Development, evaluation, and implementation of the SWEEP+ Standard at WPI and beyond

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Report submitted to:

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This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on the web without editorial or peer review.

Abstract

This project examined WPI's waste management practices and identified the structural weaknesses in the system of waste actors that prevent efficiency and sustainability. Additionally, this project contributed to the development of a waste certification, the SWEEP+ Standard for campuses. In this process, the project determined steps that WPI needs to take to improve its waste management systems and become a SWEEP+ Standard pilot member. Through the creation of a collaborative Waste Task Force and an interdisciplinary institute for sustainability, WPI can greatly advance its strides to become a living laboratory for waste innovation.

Acknowledgements

First and foremost, I would like to thank my department advisors, Prof. Katherine Foo, and Prof. Sarah Strauss, for their continued interest in my education and for their role in making this project come alive. Their wise advice can always be counted on.

This project would not have been possible without Rob Watson, who gave me the opportunity to work on an initiative that calls for a waste revolution. He was instrumental to increasing my understanding of and excitement about the considerations of waste sustainability and certifications.

I would also like to thank the countless people who participated in this project and enriched my understanding of waste at WPI. To the WPI staff, thank you for your time and willingness to share your perspectives. Special thanks to Nicole Luiz, Energy and Sustainability Manager, for always responding to my inquiries and to Company B for going above and beyond for me to explore this interest.

Furthermore, I could not have done this without the great team of women at the Cornell University Sustainability Consultants student club. Emma, Nuo, Sophie, and Annie, I will miss collaborating with you.

This project concludes my Bachelor's degree in Environmental and Sustainability Studies. I thank all the people – peers, professors, teachers, friends, family, advisors, staff – who have helped me get this far. Let us all continue to fight for a more just and sustainable future.

Executive summary

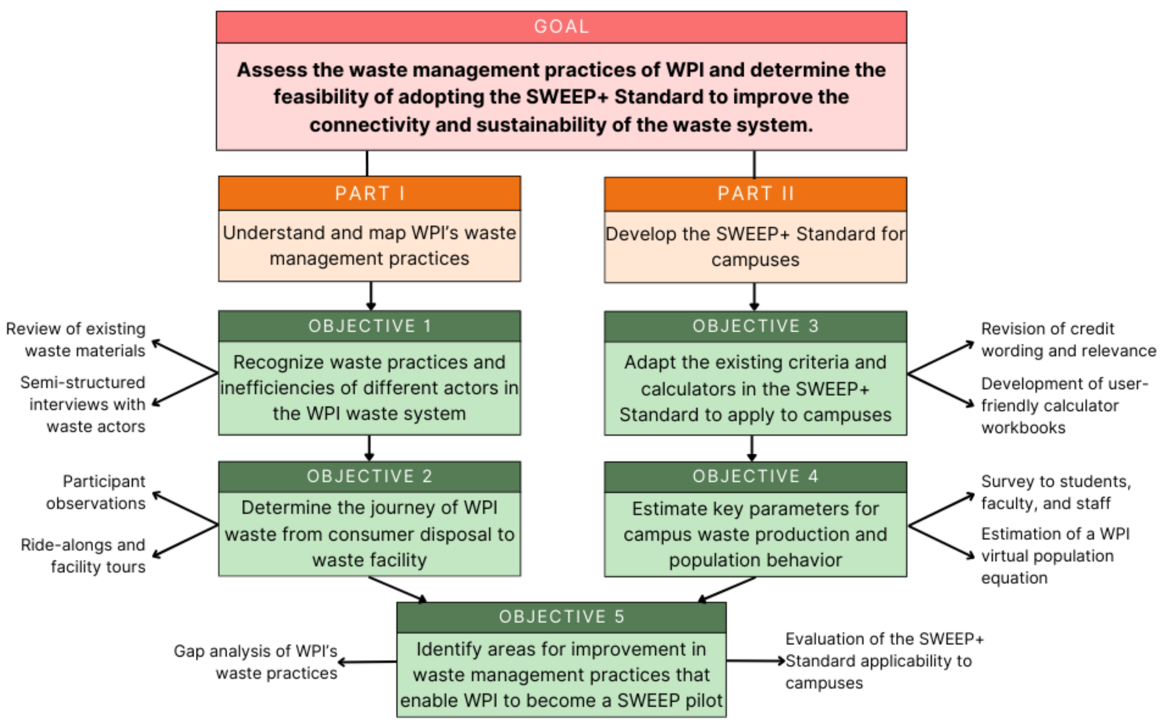
Background

High rates of waste generation are becoming increasingly worrisome due to materials' persistence across centuries and the lack of sophisticated waste management practices to assimilate them. In Massachusetts, a shortage of landfills has resulted in waste hauling across states for disposal. Current outdated waste practices deeply affect sustainability and public health via pollution and carbon emissions. The Solid Waste Environmental Excellence Performance (SWEEP) organization seeks to tackle ineffective waste management practices through a certification, the SWEEP+ Standard. Through a combination of compliance in required, optional, and innovative credits, municipalities and industries have begun their journey as SWEEP+ Standard pilots. SWEEP is interested in extending the certification to campuses. WPI faculty have expressed their interest in WPI being certified as a SWEEP+ pilot member, but little is known about waste management practices at the institution. WPI's waste practices are currently at a crossroads, representing an opportunity for sustainable change.

Methodology

This project addressed the internal gaps in understanding of WPI's waste management practices and analyzed weaknesses in the system that prevent waste sustainability. Additionally, this project contributed to the development of a SWEEP+ Standard for campuses, including the drafting of criteria, calculators, and thresholds. The methodology of this project incorporated reviews of prior WPI waste-related materials, interviews, participant observations, facility tours, ride-alongs, surveys, and a gap analysis. Four objectives, separated in two parts, resulted in the completion of a final, comprehensive objective (Figure I).

Figure I: Visual depiction of project methodology



Results and discussion

Objective 1

Through analysis of existing waste-related materials and semi-structured interviews with waste actors, I found that there are many initiatives for waste sustainability on campus but that they either stall or progress inefficiently due to a lack of continuity through time and space. Actors act independently rather than collaboratively, hindering the system's potential to devise, implement, and evaluate sustainable strategies. Additionally, high turnover in employment and the absence of a strong network of actors results in the inability for initiatives to expand and persevere.

Waste initiatives that were identified at WPI included an annual waste audit, a switch in dining hall utensils, the implementation of reusable containers, the Campus Race to Zero Waste competition, Project Zero Waste, Waste Not, and a search for food waste disposal alternatives. Many actors were involved with these initiatives, but they often terminated their participation. Contradictory statements from different actors about certain initiatives were of particular concern since they exemplified the lack of system-wide cooperation.

Objective 2

In Objective 2 I mapped out the journey of waste from initial to ultimate disposal. This system is generally obscured: custodians empty bins out of sight, compactors are hidden behind buildings, and consequences of waste are ignored. The stepwise journey of trash revealed inefficiencies along the way that incumbered best practices for waste sustainability at WPI.

At WPI, there are recycling and trash receptacles all around, which are collected by custodians when full. Food waste bins are only located at two of the dining locations. Chartwells has an informal arrangement with a pig farmer who collects food waste from campus. However, the factuality of pickups by the pig farmer were highly contested by different actors. In this cloud of confusion, the custodial staff had been trained to dump food waste into normal trash cans, really exemplifying the disconnections in the system.

Company B is responsible for hauling both the solid waste and recycling compactors from campus to the facilities. The truck driver picks up one compactor, drives to the facility, weighs the compactor, waits for its turn to dump, dumps the waste, and returns the empty compactor to WPI. The idling time at the facility while waiting to dump waste is highly variable but can be as long as two hours during peak times.

WPI's recycling is taken to a Casella Waste Systems transfer station in Auburn. This facility uses a combination of manual, mechanical, magnetic, and optical methods to sort trash. The sorted materials are compressed into balers, which are sold for reuse. On the other hand, WPI's solid waste is taken to a waste-to-energy facility operated by WIN Waste Innovations in Millbury. The facility burns trash and uses the heat to generate electricity. Waste-to-energy facilities are controversial due to concerns of air pollution, environmental justice, and high costs of operations. However, in Massachusetts, landfill capacity is limited, so without waste-to-energy plants, waste would have to be hauled across state lines to emptier landfills.

Objective 3

With the help of the Cornell University's Sustainability Consultants student club, the existing SWEEP+ Standard materials were analyzed for relevance to campus environments. The language and content of credits for industries and municipalities were changed to reflect campus realities and feasibility of compliance. Additionally, campus-specific strategies for compliance were added to the certification document.

The calculators were amended based on the needs of campuses and the feedback received from current pilot members of the SWEEP+ certification. Calculators consist of Excel workbooks where each sheet corresponds to a data-input credit where applicants provide their numbers and calculations are made automatically. The team removed irrelevant inputs and added relevant ones such as how many residential students the campus hosts. Cells were then formatted using if-then and if-else statements as well as algebraic equations to sum and calculate rates, such as total costs per ton. In addition, default values were also included in the calculators to aid participants' estimations in cases where direct data is not available. The new calculators were developed with the hopes of streamlining the user experience by allowing the existence of a single data-input sheet that feeds other relevant cells.

Objective 4

The survey for students, faculty, and staff was designed to provide information about campus usage that would facilitate the elaboration of a virtual population equation. The campus virtual population is defined as the total population if all campus members were in the premises all day, every day. The survey found that residential students spent most of their time on campus while nonresidential students did not. These values were used to develop a virtual population equation.

By inputting WPI's population numbers into these equations, it was found that the academic year virtual population at WPI is around 3,936 people. Using WPI's waste data, I estimated that each virtual citizen produced around 30.68 pounds of waste per month and 5.52 pounds of recyclables per month. To help WPI keep track of waste generation and costs, a spreadsheet that took inputs from Company B's invoices and made useful calculations was created.

Objective 5

In the last objective, I conducted a gap analysis of WPI's current practices in respect to the requirements of the SWEEP+ Standard. It identified key areas for improvement and the associated costs, workforce, and changes that would have to be incurred or implemented in order to become a SWEEP+ Pilot and improve our waste practices. All in all, WPI's involvement in the SWEEP+ Standard as a pilot member is most threatened by the university's lack of documentation and quantification of waste.

This analysis also provided more insight into necessary changed in the SWEEP+ Standard. SWEEP should consider whether additional categories that are more meaningful to campuses should be added. In Objective 3, the goal was to change existing credits, both in language and in content. However, the addition of sections or credits was not considered. The gap analysis revealed how necessary additional sections might be, both for the development of a comprehensive certification for campuses and for the allocation of meaningful points.

Recommendations

As a result of my investigation, findings, and discussion, I have identified a set of recommendations for Worcester Polytechnic Institute (WPI) to improve its waste management system (1-3) and for SWEEP to improve the SWEEP+ Standard for campuses (4):

1. Establish a Waste Task Force to analyze WPI's practices and determine possible solutions from a synergistic standpoint, resulting in a WPI Waste Management Plan.
2. Develop an implementation roadmap towards SWEEP+ Standard certification by delegating responsibility, creating detailed policies, and establishing procedures for waste quantification.
3. Coordinate waste efforts through a sustainability institute for student and faculty projects that embraces the notion of WPI as a living laboratory for sustainability and synchronizes student and faculty sustainability projects.
4. Expand the SWEEP+ Standard to better capture possibilities in campus settings by adding a new category that encompasses curriculum and academics.

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1. Introduction

The world today faces a monumental challenge in waste management, a vital concern affecting public health and the environment. The waste management industry has fallen behind the times and is failing to expand its capacity while simultaneously adapting to our growing understanding of sustainability. Against the backdrop of rapidly increasing waste generation, exacerbated by rapid urbanization and consumer lifestyles, the need for effective waste management systems is more urgent than ever. However, waste management systems are heavily fragmented, with little communication or transparency between actors from consumer disposal to ultimate end-life. This disjunction significantly impedes hopes of comprehensive solutions to waste management.

This research project embarks on a comprehensive exploration of waste management practices at Worcester Polytechnic Institute (WPI), a university in Worcester, Massachusetts. WPI is currently at a crossroads: it recently elected a new president, changed waste vendors after decades of constancy, and began a new chapter in its sustainability goals. However, little is known about campus waste, even by the university about its own campus. The goal of this project was to better understand the key players in the waste system, to identify gaps in efficiency, and devise opportunities for improvement.

The university's faculty have expressed their strong support for increased campus-wide attention to solid waste management through participation in a novel sustainability certification called Solid Waste Environmental Excellence Performance (SWEEP). This standard has recently premiered and is undergoing a pilot period with industries and local municipalities. The SWEEP+ Standard is a promising framework for sustainable waste management. Building on the legacy of the LEED certification, the SWEEP+ Standard aims to foster best practices and sustainable policies in the waste management industry.

