Environmental Solutions Initiative: 1. Sustainable Production & Consumption 2. Climate Science and Earth Systems 3. Cities & Infrastructure
Northwestern University	1. Solar Electricity and Fuels 2. Climate and Carbon Science 3. Catalysis and Green Chemistry 4. Water 5. Sustainable Materials 6. Resilient Communities
Princeton University	1. Carbon Capture and Sequestration 2. Carbon Mitigation 3. Climate and Energy Challenge 4. Climate Science and Modeling 5. Development Challenge 6. Earth History 7. Energy Conservation 8. Energy Policy and Security

	9. Energy Renewable 10. Energy Systems Analysis 11. Energy Technology 12. Environmental Biology, Chemistry, Conservation, Creative Arts, Ecology, Economics, Education and Communication, Engineering, Ethics, History and Justice, Humanities, Mitigation, Monitoring, Policy, Resources 13. Food and Agriculture 14. Geochemistry and Paleoclimate 15. Global Health 16. Grand Challenges 17. Health Challenge 18. Infectious Diseases 19. Oceanography 20. Oil, Energy and the Middle East 21. Sustainability Global Development 22. Sustainability Princeton 23. Sustainability Urban Design 24. Urban Challenge 25. Water 26. Water Challenge
Rice University	1. Energy 2. Carbon 3. Urban Issues 4. Nanosystems, Nanotechnology 5. Water 6. Carbon Sequestration
Stanford University	Woods Institute for the Environment: 1. Climate 2. Conservation 3. Food Security 4. Freshwater 5. Natural Capital 6. Oceans 7. Public Health 8. Sustainability Stanford Energy: 1. End Use/Efficiency 2. Energy Storage & Grid Modernization 3. Environmental Impacts 4. Fossil & Nuclear Energy 5. Policy & Economics

	6. Renewable Energy
University of Pennsylvania	Penn Center for Energy Innovation: 1. Energy 2. Solar 3. Photovoltaics 4. Fuel Cell 5. Nano 6. Thermoelectrics/Thermophotovoltaics
Washington University in St. Louis	International Center for Energy, Environment and Sustainability: 1. Water 2. Solar 3. Health 4. Ecosystems & Biodiversity 5. Energy, Poverty & Economics 6. Energy 7. Cities & Urban Design 8. Bioenergy 9. Carbon Capture Sequestration & Utilization 10. Climate Change McDonnell Academy Global Energy and Environment Partnership: 1. Aerosols and Air Quality 2. Aquatic Processes and Water Quality 3. Energy (Solar Energy; BioEnergy and Clean Coal Technologies) 4. Energy and Environmental Issues in Development

Appendix 7-1: Major Finances at Carnegie Mellon University

This appendix presents the overall endowment, revenue, and expenses for Carnegie Mellon University from 2013 to 2017.

	2013	2014	2015	2016	2017
Endowment	$1,075,637,000	$1,250,538,000	$1,338,224,000	$1,305,763,000	$1,719,679,000
Revenue	$1,065,466,000	$1,073,104,000	$1,112,381,000	$1,155,700,000	$1,175,312,000
Expenses	$1,023,415,000	$1,055,507,000	$1,078,388,000	$1,089,107,000	$1,128,254,000

Appendix 7-2: US University Endowments over One Billion Dollars

This appendix presents the endowment for US University with over one billion dollars in 2017.

Institution	2017 (billion USD)
Harvard University	36.021
Yale University	27.176
University of Texas System	26.535
Stanford University	24.785
Princeton University	23.812
Massachusetts Institute of Technology	14.968
University of Pennsylvania	12.213
Texas A&M University System	11.556
University of Michigan	10.936
Northwestern University	10.437
Columbia University	9.997
University of California	9.788
University of Notre Dame	9.352
University of Virginia	8.621
Duke University	7.911
Washington University in St. Louis	7.860
University of Chicago	7.524
Emory University	6.905
Cornell University	6.758
Rice University	5.814
University of Southern California	5.128
Dartmouth College	4.956

Ohio State University	4.253
Vanderbilt University	4.136
New York University	3.991
Pennsylvania State University	3.991
University of Pittsburgh	3.945
Johns Hopkins University	3.845
University of Minnesota	3.494
Brown University	3.245
University of North Carolina at Chapel Hill	3.027
University of Wisconsin–Madison	2.746
Michigan State University	2.683
California Institute of Technology	2.607
Williams College	2.568
University of Illinois system	2.557
University of Washington	2.529
Purdue University	2.425
University of Richmond	2.373
University of Rochester	2.350
Boston College	2.317
Amherst College	2.248
Indiana University	2.229
Pomona College	2.167
Carnegie Mellon University	2.154
University of California, Los Angeles	2.063
Rockefeller University	2.049
Georgia Institute of Technology	1.985
Boston University	1.957

Swarthmore College	1.956
Wellesley College	1.93
Grinnell College	1.871
Virginia Commonwealth University	1.843
Case Western Reserve University	1.799
University of California, Berkeley	1.795
Smith College	1.767
Tufts University	1.739
George Washington University	1.729
Georgetown University	1.662
University of Oklahoma	1.646
University of Nebraska	1.617
University of Florida	1.612
University of Kansas	1.612
University of Missouri	1.603
Washington and Lee University	1.547
Texas Christian University	1.521
Southern Methodist University	1.515
Bowdoin College	1.456
University of Iowa	1.387
University of Delaware	1.364
University of Alabama	1.351
University of California, San Francisco	1.307
Liberty University	1.291
Tulane University	1.288
University of Kentucky	1.285
University of Cincinnati	1.283