SWEEP hopes to expand its applicant pool by including universities and colleges, which are of significant interest due to their capacity for innovation and applied research. I worked alongside SWEEP executives and student groups across the country to reimagine the SWEEP+ Standard to be applicable for campuses, altering existing credits and calculators to fit the realities of campus waste management. In light of these changes, this project explored the potential of applying the SWEEP+ Standard at WPI, with a focus on the feasibility of adoption and opportunities for innovative involvement.

Through a multidimensional methodological approach that included interviews, participant observation, tours, surveys, and a gap analysis, I sought to analyze the behind-the-scenes work that keeps our campus clean. Moreover, I used my findings alongside the development of the SWEEP+ Standard for campuses to guide institutional waste transitions and uphold multi-actor collaboration. With much enthusiasm, this research project hopes to inspire further inquiry into waste management systems and frameworks for improvement in efficiency and sustainability by all who wonder what the future of waste management might hold.

2. Background

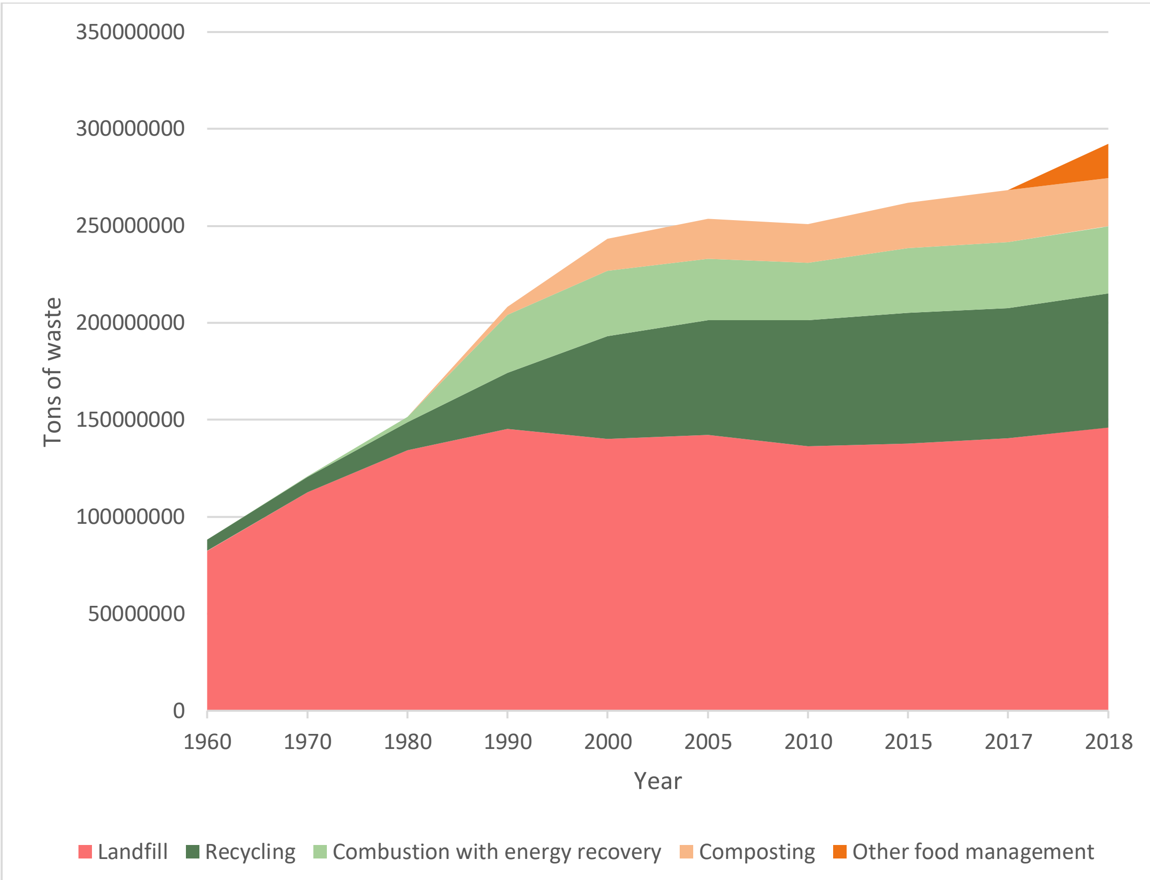
2.1 Waste management and its effects on public health and the environment

Ever since the skyrocketing of waste accumulation and unsanitary conditions at the advent of the Industrial Revolution, societies have developed systems of organized waste management. What was once a small volume of waste, easily decomposable by the elements or communal burning, has transformed into a USD$1.3 trillion industry that manages upwards of two billion tons of waste annually (Alves, 2023; Kaza et al., 2018). Unlike earlier biodegradable waste, much of the waste we produce today will persist across centuries, a worrisome reality when coupled with the fact that the average person generates 0.74 kilograms (1.63 pounds) of waste per day. Waste generation varies greatly by country, with the average American producing around 2.21 kilograms (4.87 pounds) daily (Kaza et al., 2018).

Higher rates of municipal waste generation in recent decades, especially in economically developed countries, are the product of growth-focused urbanization, capitalist economic development, and population growth (Kaza et al., 2018). Specifically, overconsumption and convenience have restructured markets to flaunt waste-intensive products like single-use dental floss and bottles made from plastics. Additionally, the growth of consumer delivery markets has increased waste from packaging, such as cardboard boxes and styrofoam containers. These discarded products not only take significant energy inputs to be manufactured, transported, and processed, but then take up to hundreds of years to break down – far longer than the mere minutes of useful life they boast. In addition, they carry a hefty carbon footprint. Furthermore, dealing with this waste is expensive, costing up to 20% of municipal budgets (Kaza et al., 2018). With such high costs, better solutions for waste should be of interest to every taxpayer.

The absence of multi-level governance and regulation of waste has left the responsibility of waste management to local and private entities. This has contributed to a status quo where single-use products are widespread, and once a product is thrown away, the waste producer no longer faces the reality its lengthy existence. From the point of pickup, waste is typically sorted and transported to a range of facilities. In the United States, the most common "end life" for waste products is the landfill, followed by recycling, combustion, and composting, as shown in Figure 1 below. Some of these methods, like recycling and composting, hope to extract value out of waste by recirculating materials. Even with these practices, waste management is far from circularity, as less than a third of the waste is recycled, and when it is, it is usually downcycled (EPA, 2022).

Figure 1: U.S. municipal solid waste management tonnage breakdown: 1960-2018 (adapted from EPA, 2022)



Waste disposal and mismanagement can lead to significant adverse health effects, which are disproportionately concentrated in low-income and minority communities. Emissions from incineration contribute to worsening air quality, which in turn harms people's respiratory systems and may cause cancer (WHO, 2021). Improperly disposed specialty items, like e-waste and batteries, can damage organs and lead to developmental impacts, especially in young children (WHO, 2021). In landfills, toxins can leech into the soil and groundwater and pollute the land, restricting future uses. Many cases of public health disasters due to improper waste management exist. In New Orleans, Louisiana, for example, a landfill site was redeveloped as a residential area in a primarily Black neighborhood, which caused the residents to experience heightened cases of illness, including breast cancer, skin problems, respiratory problems, and other types of cancer (Blanco, n.d.). Well-established scholarship demonstrates that more vulnerable communities within countries are targeted as sites for landfills and other facilities, furthering inequality and discrimination (Bryant, 1995; Mohai et al., 2009). Uneven spatial impacts exist at the community, regional, and international scales. At a global scale, higher income countries with more stringent regulations export production and waste to lower income countries, increasing pollution in already vulnerable areas with less apt infrastructure (Ben Kheder & Zugravu-Soilita, 2008).

Poor waste disposal and collection is a global problem that causes in environmental and marine pollution, which can be devastating for biodiversity and climate systems. The marine debris problem is so severe that the oceans now host garbage patches that cover areas as least twice as big as the state of Texas. The consequences of pollution have made headlines in recent years, specifically through viral stories of sea turtles confusing plastic bags for jellyfish and dead birds with hundreds of microplastics inside their stomachs (WWF, n.d.; Turns, 2023). In addition, waste disposal sites emit greenhouse gases as waste breaks down. In the U.S. alone, municipal landfills are responsible for over 82 million metric tons of carbon dioxide equivalent yearly and are the third largest source of anthropogenic methane emissions nation-wide (EPA, 2023a; EPA, 2023c). These emissions continue to enhance the greenhouse effect and warm the planet, leading to a plethora of adverse effects including sea-level rise, extreme weather events, mass extinction, collapse of food systems, and disruption of human livelihoods.

Understanding the root problem in waste management involves acknowledging the current system's reductionist nature and lack of "flexibility and long-term thinking" (Seadon, 2010, p. 1639). Sustainable waste management requires greater system-wide sophistication and innovation. Meanwhile, the U.S. population and GDP continue to grow, and development drives overconsumption. Current systems may become insufficient to keep up with ever-growing demand. In fact, landfill capacity in the United States is steadily decreasing, and the Northeast, the most affected region, has lost 30% of its capacity in the past five years (Thompson & Watson, 2018). To deal with excess waste generation, many states have turned to waste hauling across states. This practice, however, only works as a momentary fix as it increases costs, reduces sustainability, and fails to address the problem at the root. Long-term, holistic, environmentally conscious, cost-effective solutions are key to revolutionize the industry and secure a safe future on Earth.

2.2 The SWEEP+ Standard for campuses

In the late 1980s, voluntary sustainability certifications emerged as a means of filling the gap between insufficient government regulations and demand for greater sustainability (Lambin & Thorlakson, 2018). Certifications are born when a standards board proposes a set of standards, typically formatted as credits with respective points, that show compliance with specific goals. Entities then pursue these standards by providing documentation and participating in inspections carried out by the certifying agency (Otto & Mutersbaugh, 2015). If approved, the certified entity can display the achievement of having been certified as sustainable by a third party (Font & Harris, 2004). Voluntary environmental certifications allow communities enjoy the benefits of more rigorous standards that would otherwise take years to be established through regulatory action. Some argue that a certification can become a form of policy in and of itself, part of a hybrid governance for sustainability that grants a level of autonomy in regulation that is oftentimes reserved for the state (Lambin & Thorlakson, 2018). With widespread popularity, certifications can become industry standards or models that are further adopted and even legislatively sanctioned.

The Solid Waste Environmental Excellence Performance (SWEEP) organization was born in 2016 in hopes to identify and reward sustainable best practices and policies as well as the waste management service providers that support them (SWEEP, 2023). Rob Watson, SWEEP's founder and president, is a founding member of LEED, the world's most widely used green building certification. With a similar vision, the SWEEP+ Standard was developed as a sustainability certification with the hope of overcoming the solid waste industry's stall in the face of urgency.

The SWEEP+ Standard awards applicants (which, until now, included only local governments and industries) a maximum of 100 points across five performance categories: (1) sustainable materials management policy (SMMP); (2) waste generation and prevention (WGP); (3) solid waste collection (SWC); (4) post-collection recovery (PCR); and (5) post-collection disposal (PCD). Additionally, 10 bonus points are awarded for innovation in solutions. The certification allows entities to collaborate to achieve certain credits, awarding mutual points for partnerships between actors, like businesses and their respective waste vendors. Currently, the SWEEP+ Standard is undergoing a pilot stage with nine local governments and three industry participants. Feedback thus far has been promising, prompting the organization to expand its scope to include campus applications. Campuses fall somewhere in between governments and industries. Like governments, they house residents, host businesses, offer a variety of services, and engage communities. Like industries, they contract vendors, attract customers, and push the limits of technological advancement. As a result, SWEEP+ can be adapted to include campus applicants by adapting and complementing existing materials.

Campuses produce significant amounts of waste via their students, staff, faculty, and other members. Little is known about campus waste, which typically falls at the bottom of priorities for campus sustainability, which in turn is often the least of concerns of campus administrations. Successful programs for environmental stewardship on campuses possess the following characteristics: positive executive support, a written environmental policy, creation of a structural framework for planning, incorporation of environmental responsibility into the curriculum and research, campus ecological planning and design, development of a sense of place, measurable reduction of cost and waste, good public relations and documentation, financial accountability, and provision of leadership development and training (Mason et al., 2003). But institutions are far from attaining these characteristics in the realm of waste. Smyth et al. (2010) argue that few institutions, and even less institutions of higher education, have even achieved the first step of waste quantification and characterization. A waste certification could become crucial in prescribing pathways for institutions to follow in the establishment of a framework of documentation and oversight.

Additionally, including colleges and universities in the certification could be a game-changer for waste research. Campuses can act as real-world environments for applied research in sustainability and sustainable development. Although many universities offer courses about sustainability and promote clean technologies, they have generally failed at incorporating these practices institutionally for the co-production of sustainable realities. The goal is for institutions to become living laboratories for participation and active citizenship, connections with nature, respect for the environment, and energy efficiency and sustainable consumption (UNESCO, 2021). Evans et al. write that "universities concentrate huge amounts of untapped human resources" which can be used at living laboratories by emphasizing co-creation and an iterative process (2015, p. 1). With SWEEP's emphasis on innovation, the certification could become a launching pad for students to explore sustainable waste management and possibly innovate industry practices.

2.3 Worcester Polytechnic Institute's waste opportunities

Worcester Polytechnic Institute (WPI) is a medium-sized private research university in Worcester, Massachusetts, which distinguishes itself through its commitment to a project-based curriculum. In recent years, more emphasis has been placed on the institution's environmental practices. In 2014, WPI established the Office of Sustainability, which develops five-year plans for sustainability on campus and releases yearly reports on progress. This plan embraces the concept of campus as a living and learning sustainability laboratory where on-campus projects, student clubs, research initiatives, and relevant departments drive potential initiatives. WPI has been awarded a Gold rating under AASHE's Sustainability Tracking, Assessment & Rating System (STARS) program. Despite the high overall rating, WPI received only 4.75 out of 8 possible points under the "Waste Minimization and Diversion" credit.

In 2022, WPI students presented an open letter to the university to demand divestment from fossil fuels with endowment funds. In support and as a response, the WPI faculty passed a resolution in 2023 titled "Divesting, Investing, and Transforming for Carbon Neutrality: Accountability in Energy Systems, Climate Action, and Sustainability at Worcester Polytechnic Institute." In it, faculty lay out a set of twelve recommendations to remedy WPI's sustainability shortcomings. One of these items proposes improvements in the waste category as follows:

> *Worcester Polytechnic Institute Faculty... strongly supports a broader level of campus-wide attention to solid waste management through participation in the SWEEP Standard or similar approach.*

Some research at WPI already focuses attention to solid waste management. Notably, WPI professors Dr. Brajendra Mishra, Dr. Adam Powell, and Dr. Yan Wang are involved in a cooperative research center, the Center for Resource Recovery and Recycling, which focuses on advancing technologies that recover, recycle, and reuse materials throughout the manufacturing process. Additionally, Dr. Berk Calli heads the Manipulation and Environmental Robotics Lab, which focuses on robotic manipulation projects that sort recyclables and recover metal scraps. Furthermore, Dr. Mingjiang Tao is leading research to synthesize and characterize a new type of cementitious material suing abundant industrial and energy wastes (e.g., fly ash, red mud, and rice husk ash).

With the decreasing capacity of landfills in Massachusetts, the university's steps towards better waste practices are of special importance. Currently, the system of waste management at WPI is primarily held up by two entities: the Facilities Office, which collects and empties trash cans campus-wide, and the waste vendors, who collect waste from campus and transport it to waste facilities. Beyond the two main entities, students, the Office of Sustainability, the Green Team student club, campus food provider Chartwells, and the waste facilities are all part of the greater system. The multiple entities that participate in the production, collection, disposal, and planning of waste have diffused responsibilities and poor communication among themselves.

For forty years, WPI contracted Company A for solid waste and recyclables collection and disposal without many changes in contract renegotiations. Company A is a large-scale waste management company that provides services to millions of households, businesses, industries, and municipalities. The vendor was responsible for developing and installing the infrastructure required for waste collection (i.e., the compactors) and collecting waste at varying frequencies throughout the year. The familiarity and comfort of a consistent vendor deterred WPI from making the drastic changes required for waste sustainability, such as the compilation of detailed waste data, diversion from landfills, and system-wide transparency.

In July of 2023, Company B replaced Company A as WPI's waste vendor. Company B is a regional family-operated waste management company. The novelty of the vendor to WPI has given the institution space to negotiate and request more information about waste. With this vendor, the university is able to gain more insight into waste production via monthly recounts of pickups and their respective weights. Furthermore, Company B's openness to collaboration has allowed WPI to increase its understanding and even alter waste practices that have been upheld for decades. As a result, a more strategic and sustainability-focused perspective has emerged with the collaboration of Company B's leadership. This relationship of flexibility and interest in sustainability places WPI (and even Company B) at a good starting point for the SWEEP+ pilot.

The collection of food waste, hazardous waste, and e-waste is independent from Company B and warrants additional plans for improvement. E-waste and hazardous waste are collected by two separate vendors who pick up the items periodically due to the much smaller volume. Food waste is handled through an informal connection with a pig farmer who collects leftovers from food halls and uses it as feed for livestock. This connection and arrangement are through Chartwells, the campus food provider. Massachusetts's Commercial Food Material Disposal Ban, which bans entities that produce more than half a ton of food/organic waste weekly from disposal of these materials, threatens WPI's compliance if the pig farmer terminates or pauses the agreement (Mass.gov, 2022). Thus, WPI is seeking a more permanent, formal solution to its food waste.

As is evident, WPI is at a crossroads in its waste management practices, which opens many opportunities for administrative, staff, faculty, and student involvement. The SWEEP+ Standard could provide a roadmap for achieving sustainability in waste and even reduce costs. An assessment of the steps it would take for WPI to become a pilot member is necessary to evaluate the commitment it would require from the university. For these reasons, this student project was designed to analyze and map WPI's waste practices and continue to develop the SWEEP+ Standard for campuses.

3. Methodology

This project addressed the internal gaps in understanding of WPI's waste management practices and analyzed weaknesses in the system that prevent waste sustainability. Additionally, this project contributed to the development of a SWEEP+ Standard for campuses, including the drafting of criteria, calculators, and thresholds. The methodology section describes how information was gathered, analyzed, and presented to inform the conclusions of this research study. The development of this methodology and report required careful consideration of ethical practices in human subjects research. An IRB exemption due to minimal risk was received for this project's methodology. Participants were asked if they wanted to review the report before submission, and a copy was provided to those who wanted it. Some participants decided to remain anonymous while others wanted to share their name in this report.

This project was realized through the following objectives, separated in two bifurcated but ultimately interactive parts, summarized visually in Figure 2.

Part I: Understand and map WPI's waste management practices

Objective 1: Recognize waste management practices and inefficiencies from the perspective of different actors in the WPI waste system.

Objective 2: Determine the journey of WPI waste from consumer disposal to waste facility.

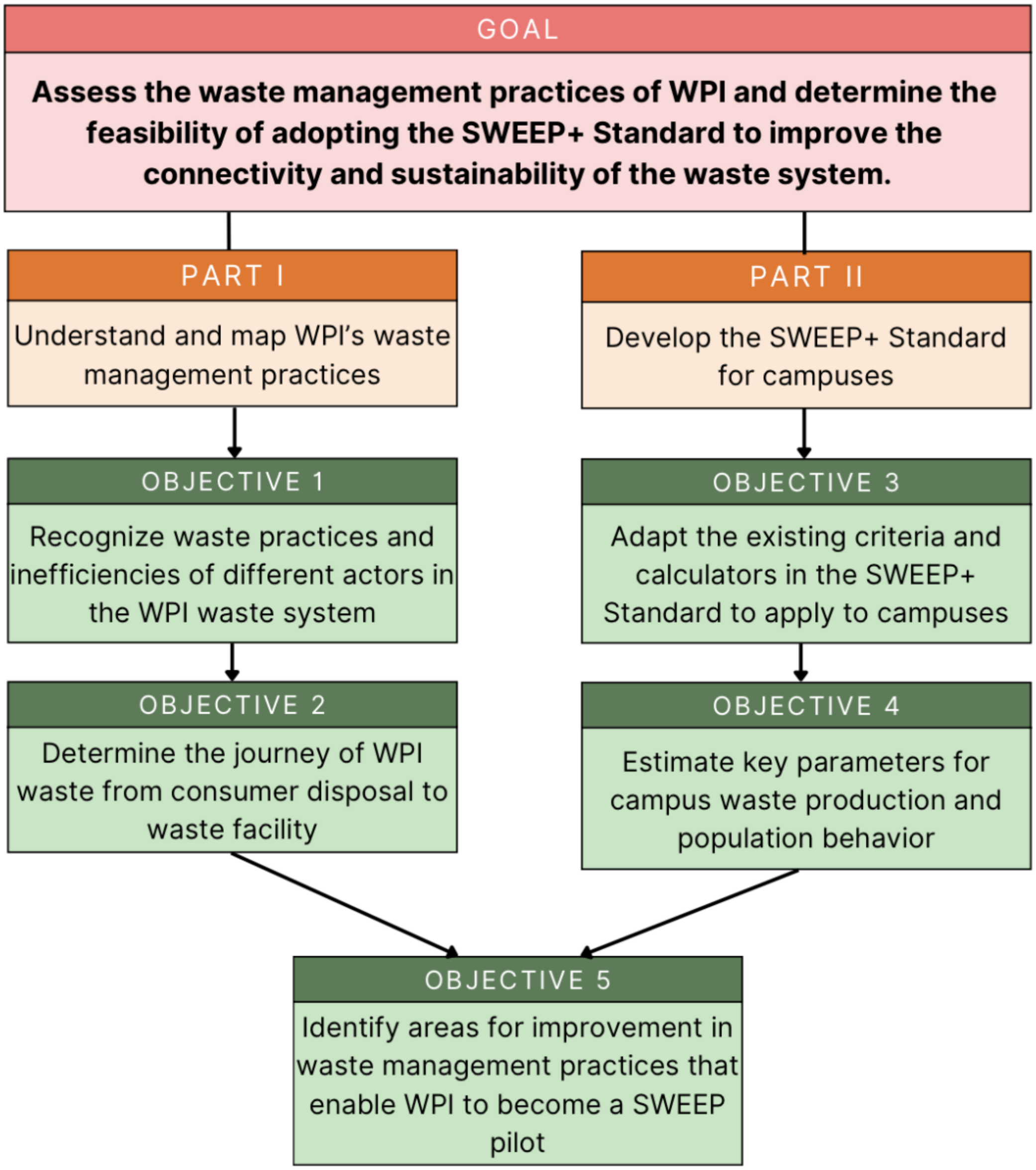
Part II: Develop the SWEEP+ Standard for campuses

Objective 3: Adapt the existing criteria and calculators in the SWEEP+ Standard for applicability to campuses.

Objective 4: Estimate key parameters, including campus virtual populations and average waste production at WPI.

Objective 5: Identify areas for improvement in waste management practices that enable WPI to become a pilot for the SWEEP+ Standard.

Figure 2: Visual depiction of project methodology



3.1 Objective 1: Recognize waste management practices and inefficiencies from the perspective of different actors in the WPI waste system

The first objective sought to identify the waste management practices and gaps in efficiency in waste actors across WPI. I used two different methods to do this. First, I reviewed previous student projects and sustainability materials at WPI to contextualize WPI's waste practices as far as they had been formalized. Second, I interviewed key figures in WPI's involvement in sustainability and waste management. By using these two approaches, I gathered information about what WPI is already doing, what issues are identified by stakeholders, and how much these stakeholders interacted with one another.

Data collection

To find previous student work about waste management at WPI, I searched the Digital WPI Library for key words including "waste," "waste management," "recycling," and "food waste," using filters by location. I also reached out to faculty involved in campus sustainability who had advised many on-campus projects, who pointed me to a Canvas course with previous project listings and reports. Sustainability materials, including WPI's annual sustainability reports and five-year plan, were gathered from the WPI website.

Semi-structured interviews were arranged with Paul Mathisen (Director of Sustainability for WPI), Nicole Luiz (Energy and Sustainability Manager for WPI), the Facilities Manager for WPI, Denis Brown (Resident District Manager for Chartwells, the food provider at WPI), Gabriel Espinosa (President of the Green Team at WPI), and the CEO of waste vendor Company B. Each participant was asked exploratory questions about their involvement in WPI's waste systems and any gaps or inefficiencies from their perspective. Interviews with varied participants allowed me to explore the specific expertise and experiences of each group. Due to the semi-structured nature of the interviews, I was able to not only capture the explicit content of the conversations but also to delve into the underlying ideas, assumptions, and conceptual structures that emerged. Interview questions are included in Appendix A.

Analytical approach

Previous works were analyzed by identifying existing waste initiatives at WPI and noting existing connections between actors. These themes and topics were followed up on to validate their progress and used in the unstructured interviews to ask for participants' knowledge and opinions about them.

The extensive conversations with various individuals were documented through detailed notetaking. Through these notes, I carried out a content-driven thematic analysis of the patterns that arose in the data (Guest et al., 2011). In this method, the researcher carefully reads and rereads the data looking for key words, trends, themes, or ideas that will outline the analysis before any of the analysis takes place. Overall, the goal of gathering this data was to lay an exploratory base for agents' knowledge about campus waste.