Lehigh University	1.278
Texas Tech University	1.262
Syracuse University	1.259
Baylor University	1.23
Rutgers University	1.22
University of Colorado	1.22
University of Tennessee system	1.215
Wake Forest University	1.205
Trinity University (Texas)	1.194
Baylor College of Medicine	1.166
University of Georgia & Related Foundations	1.152
Berea College	1.15
Saint Louis University	1.147
University of Utah	1.127
North Carolina State University	1.123
University of Maryland System & Foundation	1.099
Middlebury College	1.074
Princeton Theological Seminary	1.066
Wesleyan University	1.065
University of Tulsa	1.026
Vassar College	1.002

Appendix 7-3: Endowment Per Student for Peer Institutions

This appendix presents the endowment per student for Carnegie Mellon University and its peer institutions.

Institution	Endowment (Billions)	Full Time Students	2017 Endowment Per Student	2007-2012 Endowment Per Student
California Institute of Technology	2.607	2,240	$1,163,839	$803,681
Carnegie Mellon University	**2.154**	**13,961**	**$154,287**	**$89,986**
Cornell University	6.758	23,600	$286,356	$180,466
Duke University	7.911	15,192	$520,735	$343,975
Emory University	6.905	15,252	$452,728	$323,284
Georgia Institute of Technology	1.985	29,370	$67,586	$74,480
Massachusetts Institute of Technology	14.968	11,466	$1,305,425	$943,093
Northwestern University	10.437	21,421	$487,232	$294,532
Princeton University	23.812	8,273	$2,878,279	$2,154,227
Rice University	5.814	7,022	$827,969	$696,316
Stanford University	24.785	17,178	$1,442,834	$1,124,105
University of Pennsylvania	12.213	21,907	$557,493	$276,355
Washington University in St. Louis	7.860	15,303	$513,625	$389,597

Appendix 7-4: Expense and Equity Ratio for Peer Institutions

This appendix presents the percent change in expense ratio and equity for Carnegie Mellon University and its peer institutions over the period of 2007 to 2012.

Institution	Expense Ratio Change (%)	Equity Ratio Change (%)
California Institute of Technology	4	-15
Carnegie Mellon University	**18**	**1**
Cornell University	32	-7
Duke University	31	-10
Emory University	18	-5
Georgia Institute of Technology	1	1
Massachusetts Institute of Technology	22	-9
Northwestern University	34	1
Princeton University	68	-6
Rice University	68	-6
Stanford University	-15	-4
University of Pennsylvania	20	-6
Washington University in St. Louis	39	4

Appendix 7-5: Top 50 Alumni Networks in US

This appendix presents the 50 most highly rated alumni networks in the US for 2016. Two major metrics and an overall score were provided by *Best College Values.*

Institution	Fraction of Alumni In Management Positions	Fraction of Alumni Giving	Overall Score
Stanford	0.3668	0.34	30.53
Harvard	0.347	0.37	30.42
Columbia	0.3358	0.34	29.67
Dartmouth	0.3962	0.49	28.64
Notre Dame	0.3109	0.44	28.35
Northwestern	0.3806	0.31	28.10
Cornell	0.3384	0.31	28.07
Yale	0.3303	0.38	27.82
Duke	0.2966	0.38	27.30
Southern California	0.3008	0.43	27.27
MIT	0.3696	0.36	26.66
Princeton	0.3282	0.60	26.25
Pennsylvania	0.2864	0.08	26.04
Georgetown	0.3229	0.27	26.00
Cal Berkeley	0.2804	0.13	25.81
North Carolina	0.2334	0.22	25.32
Michigan	0.2674	0.16	24.77
Virginia	0.2991	0.22	24.55
Emory	0.285	0.36	24.52
Chicago	0.3191	0.32	24.34
Texas	0.226	0.15	23.61
Johns Hopkins	0.2602	0.33	23.28
Brown	0.3108	0.37	23.21

UCLA	0.2767	0.13	23.12
New York	0.2963	0.09	23.12
Wisconsin	0.224	0.12	22.40
Vanderbilt	0.2766	0.24	22.21
Penn State	0.2138	0.22	22.12
Indiana	0.2419	0.16	22.07
Rice	0.2766	0.33	21.51
Carnegie Mellon	0.2791	0.18	21.48
Washington	0.2309	0.16	20.52
Boston College	0.308	0.26	20.50
Purdue	0.2142	0.21	20.28
Georgia Tech	0.225	0.28	20.20
Maryland	0.2368	0.10	19.91
George Washington	0.2921	0.09	19.80
Ohio State	0.2416	0.15	19.45
Illinois	0.2359	0.098	19.33
Texas A&M	0.170	0.21	19.16
Georgia	0.2528	0.13	18.48
Auburn	0.2282	0.32	18.39
Minnesota	0.2348	0.14	18.04
Brigham Young	0.2269	0.18	17.96
Boston	0.3021	0.08	17.94
Clemson	0.2167	0.28	17.89
Alabama	0.2049	0.31	17.85
Florida	0.2493	0.16	17.79
Syracuse	0.2959	0.17	17.76
Michigan State	0.2422	0.15	17.7