Research limitations

The main limitation of finding previous works about waste at WPI was that important studies and projects not indexed or housed within the WPI Digital Library or Canvas might have been overlooked, potentially omitting relevant findings. For the semi-structured interviews, a limitation that was encountered was the apprehension of some actors to participate in student research studies, which may have limited their responses. Moreover, actors with an economic stake in WPI's waste management may have skewed answers.

3.2 Objective 2: Determine the journey of WPI waste from consumer disposal to waste facility

The second objective mapped the disposal, collection, transportation, and treatment of waste from its origin at WPI to its end-of-life at waste facilities or beyond. I used ethnographic methods of participant observation, facility tours, and unstructured interviews to engage different actors in the waste management system. Furthermore, I used geographical data to map routes of transport.

With the completion of this objective, a more comprehensive view of WPI's waste system was produced, increasing the transparency and visibility of a hidden process.

Data collection

Participant observation sessions were arranged with WPI's custodians and Company B's garbage truck drivers. Custodians were shadowed during their trash collection duties in two buildings: a residential building (Institute Hall) and a recreational building with a dining hall (Rubin Campus Center). A ride-along with a custodian on WPI's trash truck was organized to observe the process of pick-up and drop-off at the compactors. Another ride-along with one of Company B's drivers was arranged to pick up solid waste at WPI, drop it off at the facility, pick up recycling at WPI, and drop it off at the facility. To better illustrate the gathered information from the garbage truck ride-along, a GPS-based app called RouteHistory was used to track the route that was taken and the time that was spent loading, driving, idling, and dumping. During all of these observation sessions, clarification and open-ended questions were asked.

Tours were also scheduled at the two primary facilities that treat WPI's waste, WIN Waste Innovations in Millbury, MA and Casella Transfer Facility in Auburn, MA. During these tours, myself and other tour-goers asked questions from the experienced employees. Additionally, information gathered in the interviews I conducted in Objective 1 was also used to contextualize the work of each group.

Analytical approach

Detailed notes were taken during participant observations and facility tours. The data analysis for this participant observation study focused on synthesizing and interpreting the extensive observational data. For the custodian observations, the visiting of multiple buildings allowed for the identification of patterns and discrepancies in waste management practices.

The RouteHistory GPS data was analyzed to map out the routes, quantify time spent in different stages of waste collection, and identify potential areas for optimization. The findings from this analysis not only shed light on the operational aspects of waste management but also highlighted the human element in these processes, offering valuable insights for future improvements and policies.

Research limitations

One limitation of participant observations is the heightened carefulness of the subject when being observed, which might have misrepresented usual practices. For the RouteHistory tracking, one limitation was that GPS location data did not accurately record small movements like those made when loading and unloading the compactor from the truck.

3.3 Objective 3: Adapt the existing criteria and calculators in the SWEEP+ Standard for applicability to campuses

The third objective assessed the current SWEEP+ Standard (including criteria and calculators) for local businesses and industries and adapted it to campus environments. This objective was completed in unison with the Cornell University Sustainability Consultants student club, which has a subcommittee that has been working with SWEEP for multiple semesters, a process which has involved additional student groups in academic institutions. The collaboration across campuses and majors allowed for different expertise and skill sets to be used to their full potential. This objective was not fully completed by the end of this research study and will be continued in the future by other interested students.

Data collection

The SWEEP+ Standard for industries and the SWEEP+ Standard for local governments were collected from the SWEEP website. Calculators for requiring credits were provided to the student group by the SWEEP board of executives.

Analytical approach

Each credit was analyzed in tandem with its respective calculator in two teams. The standards team worked on the language of the credit, rewording criteria with campus terminology, deleting irrelevant sections, adding additional requirements, and proposing potential campus-specific pathways to compliance. The calculator team took the newly crafted credits and incorporated changes into existing calculators in Excel. Special attention was paid to the user experience, including the cross-population of tabs through a single input sheet and the use of accessible language in explanations. These changes were then reviewed by Rob Watson, President of SWEEP, who provided feedback. The final versions will be submitted to the SWEEP Standards Committee for approval once they are completed.

Research limitations

The main limitation of this method is that the campus certification is fully based on what was deemed necessary for industries and local governments, and although some new additions were included, there might be areas that are uniquely specific to campuses that were not yet addressed by the new certification.

3.4 Objective 4: Estimate key parameters, including campus virtual populations and average waste production at WPI

The fourth objective sought to establish some baselines about campus waste since the literature on the matter was very limited. These baselines allow SWEEP to have a ballpark idea about how students, faculty, and staff behave on campus, make use of its resources, and therefore generate waste. This objective developed an equation that incorporates students, faculty, and staff into a homogenous virtual population. This virtual population will simplify calculations per capita and standardize applicants' responses to better understand environmental impact. Furthermore, the data collected will serve to understand the campus population's attitudes towards sustainable waste management.

Data collection

A survey was used to achieve this objective. The survey targeted students, staff, and faculty at WPI and Cornell University. They were administered via email and through printed flyers with QR codes at both universities. The emails were sent to aliases within campus. They asked students, faculty, and staff about their usage of campus resources (amount of time spent and meals eaten). The survey questions are shown in Appendix B. Responses were recorded anonymously.

Analytical approach

The survey organized data based on the type of campus citizen (residential student, non-residential student, faculty, full-time staff, part-time staff). The average number of hours spent on campus and the average number of meals eaten weekly on campus by each group were calculated. With this information and existing national waste averages, an equation for the virtual population of a campus was developed using this data to inform coefficients, as shown below:

$$\begin{gathered} virtual\ population = \\ a * (\#\ of\ residential\ students) \\ +b * (\#of\ full\ time\ nonresidential\ students) \\ +c * (\#\ of\ part\ time\ nonresidential\ students) \\ +d * (\#of\ full\ time\ equivalent\ employees) \end{gathered}$$

Research limitations

The primary limitation of the survey is that it assumes time spent on campus and meals eaten on campus as the primary determinants of waste production on campus. This is a simplification of reality, but it allows SWEEP to make preliminary calculations about the estimated population.

3.5 Objective 5: Identify areas for improvement in waste management practices that enable WPI to become a pilot for the SWEEP+ Standard

The last objective identified key areas for improvement in WPI's waste management strategies. Additionally, it contextualized these gaps in relation to the SWEEP+ Standard, pinpointing specific changes that would need to be made in order to become a pilot member. This was done by using a gap analysis sheet devised by SWEEP to help prospective applicants understand achievements and expectations. This objective was crucial in developing a set of recommendations for WPI to reform its practices.

Data collection

All relevant data about WPI's waste management practices, including contracts with Company B, invoices from the waste vendor, weights of waste collected, and the existence of waste plans and goals, was requested from the Office of Sustainability. Furthermore, data about the number of students (residential or non-residential, undergraduate or graduate), number of employees (full-time or part-time), and use of dining halls (average meal swipes per day) were collected from the Office of Institutional Research, the Housing and Residential Experience Center, and Chartwells. Additionally, all gathered data from previous objectives was also used to inform this analysis. Paul Mathisen, who was responsible for WPI's STARS application, was consulted to find out and confirm what kinds of information WPI collects and does not collect, along with how difficult it would be to collect missing items.

Analytical approach

The collected data was used to fill out a gap analysis sheet provided by SWEEP, which included all current credits of the certification and the requirements associated with them. The original sheet was designed for local governments and industries, so it was slightly altered based on campus applicability (more about this in section 3.4). This sheet listed required submissions to SWEEP for successful certification and asked potential applicants to rate their compliance on a scale of “yes” (>80% compliance), “maybe/yes” (>60% compliance), “maybe/no” (>30% compliance), and “no” (<30% compliance). The virtual population calculated in Objective 4 was used to calculate WPI’s per capita waste production. The filled-out gap analysis sheet provided a recount of awarded points based on WPI’s inputs.

Research limitations

The main limitation to this approach was that the points allocation system has not yet been amended for campuses, so the gap analysis points calculations may not be an accurate reflection of WPI’s progress towards the SWEEP+ pilot. However, the breakdown per credit still provides useful information for the campus.

4. Results and discussion

This study revealed that the primary issues affecting sustainable waste management at WPI are a lack of communication and continuity in waste sustainability efforts, improper waste separation practices by both students and employees, and an absence of waste quantification and tracking procedures throughout campus. This project also amended the SWEEP+ Standard to become applicable to campuses but found that many of the current criteria fail to capture the essence of universities and their potential impact. The following sections present the findings and implications of each of the objectives. All together, they inform the deliverables, recommendations, and conclusions of the project.

4.1 Objective 1: Recognize waste management practices and inefficiencies from the perspective of different actors in the WPI waste system

The review of previous student projects and interviews with key figures in WPI's waste systems showed that many initiatives exist on campus but that they often stall or progress inefficiently due to a lack of communication and continuity across time and space. An overall absence of centralization has led actors to act independently rather than collaborate and share knowledge for best results. As it currently exists, the balkanized waste system is unable to devise, implement, and evaluate holistic strategies.

The review of previous student projects found five interactive qualifying projects (IQPs) that had explored waste practices at the WPI campus. These reports were written between 1994 and 2018 and were mostly focused on food waste and recycling. The main takeaways from each are described below.

- "Paper-recycling and paper-reduction possibilities at WPI" (Lof & Verhoef, 1994): This IQP was a first look at recycling at the institution that investigated possibilities of paper waste recycling and reduction with a focus on people's behavior. The authors suggested that adding more recycling bins and increasing students' excitement and willingness to partake in recycling efforts would improve recycling rates.
- "Management of waste at Worcester Polytechnic Institute" (Chaves et al., 2015): This IQP examined consumer waste sorting processes and efficiency at WPI and compared them to other institutions. Chaves et al. recommended better visual signage, annual trainings of Facilities' staff, more and more visible food waste bins, improvements to the WPI Sustainability website, posts on social media and emails to share information with students, standardized "slim-Jim" bins, and compostable utensils and plates in dining halls.
- "Improving WPI campus community recycling" (Dimestico et al., 2017): This project focused on developing recommendations to upturn campus recycling. These included a bulk plastic recycling pilot, specific and relevant recycling signage, and replacing non-recyclable materials with recyclable ones on campus.
- "Sustainability at WPI: Food waste management" (Cammarata et al., 2017): This project explored current disposal methods used by Chartwells and alternatives implemented at other institutions. Cammarata et al. recommended composting as a solution to food waste. Summaries of interviews with other institutions were included in this report and were helpful to identify possible interviewees and to gather additional data.

- “Waste reduction through a reusable container program” (Mooney et al., 2018): This IQP hoped to reduce disposable waste by assessing current practices, researching opportunities, and evaluating the feasibility of these changes. The authors recommended installing an external OZZI machine to encourage the use of reusable containers on campus.

Although these IQPs provided some valuable information to my understanding of waste at WPI, their results failed to provide a comprehensive picture of the waste system and of the progress towards waste sustainability. These shortcomings were apparent in three ways. First, only two of the IQPs engaged with our waste vendor at the time, Company A. When they did, contributions were limited to facility tours and short interviews. Second, no visualizations or methods for improvement in system-wide connectivity were developed or proposed by any of the groups. Third, it was unclear how any of the recommendations had been pursued (or not). These realizations guided the choice of methodology for a reevaluation of the waste system.

In the actor interviews, common themes included lack of connectivity and lack of continuance in sustainability initiatives. The Green Team and the Office of Sustainability are in frequent contact, but the Facilities Office was often isolated from their communication. This issue was previously identified and resulted in the creation of a new management position that reports to both the Office of Sustainability and the Facilities Office in 2022. Since, communication has reportedly improved among senior management, but did not appear to reach lower-ranking employees. Even with this new position, Chartwells, Company B, and other waste vendors acted as satellites to the waste system, orbiting the conversations without real involvement.

Chartwells is in recent contact with the Green Team following a change in leadership that has brought about more interest in dining hall sustainability. Chartwells is the only entity in contact with the pig farmer who collects WPI’s food waste, which led to misunderstandings in waste management practices and even to tension across the system. For example, custodial staff expressed that they had been incorrectly trained to dump food waste into regular waste bins because they believed there was no outlet for food waste at WPI. At the same time, the Facilities Office mentioned that lack of education on the student side prevented them from being able to recycle properly due to frequent contamination. These examples show how fragmented communication has adverse consequences for the efficacy of waste sorting programs.

Furthermore, high turnover combined with weak networks hindered the ability of waste initiatives to expand and continue over time. Interviews with actors in WPI’s waste system were used to follow up on initiatives revealed by the IQPs and sustainability reports as well as explore other waste sustainability projects currently ongoing. One significant finding was that intermittence in employment played a devastating role in the progress of initiatives. Interviewees from the IQPs mentioned that certain initiatives that had been underway were abandoned because the people in charge left WPI. This was not only true for WPI employees, but also for employees of waste vendors. According to the Office of Sustainability, Company A had, at one point, a sustainability representative who greatly supported on-campus sustainability initiatives. In 2021, this person stopped working at Company A and the position was not replaced, cutting off assistance in on-campus projects. Interestingly, none of the people that the IQP groups interviewed hold their roles as sustainability officers, facilities managers, student club executives, and dining hall managers at WPI anymore. This further explains the abrupt drop-off of certain projects and the inability of new ideas to materialize.

The review of previous student work and interviews with waste actors identified multiple initiatives that have been implemented at WPI. In the following paragraphs, I describe them along with their current status of operation, which people/offices are involved in their progress, and uncertainties that remain.

Annual waste audit

The Green Team, with the help of fraternity volunteers, conducts a waste audit once a year. The report calculates how much waste is produced, recycled, and wrongly sorted. These audits were halted post-covid but are set to restart in the 2023-2024 school year. In speaking with Company B and the representatives from our waste facility partners, it was revealed that waste audits are conducted periodically at the facilities as well. Representatives from the Facilities Office communicated that they have minimal involvement in these initiatives beyond carrying the trash bags to the designated audit location but would like to be more involved. They also commented that none of the results of this and other initiatives reach them after the reports are completed. At the same time, the Green Team mentioned that part of the reason why the audits are difficult to schedule is due to the Facilities Office' limited availability.

Dining hall utensils

According to past IQPs, campus dining halls used disposable utensils made of such low-quality plastics that their recycling was not possible. Chartwells had claimed that the reason they did not replace these was because the automatic dispensers required by WPI did not fit compostable utensils (Dimestico et al., 2017). Since, the Morgan Dining Hall and the Fuller Dining Hall have instituted the use of metal utensils that are washed and reused. At the Rubin Campus Center, utensils continue to be made from polystyrene (#6 plastic), which are not recyclable at the facility WPI uses. When asked, Chartwells described that the use of compostable utensils would be more expensive per unit, and that in order to use metal cutlery at the Rubin Campus Center, at least $50,000 would need to be allocated to a renovation of the dining facility.

Reusable containers

A 2016 initiative installed a "Green2Go" vending machine that allowed students to rent a reusable container that could be returned for a new one. This way, students could take food to go from dining halls without having to store it using single-use plastics. The implementation proved difficult because few students and faculty actually used the reusable containers, both due to lack of awareness about its existence and due to the inconvenience of fees (Mooney et al., 2018). Moreover, when the Mooney et al. IQP team inspected the machine, they found that it was broken. This team suggested that WPI use the commercial OZZI machine, which is more reliable and is compatible with WPI IDs. Currently, the OZZI system is in place in the Morgan Dining Hall. The Green Team is not in charge of this program on campus; rather, it is managed by Dining Services. The system has been tweaked to eliminate the need for a vending machine. Instead, students pay $5 to the Chartwells employee at the front of the dining hall to receive the container. The dirty container can be returned for a clean container or for a carabiner that can be later exchanged for a clean container. According to the Office of Sustainability, the program was originally introduced at the Rubin Campus Center and then expanded to Morgan Hall. However, according to Chartwells, the Rubin Campus Center does not count with the infrastructure or space to rent and store the containers. These contradictions highlight the gaps in communication between departments.

Campus Race to Zero Waste

In previous years, WPI participated in a nationwide university competition called Campus Race to Zero Waste (formerly known as RecycleMania). The competition is an 8-week program that asks campuses to weigh their waste and compare it to other institutions (Campus Race to Zero Waste, 2023). WPI participated in 2019 and received an Honorable Mention in the Food Waste category. According to the Green Team, we have not participated since because the program was not deemed effective by club executives. However, upon speaking with the Office of Sustainability, I learned that this initiative did, in fact, take place in early 2023 on campus, but without strong involvement with the Green Team. The WPI sustainability website has not updated any information about the initiative, which may hinder the flow of information.

Project Zero Waste

The Green Team hosted an initiative called "Project Clean Plate" starting in 2018 in the buffet-style Morgan Dining Hall. The goal was to reduce food waste generated by leftovers. Students with clean plates were given incentives, such as raffle tickets to win prizes. However, students and Chartwells employees raised concerns about the program because it shamed those struggling with food insecurity or eating disorders. As a result, the program was renamed "Project Zero Waste," and incentives were taken away. Different incentives were proposed, such as a university-wide reward in the form of a charitable donation of food or money to a local shelter if waste was reduced by 5% each term. However, the collaboration between the Green Team and Chartwells to make this happen was unfruitful, and inconclusive results from previous years further hindered the program's progress. The program was discontinued at the start of the 2023-2024 academic year, although the Green Team continues to work on creative ways to better engage the student population.

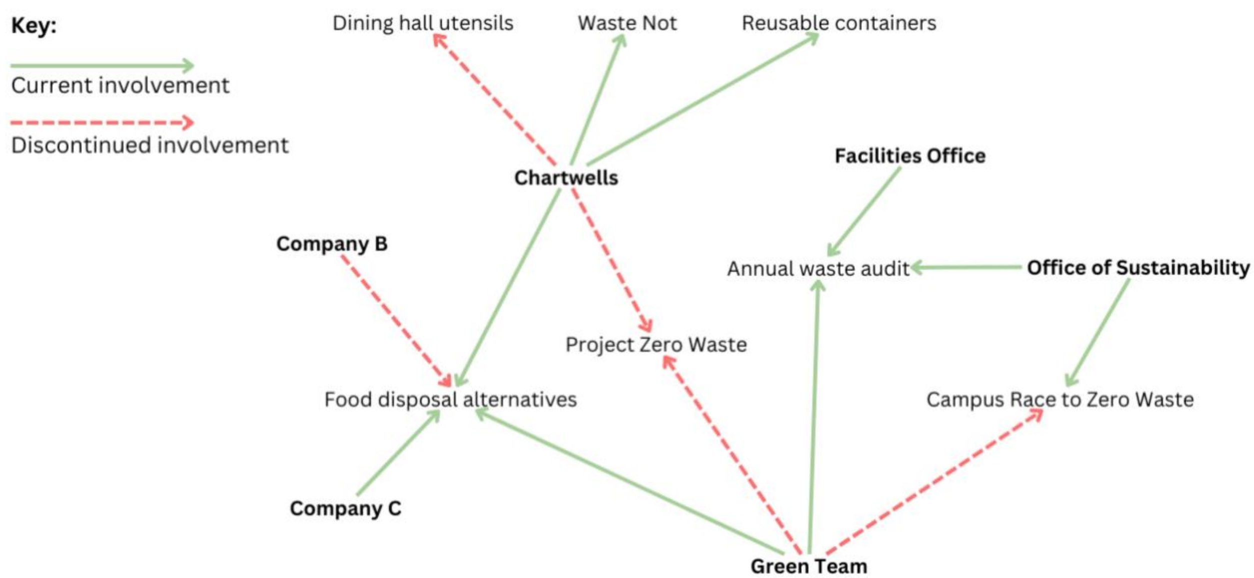
Waste Not

Waste Not is an initiative by Chartwells that has just started at WPI. The initiative consists of training kitchen staff about food waste and throwing away the least food possible. Employees use food scraps, such as vegetable cores and beef fat, in soups and stocks instead of disposing of them. When they do dispose of scraps, they do so in transparent bins with volume markings. The transparency of the receptacles allows for greater awareness of food waste and also helps managers to notice when scraps that could be reused are thrown out. When the bins are emptied, their volume is logged into a system that keeps track of food waste. Chartwells calculates that one quart of food waste costs them approximately $3, which is a significant incentive to reduce waste. Due to the program's novelty at WPI, data about food waste is not yet available.

Food waste disposal alternatives

One possibility for food waste management is that of an on-campus anaerobic digester that would support the ongoing campus energy transition by turning food waste into energy, a strategy that Massachusetts companies have started to adopt (Moran, 2022). However, per the recommendation of the IQP group, compost is the primary strategy being considered as a possible alternative to the pig farmer's informal collection of food waste from the dining halls. This recommendation is supported by Chartwells, which holds that the informality of the arrangement with the pig farmer is unreliable and prevents food waste metrics from being calculated. The absence of metrics negatively affects operations as little knowledge is gathered about food losses, which not only affects sustainability but also costs. During the interviews, it was learned that our current waste vendor, Company B, also collects food waste for feed for a local farm. The Office of Sustainability and the Green Team were initially unaware of this. The implementation of food waste collection by Company B would require installing a compactor and a deodorizer, as well as incurring hauling and per ton costs. According to Company B, our fees per ton would be reduced if we decided to go ahead with this plan because we would reach a threshold in pricing. The Green Team considered this option but decided that it was too costly and required significant implementation efforts. The Green Team and Chartwells prepared a proposal to complete a pilot program with Company C, a vendor that collects organic waste and composts it to generate fertile soil, which is then sold. At the time of writing, an official contract with Company C is being finalized to start a pilot program at select dining halls in the spring semester. If successful, the Green Team and Chartwells hope to expand the program campus-wide. A visualization of the initiatives along with the actors that manage them is shown in Figure 3.

Figure 3: Current and discontinued involvement of waste actors in waste initiatives



4.2 Objective 2: Determine the journey of WPI waste from consumer disposal to waste facility

The completion of the second objective revealed that the waste management process is hidden and invisible to the average consumer since custodians empty bins out of sight, compactors are stowed away behind buildings, and the consequences of waste are ignored by a public that deems them disgusting and disturbing. The obscure journey of waste from initial to ultimate disposal is quite intricate. It begins with consumer disposal, which is followed by waste collection by the Facilities Office. Once waste is in the compactors, it is transported by Company B to two facilities, the Casella Waste Systems transfer station and the WIN Waste Innovations waste-to-energy plant. The following paragraphs describe this process in detail based on the findings from participant observation sessions, facility tours, and open-ended interviews.

Consumer disposal

The first step is consumer disposal. Throughout campus, there are numerous bins for recycling and trash, color-coded based on their use. Food waste bins are located at two campus dining halls, but not elsewhere on campus. Above many of these receptacles, signs about appropriate sorting practices inform students about what is and what is not acceptable. Still, there is significant contamination of recyclables with non-recyclables, which slows down the sorting process for custodians and later at the recycling facility. At the recycling facility, I was able to inspect WPI's recyclables, shown in Figure 4. From this sample, plastic bags were a common misplaced item.

Figure 4: WPI's recyclables at the Casella facility

Facilities Office

The custodial staff at WPI (under the Facilities Office) is in charge of collecting waste and recycling, bringing them to the compactors, and replacing bags. The procedure calls for the use of green bags for recycling bins and clear or black bags for trash. The difference in color prevents confusion at the time of dumping. In buildings nearby the compactors, like the Rubin Campus Center, the custodians carry the bags to the compactors. In buildings farther away from the compactors, like Institute Hall, a custodian collects waste and places it in a designated area for pickup. A truck operated by another WPI custodian circles the campus, picks up trash bags, and transports them to appropriate compactors. Custodians check recyclables for excessive contamination. While I shadowed a custodian at the Rubin Campus Center for two hours, multiple recycling bags had to be thrown away as waste due to contamination from plastic cups filled with liquid. When the recyclables pass inspection, custodians place them into recycling compactors without the bags. However, as evident in Figure 4, multiple green plastic bags filled with recyclables were present in the recycling. This is of particular concern because it suggests a lack of training of custodial staff.

Food waste

Food waste on campus is being improperly handled due to a cloud of confusion about food waste disposal and a lack of campus-wide food waste receptacles. Food waste is not supposed to be handled by custodial staff. Rather, Chartwells employees dump food waste into barrels that are picked up by a pig farmer. During my investigation, I received very conflicting accounts about the pig farmer, an elusive figure known primarily by his title. Some said he did not pick up waste at WPI anymore; others said he came on a weekly basis. Some said that he was planning on retiring; others said that he was happy to continue collecting our waste. Some said he did not have the capacity for all the waste we produced; others said he asked for more. As this pursuit unraveled, the need for a project like this one became more and more apparent. Data collection should not be this complex and obscure; the facts about waste disposal should not be hidden behind layers of conflicting answers.

According to Denis Brown, head of Chartwells at WPI, the pig farmer comes weekly but has taken breaks as long as four months long in the past. During his breaks, food waste is just thrown away as solid waste. Crucially, custodial staff mentioned being trained to dump food waste into normal trash cans because they believed the pig farmer was no longer coming to WPI. It is likely that because of the pig farmer's unreliability and the contradictory accounts of his existence, the Facilities Office was unaware that he was, in fact, still coming to collect food waste. These stories encapsulate the structural challenges that WPI faces with different actors not knowing what the other is doing, which causes difficulty in serious planning when opposing truths and explanations are held up by different parties.

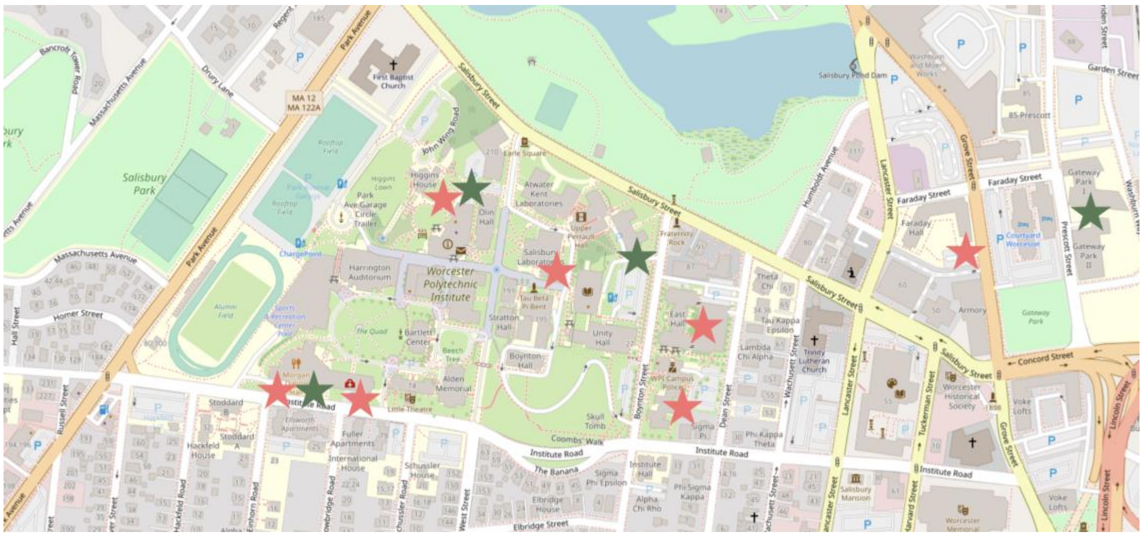
Food waste is also not collected campus-wide, both in kitchens and from student leftovers. Although the bigger dining halls collect food waste in their kitchens, smaller, restaurant-style locations do not. In much the same way, student food waste is only collected at the large dining halls, and there are no food waste receptacles outside of dining locations. Without a comprehensive system for food waste collection at WPI, it is understandable that custodians and students cannot get on the same page about proper practices for disposal.

The above-listed concerns show that food waste solutions at WPI are insufficient and may not be compliant with Massachusetts's Commercial Food Material Disposal Ban. Additionally, the informal nature of the arrangement with the pig farmer precludes WPI and Chartwells from collecting critical information about food waste production rates. Without a formalized pickup schedule on part of the pig farmer, realistic estimates about food waste generation are impossible. Chartwells and the Green Team have acknowledged this gap and, as previously mentioned in section 4.1, are actively pursuing alternatives for food waste on campus.

Compactors and within-campus disposal

WPI has 11 compactors (4 for recycling, 7 for solid waste) and 12 toters/dumpsters (2 for recycling, 10 for solid waste) throughout campus and WPI-owned housing. A map of campus compactors is shown in Figure 5. One question that was pending at the beginning of this study was whether quantification of waste per building would be possible. However, when the WPI truck collects and dumps waste, it takes it to whichever compactor is most accessible at the time, which depends on a variety of factors, including how full the compactor is and where the custodian is headed to. This practice, although practical, also prevents WPI from better understanding the major sources of waste on campus.

Figure 5: Distribution of recycling (green) and solid waste (pink) compactors at WPI



Company B

Once waste and recyclables are inside the compactors, Company B takes control. The frequency of collection varies by compactor and dumpster, ranging from once a week for high-traffic areas like the Rubin Campus Center to once a month for lower-demand residential buildings. To better understand the pick-up and drop-off process, I rode alongside a senior and experienced driver for Company B during a recyclables and a solid waste pickup. For most of WPI's needs, a rear-loading truck operated by a hydraulically powered fork picks up compactors and secures them to the vehicle, as shown in Figure 6. These trucks are very fuel inefficient, using a gallon of fuel per 4 to 7 miles traveled (the particular truck I rode on had an average rate of 5.3 miles per gallon). As a result, the proximity between the pickup location and the waste facility is a crucial determinant of sustainability.

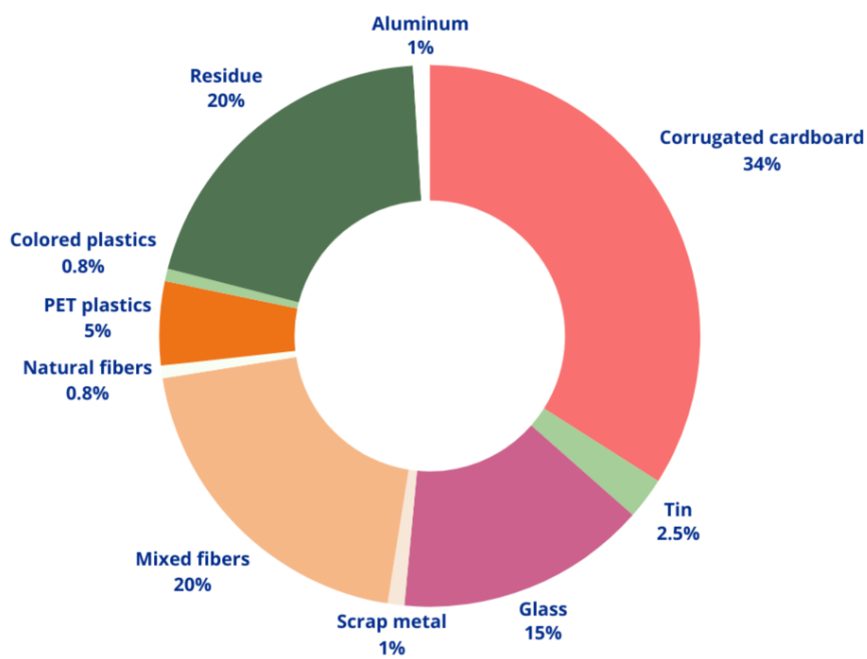
Figure 6: Garbage truck picking up the compactor at the Rubin Campus Center at WPI

Casella Waste Systems

The recycling facility is located in Auburn and is operated by Casella Waste Systems. This facility was retrofitted in 2005 into a single-stream recycling plant. It receives around 400 tons of recyclables per day, which are sorted by a combination of manual, mechanical, magnetic, and optical methods. Workers begin the process by removing bulky items and nonrecyclables from the stream. Then, glass is crushed and falls down through a screen that does not allow other materials to pass. Magnets separate ferrous metals from the remaining materials. Rollers are used to sort cardboard and paper, which then go to a stage of quality control to ensure there is no contamination. Plastics are then optically sorted by type using cameras, lights, and air jets. Lastly, nonferrous metals are extracted manually. All of the separated materials are then compressed into bales (shown in Figure 7) that are shipped out for profit. Glass is reused to make new bottles. Fibers are used to make lesser-grade napkins and paper. Plastics are reused as outdoor furniture and lesser grade containers. Metals are reused to make cans and lesser grade alloys. According to facility operators, the percent breakdown of materials is as follows: 34% corrugated cardboard, 20% mixed fiber, 15% glass, 5% PET plastics, 2.5% tin, 1% aluminum, 1% scrap metal, 0.75% natural fiber, 0.75% colored plastics, and 20% residue (see Figure 8). The primary cause of inefficiency in a transfer facility like this one is non-recyclable residues, particularly in the form of shredded paper and batteries. Shredded paper cannot be sorted by the mechanical processes and infiltrates the isolated materials at every stage. Batteries cause fires in the facility which pose danger to the workers and result in downtime.

Figure 7: Colored plastic and cardboard balers at the Casella transfer facility

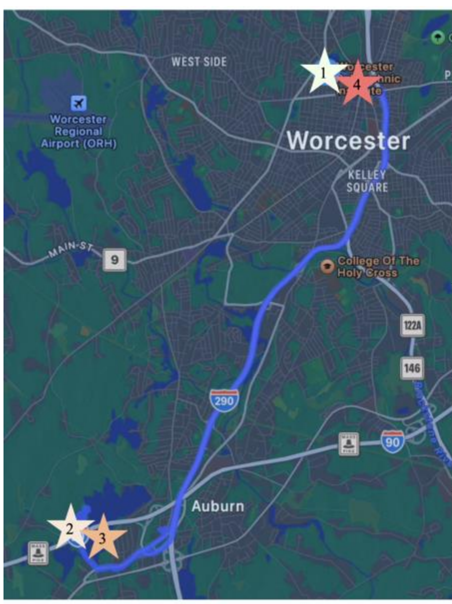
Figure 8: Percent breakdown of materials at the Casella recycling facility



The hauling of a compactor takes multiple steps. After unplugging the compactor from its energy source and loading it to the truck, the driver travels to the facility. At the facility, the truck passes through a large scale that weighs the contents of the compactor and the truck. Here, a ticket is created by a facility operator under the name of the vendor. The driver logs the arrival at the facility, the purpose of the haul, and the client's name into a truck-integrated tablet. Then, the compactor is unloaded and reloaded in the truck but in the opposite orientation to allow dumping. Once this is done, the driver joins the queue of trucks waiting to deposit their waste. The idling time is highly variable and inefficient. Wait times primarily depend on time of day, month of the year, and the availability of other nearby facilities. Trucks take turns to dump the waste in a designated area. After that, the compactor has to be turned around again to be in the correct position for drop-off on campus. Before departing from the facility, the truck is once again weighed. An invoice is then produced by the facility, which details the net weight of the waste. The driver inputs this information into the tablet system, which is how WPI later obtains weight data and is billing information.

On this particular trip, the dumping of recyclables at the Casella facility took a total of 66 minutes from pickup at WPI to return to WPI. The distance of this journey was of 21 miles, which required about 4 gallons of fuel. Idling time on this occasion was 15 minutes, a relatively low wait time according to the driver. These findings are shown in Figure 9 alongside a map of the route taken from WPI to the facility.

Figure 9: Description of the hauling route from WPI to the Casella facility



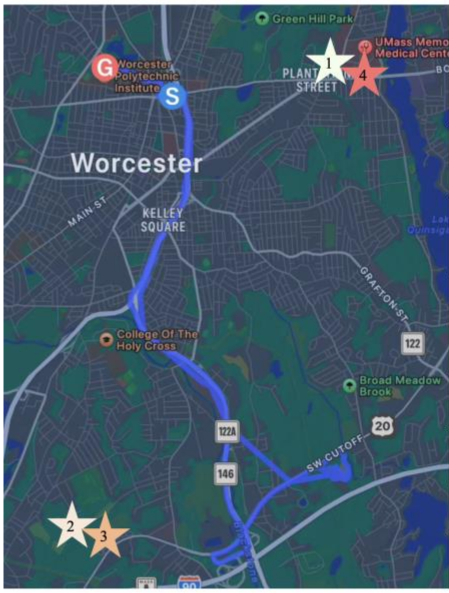
Marker	Description	Procedure
1	Pick-up at WPI	Loading of the compactor on the garbage truck
2	Arrival at Casella facility	Weighing of the truck and turning compactor around
3	Departure from Casella facility	Dumping and weighing of the truck
4	Return to WPI	Unloading of the compactor at WPI

Marker	Time elapsed (mins)	Distance (miles)	Fuel (gallons at 5.3 mi/gal)
1	0	0	0
2	24	10	1.9
3	39	11	2.1
4	66	21	4.0

WIN Waste Innovations

Company B returns the recycling compactor to the Rubin Campus Center and picks up the solid waste compactor. Like with the recyclables, the compactor is loaded, turned, dumped, turned again, and returned. The weight of the waste is measured in the same way, and Company B receives another invoice which is loaded onto their platform. For solid waste, WPI primarily uses a waste-to-energy facility in Millbury operated by WIN Waste Innovations (formerly known as Wheelabrator). In cases where the line to dump is too long, drivers are directed to go to the Casella facility in Auburn, which has a landfill operation besides the previously mentioned recycling plant. On this particular trip, the dumping of recyclables at the WIN Waste Innovations facility took a total of 110 minutes from pickup at WPI to return to WPI. The distance of this journey was of 15 miles, which required about 2.8 gallons of fuel (please note that this number does not account for the lengthy idling time because fuel consumption data per unit of idling time was not available). Idling time in this occasion was 60 minutes, a clear marker of inefficiency. According to the driver, although this was a long wait, it can sometimes take more than two hours to dump. These findings are shown in Figure 10 alongside a map of the route taken from WPI to the facility.

Figure 10: Description of the hauling route from WPI to the WIN Waste Innovations facility



Marker	Description	Procedure
1	Pick-up at WPI	Loading of the compactor on the garbage truck
2	Arrival at WIN Waste Innovations facility	Weighing of the truck and turning compactor around
3	Departure from WIN Waste Innovations facility	Dumping and weighing of the truck
4	Return to WPI	Unloading of the compactor at WPI

Marker	Time elapsed (mins)	Distance (miles)	Fuel (gallons at 5.3 mi/gal)
1	0	0	0
2	21	7	1.3
3	81	8	1.5
4	110	15	2.8

The WIN Waste Innovations facility (shown in Figure 11) is a waste-to-energy plant that has been in operation since 1987. It is capable of managing 1,500 tons of trash daily by combusting the waste in two burners. The waste is first dumped into a designated area, where it is picked up by two giant claws operated by two workers. The waste is fed into the burners consistently and gradually as to prevent overflow or underfeeding. In the facility, a small window provided a glimpse at the scorching trash, as seen in Figure 11. The carbon dioxide that is released from the combustion process is then used to generate electricity, which is sold into the Massachusetts grid. The released gases are stripped of toxins via scrubbers to comply with federal and state air emission standards. This facility produces up to 45 megawatts of power, which allow it to power its own operations as well as over 30,000 homes. The incineration process reduces the weight of trash by 80% and its volume by 90%. The remaining ash is taken to the WIN Waste Innovations ash landfill in Shrewsbury.

Figure 11: Millbury WIN Waste Innovations waste-to-energy facility

Waste-to-energy facilities like this one are highly controversial for a variety of reasons, including contributions to air pollution, environmental justice, and high costs. A 2019 report published by the Tishman Environment and Design Center found that the WIN Waste Innovations facility was among the top twelve dirtiest waste-to-energy facilities in terms of emissions of nitrogen oxides (3.42 pounds per ton of waste for a total of 1,586,220 pounds in a year) and sulfur dioxide (1.1 pounds per ton of waste for a total of 603,770 pounds in a year) (Baptista & Perovich, 2019). Although the concentration of these pollutants was below regulatory standards, these still affect residents' proclivity to respiratory infections, reduced lung function, asthma, genetic mutations, throat swelling, reduced female fertility, and worsening heart disease (Baptista & Perovich, 2019). The operators of the facility argue that the alternative – landfills – also release toxic chemicals but into the air, soil, and groundwater.

The report also found that 79% of waste-to-energy facilities in the United States are located in environmental justice communities, which are defined as communities with more than 25% of low-income and/or non-white residents (Baptista & Perovich, 2019). The Millbury facility surpasses both parameters. This means that the adverse health effects are concentrated in already afflicted communities. WIN Waste Innovations acknowledges environmental justice issues and pursues environmental action plans through partnerships with community leaders. These include contributing to STE(A)M education and mentor programs, offering on-site visits to the facility, and funding technology access for low-income students.

Another criticism of waste-to-energy facilities is that they are costly to operate. The Tishman Environment and Design Center report found that waste-to-energy facilities rely on selling electricity back to the grid to keep operations profitable (Baptista & Perovich, 2019). They charge

$8.33/MWh for electricity, which is almost twice as much as the second most expensive source of electricity, and four times as much as the third. Furthermore, many facilities classify for renewable energy subsidies, a policy that is highly contested.

Facility operators argue that waste-to-energy facilities and costs should not be considered in a vacuum but as an alternative to landfills. Unlike landfills, waste-to-energy facilities make a valuable byproduct from the trash. Additionally, they produce carbon dioxide instead of methane, which has a much higher potential for trapping heat in the atmosphere. Also, waste-to-energy facilities increase the state's capacity to assimilate waste. In Massachusetts, only 10 of the 50 total landfills are operational (EPA, 2023b). New waste-to-energy facilities are not being granted permits by the state, which is leading to an overwhelming demand of waste management being met with insufficient supply of services. As a result, Massachusetts now exports excess waste to other states who have more landfill availability, primarily Ohio. With no better large-scale solutions for Massachusetts facilities, the operation of waste-to-energy plants is crucial to public safety. However, there is no telling how much longer plants like these will continue to operate. Taking into consideration the low capacity of landfills in Massachusetts, innovation in waste management approaches is instrumental not only for achieving sustainability but also for securing public health.

4.3 Objective 3: Adapt the existing criteria and calculators in the SWEEP+ Standard for applicability to campuses

The students from Cornell University's Sustainability Consultants student club and I analyzed some of the SWEEP+ Standard's current criteria and calculators to determine their relevance for campus environments and to streamline data inputs. Table 1 provides some examples of how the criteria were adapted. Once all of the criteria are changed, they will be submitted to the SWEEP Standards Committee for review, feedback, and approval.

Table 1: Sample adapted SWEEP+ Standard criteria

<table>
<tr><th>Local government</th><th>Industry</th><th>Campus</th></tr>
<tr><td colspan="3">SMMP: Materials processing infrastructure and market development policy</td></tr>
<tr><td>Develop and adopt a policy that facilitates and supports the development of public and/or private processing and manufacturing infrastructure for recovered materials and incentives for purchasing the output of these facilities.</td><td>Not applicable.</td><td>Develop and adopt a policy that supports the development of local processing and manufacturing infrastructure for recovered materials. Create incentives for campus occupants to purchase the output of these facilities.</td></tr>
<tr><td colspan="3">SMMP: Solid waste greenhouse gas and air emissions footprint reduction policy</td></tr>
<tr><td>Tier 1: Adopt a policy to measure and reduce the per capita greenhouse gas OR adopt a policy to reduce other criteria air pollutants and HAP footprint of the collection, recovery and disposal of waste within the jurisdiction by at least 20 percent compared with a 2015</td><td colspan="2">Tier 1: Adopt a company or campus goal to measure and reduce the greenhouse gas footprint OR adopt a company or campus goal to reduce other air pollutants and HAP footprint of the collection, recovery and disposal of waste by the Company or Campus by at least 20 percent compared with a 2015 baseline within 5 years of</td></tr>
</table>

baseline within 5 years of policy adoption. Tier 2: Adopt a policy to measure and reduce BOTH the per capita greenhouse gas AND other criteria air emissions footprint of the collection, recovery and disposal of waste within the jurisdiction by at least 25 percent compared with a 2015 baseline within 5 years of policy adoption.	goal adoption. Require measuring and documenting GHG and toxic emissions with the best available technology that captures emissions/leakages throughout the entire system. Tier 2: Adopt a company or campus goal to measure and reduce BOTH the per capita greenhouse gas AND other criteria air emissions footprint of the collection, recovery, and disposal of waste by the Company or Campus by at least 25 percent compared with a 2015 baseline within 5 years of goal adoption. Require measuring and documenting GHG and toxic emissions with the best available technology that captures emissions/leakages throughout the entire system.
SMMP: Comprehensive sustainable materials management lifecycle analysis and policy program	
Tier 1: Develop a comprehensive 10-year (at a minimum) SMM, Zero Waste, Closed Loop, Circular Economy, or comparable plan that includes provisions for periodic updates to reflect new opportunities or significant legislative changes. Prepare a comprehensive waste characterization study (WCS) for materials handled within the local government jurisdiction. Conduct material-specific analysis for all material categories identified in the WCS that prioritizes policies and programs that provide the greatest environmental benefit. The analysis should assess environmental elements of the material categories, as well as social and economic elements of the material categories. Minimally, the assessment should include: • Evaluation and documentation of all GHGs, hazardous air pollutants, the number of people impacted within a given radius and the demographics and health disparities of the impacted population, and jobs generated. • Evaluation and quantification of the externalized costs of environmental	Tier 1: Develop a set of comprehensive long-term economically, socially and environmentally sustainable corporate goals for the company or campus that includes provisions for periodic updates to reflect new opportunities. Support the development of and/or utilize a comprehensive waste characterization study (WCS) for materials handled within the Company's or Campus's service area, or the territory of the jurisdiction seeking SWEEP+ Certification where the Company does business or the campus is located. Include operational sustainability and value chains. Conduct material-specific analyses for the top 10 material categories identified in the WCS that prioritizes policies and programs that provide the greatest environmental benefit. The analysis should assess environmental elements of the material categories, as well as social and economic elements. At a minimum, the analysis should include: • Evaluation and documentation of all GHGs, criteria air pollutants, hazardous air pollutants, the number of people impacted within a given radius and the demographics and health disparities of the impacted population, and jobs generated. • Evaluation and quantification of the externalized costs of the health impacts of pollution on impacted communities,

and social impacts disposal facilities and sites from air emissions, production and disposal, and assessing social and economic components. The Plan will list and propose actions for at least the top 10 materials that result in the largest environmental benefit, or improvement, based on the current version of the EPA WARM model analysis using the methodology outlined in the Certification Manual. The Plan will also require keeping track of how all materials identified in the WCS are being generated and reduced. It will also list the strategies, policies, programs and projects being considered to achieve these goals. Tier 2: Conduct the comprehensive SMM analysis and develop policy program solutions described in Tier 1 based on analysis using a lifecycle assessment tool, such as MEBCalc**,** or equivalent tools, instead of EPA WARM. Use the baseline assumptions described in the Certification Manual. Achieve reduction in per capita waste disposal.	environmental and social impacts of air emissions from disposal facilities and sites, and production and disposal. The assessment should not account for waste diverted from landfills to waste to energy and thermal conversion facilities. The Plan will list and propose actions for at least the top 10 materials that result in the largest environmental benefit, based on the current version of the EPA WARM model analysis using the methodology outlined in the Certification Manual. The Plan will also require keeping track of how all materials identified in the WCS are being generated and reduced. It should achieve reductions in per capita waste disposal rates and list the strategies, policies, programs and projects being considered to achieve these goals. Tier 2: Conduct the comprehensive SMM analysis and develop policy program solution described in Tier 1 based on analysis using a lifecycle assessment tool, such as MEBCalc, or equivalent, instead of EPA WARM. Use the baseline assumptions described in the Certification Manual. It should achieve reductions in per capita waste disposal rates and list the strategies, policies, programs and projects being considered to achieve these goals.

The team also worked on developing possible pathways to compliance for performance standards. Sample campus-specific strategies are detailed in Table 2.

Table 2: Sample campus-specific strategies for performance standard compliance

Credit	Campus-specific strategies
SMMP: Materials processing infrastructure and market development policy	• Convene an Enabling Board that consists of campus occupants and employees to support local economic development through material recovery and processing infrastructure. • "Buy local" and "buy recycled" content incentives in procurement. Incentives can include grants and technical assistance. • Set up a "last chance" outlet that sell reusable goods that have been either donated to or salvaged by waste processing facilities. For example, a university could have an end of the year drive to resell student dormitory items.
WGP: Economic	• Track costs for different aspects of the Campus's waste management: collection, processing, disposal, etc.

assessment of solid waste management program	• Specifically provide food waste costs for on-campus eating facilities. • Include employment numbers in relation to waste management on campus. • Make the top-level cost figures available to campus residents. • Provide total costs of each program (recycling, trash, compost) per on campus residence or per capita. • Provide comparison for costs of each program per year to campus occupants.

While adapting the standards, we grappled with whether campuses should be asked to complete crucial tasks that require high efforts. Since the waste management industry has not advanced as fast as it should have, there are certain practices that are indispensable but cost thousands of dollars or are undeveloped and inaccessible. Undertaking these challenges may be more suitable for local governments, which have more funding and staff. At the campus level, though, the monumental effort required to comply with those standards would serve as a deterrent to applicants. We concluded that these efforts should still be included as optional credits with high points, so that institutions that chose to tackle these tasks would be highly rewarded. This debate poked at the core balance that needs to be achieved in certifications so that they can be useful and applicable at larger scales.

Once we adapted the standards, we amended the calculators based on the needs of campuses and the feedback received from current pilot members of the SWEEP+ certification. Calculators consist of Excel workbooks where each sheet corresponds to a data-input credit where applicants provide their numbers and calculations are made automatically. These calculators are useful both to keep track of inputs on the applicant's side but also to provide SWEEP auditors with uniform data across the applicant pool. They are crucial in ensuring the legitimacy of the SWEEP+ Standard as they serve as a primary medium for data entry and quantification.

The team took several steps to improve and adapt the calculators. First, irrelevant inputs were taken away. For example, the original calculators required campuses to separate the costs of collection, disposal, and processing, which is not a feasible request for campuses which do not operate their own facilities and therefore cannot access these breakdowns of costs. Second, more relevant inputs were included, such as how many residential and nonresidential students the campuses host. Then, cells were formatted using if-then and if-else statements as well as algebraic equations to sum and calculate rates, such as total costs per ton. Multiple approaches towards quantification were offered to future applicants in these calculators, including per capita, per ton, per material, and per budget options. In addition, default values were also included in the calculators to aid participants' estimations in cases where direct data is not available. For example, the default percent breakdown of costs was provided.

Current applicants mentioned that data input was redundant and lengthy. Thus, these new calculators were developed to streamline the user experience. Specifically, cells were connected throughout the entire workbook to allow for a single data-input point that feeds other relevant cells. We created a master input sheet that included data entry cells for waste per type, total costs, and population numbers. With the addition of more data-input credits to the workbook, more parameters can be added to the master sheet so that applicants only have to input each number once.

4.4 Objective 4: Estimate key parameters, including campus virtual populations and average waste production at WPI

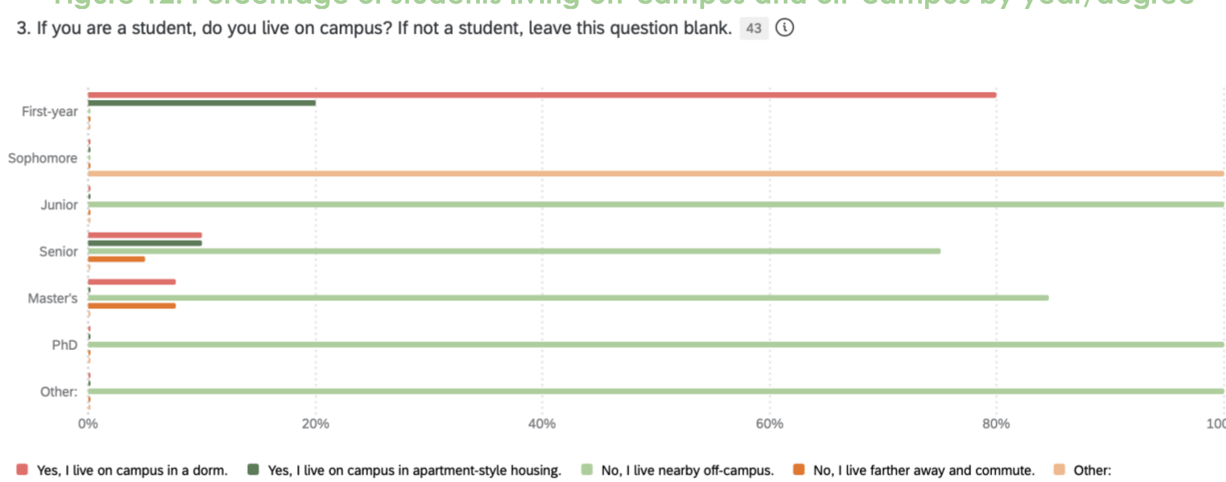
The fourth objective established some baseline equations and numbers to be integrated in the SWEEP+ Standard calculators. The development of these parameters was not exhaustive as the data collected was limited. Still, the acquisition of more data points can be easily incorporated to refine findings to achieve greater accuracy. The survey, which targeted students, staff, and faculty, received a total of 60 responses. In the following paragraphs I present the findings from each question in the survey and suggest future avenues for collecting missing information.

Survey responses

The first two questions determined the composition of respondents. The first question asked the survey-taker whether they were a student, faculty member, or staff member. The large majority of responses came from students (93%), while faculty represented 2% and staff 4%. The lack of faculty and staff responses prevented more accurate estimates about their campus use. Still, since faculty and staff are employed at institutions, estimating how much time they spend on campus is easier. All respondents were full-time students or employees, so there is no information about the habits of part-time students or employees, and how this may affect waste. The second question asked students what their year or degree program was. The majority of respondents were seniors (47%), followed by master's students (30%), first-year students (12%), juniors (5%). Sophomores, PhDs, and "other" categories represented 2% each.

The third and fourth questions hoped to determine how much time was spent on campus via general metrics about students. The third question determined that all first-year students lived on campus, while upperclassmen were more likely to live nearby but off-campus (see Figure 12). The fourth question asked students whether their classes were typically online or in person. The results showed that 80% of students had fully in person classes, 17% had mostly in person classes, and 2% had mostly online classes.

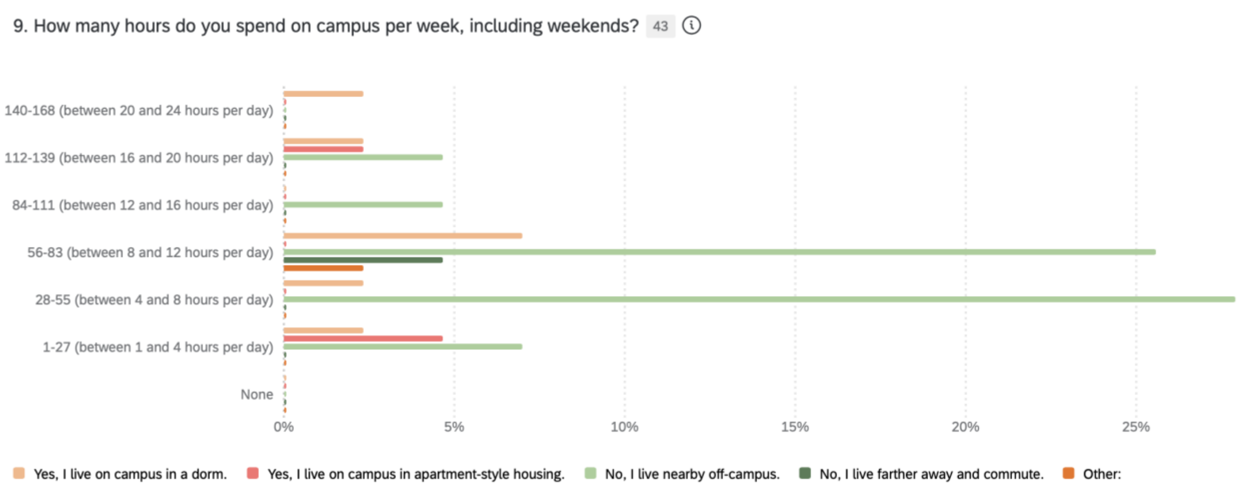
Figure 12: Percentage of students living on-campus and off-campus by year/degree



Questions 5, 6, and 7 asked about campus dwellers' eating and cooking habits on campus. For the virtual population estimate, it was assumed that students, faculty, and staff produced solid waste and recyclables at similar rates. However, the production of food waste was expected to vary widely since students eat meals on-campus more often than the rest. Thus, these questions hoped to determine how much more food waste is produced by students than by faculty and staff. Of surveyed students, one-thirds had meal plans while two-thirds did not. Most lowerclassmen had meal plans, while most upperclassmen did not. The sixth question asked whether students cooked on campus. 58% of respondents reported that they cooked no meals weekly, while the rest of the responses varied relatively evenly from 1-4 meals to 18+ meals. The seventh question asked all survey-takers how many meals they ate on campus per week. The most common response was 1-4 meals, with 40% of responses. This was followed by 5-8 meals (21%), 9-12 meals (17%), no meals (17%), 13-17 meals (2%), and 18+ meals (2%).

Questions 8 through 10 asked all responders about their habits on-campus. Question 8 asked respondents how many days of the week they spent on campus. 33% went to campus five days of the week, 22% seven days, 20% six days, 18% four days, 4% three days, and 2% one day. No respondents indicated that they went to campus none or two of the days of the week. The ninth question asked how much time they spent on campus per week. Residential students spent the majority of their time on campus while nonresidential students did not (see Figure 13). Question 10 asked respondents whether these patterns continued over winter and summer breaks. The majority (57%) did not attend campus during either break. 25% were present during both breaks. 11% only stayed over winter break, while 5% only stayed during summer break. The remaining 2% chose "other" as a response but did not specify.

Figure 13: Hours spent on campus by survey respondents



The last three questions asked respondents about their waste production habits and requested inputs about what their campus administrators could do to improve waste sustainability. Question 11 found that 81% of respondents were careful and mindful about their waste production, with 36% of those affirming that they try their best to reduce waste. 18% were not very or not at all conscious of their waste production. The twelfth question asked participants how well they followed sorting guidelines for different waste types. 58% answered that they followed general guidelines but were unsure about exceptions, while 22% felt comfortable with both general guidelines and specifics. 16% expressed feeling confused, but no one reported being indifferent about which bin to throw what in. The last question was open-ended and asked participants how they thought campus administrators could improve strategies to reduce, sort, and manage waste on campus (see Table 3).

Table 3: Survey participants' thoughts about what the campus administration should do to improve strategies to reduce, sort, and manage waste

Strategy	Number of responses
Improve signage about what waste belongs where	9
Implement campus composting	6
Offer or sell reusable containers and utensils	5
Redistribute leftover food from dining halls	5
Eliminate unnecessary waste	5
Better communicate sustainable practices	4
Change bin types	2
Be more transparent about waste management practices	2
Implement multiple-stream recycling	2
Add more bins	1
Decrease waste in laboratories	1
Increase course offerings about waste management	1
Source food locally or from campus gardens	1
Better enforce waste sustainability	1

Virtual population

Calculations for the virtual population and the waste per student were realized for WPI. These were based only on solid waste and recyclables since no further quantification of waste generation currently exists. A virtual population is defined as an equivalent population if all members of the community spent all hours on campus. To estimate the virtual population at WPI, Equation 1 was developed. The coefficients for the equation were determined using the results of the first survey and data about WPI as follows:

1. Residential students were estimated to spend 16–24 hours on campus per day by the survey, so with an average of 20 hours, their equivalence coefficient was determined as 20/24 = 0.833.
2. Full-time, nonresidential students varied widely in their responses to the survey. A calculation of weighted average of responses found that 8.4 hours was the average time spent on campus per day, informing an equivalence coefficient of 8.4/24 = 0.35.
3. Part-time, nonresidential students did not participate in the survey. Therefore, this coefficient was estimated based on the number of credits of part-time students in comparison with full-time students. Since part-time students take under 12 credits per semester, while full-time students take around 18 credits per semester, they were assumed to spend half as much time as full-time students on campus. Thus, the coefficient was 0.35/2 = 0.175.
4. Full-time equivalents of employees were determined assuming a 35–40-hour work week. Therefore, these employees spend between 5 and 5.7 hours per day (including weekends) at WPI. Therefore, 5.35/24 = 0.223.
5. These coefficients were used to inform the school cycle virtual population, which spans from late August to early May (simplified to four months to also account for Thanksgiving

break) with a one-month break between mid-December and mid-January. According to the survey, campus presence during academic breaks (total of five months) is reduced according to this calculation 0.25*1 + 0.11*0.2 + 0.05*0.8 + 0.57*0 = 0.312. Therefore, the virtual population for the school cycle was multiplied by 0.312 to determine non-school cycle campus presence. With a weighted average based on the number of months of break, the calendar year virtual population should be the school cycle population multiplied by 0.713.

Equation 1: Virtual population equation for WPI

$$virtual\ population\ (calendar\ year) = 0.713 * [0.833 * (\#\ of\ residential\ students) + 0.35 * (\#of\ full\ time\ nonresidential\ students) + 0.175 * (\#\ of\ part\ time\ nonresidential\ students) + 0.223 * (\#of\ full\ time\ equivalent\ employees)]$$

$$virtual\ population\ (during\ school\ cycle) = 0.833 * (\#\ of\ residential\ students) + 0.35 * (\#of\ full\ time\ nonresidential\ students) + 0.175 * (\#\ of\ part\ time\ nonresidential\ students) + 0.223 * (\#of\ full\ time\ equivalent\ employees)$$

$$virtual\ population\ (not\ during\ school\ cycle) = 0.312 * [0.833 * (\#\ of\ residential\ students) + 0.35 * (\#of\ full\ time\ nonresidential\ students) + 0.175 * (\#\ of\ part\ time\ nonresidential\ students) + 0.223 * (\#of\ full\ time\ equivalent\ employees)]$$

Table 4 shows a summary of the data received about WPI's population. Employees were calculated as a sum of WPI employees (not including student workers) and Chartwells employees. The full-time equivalent for employees was already available for WPI employees, and the same calculation was used to determine the full-time equivalent of Chartwells employees (part-time employees at a 1/3 equivalence). Residential students were assumed to be full-time students. For WPI's waste data, the solid waste and recyclables weights for September and October were retrieved from Company B's invoices. Using this data, the calculations for the virtual population of WPI were carried out in **Equation 2**.

Table 4: WPI's population (2022)

Undergraduate students	Full-time	5,302
	Part-time	151
Graduate students	Full-time	895
	Part-time	1,005
Residential students (also counted as full-time students)		2,530
Employees	Full-time	1,454
	Part-time	252
	Full-time equivalent	1,538
Total population	Total population	9,059
	Virtual population (school cycle)	3,936
	Virtual population (non-school cycle)	1,228
	Virtual population (calendar year)	2,806

Equation 2: Virtual population calculation for WPI

$$virtual\ population\ (during\ school\ cycle) = 0.833 * (2{,}530) + 0.35 * (3{,}667) + 0.175 * (1{,}156) + 0.223 * (1{,}538) = 3{,}936$$

$$virtual\ population\ (not\ during\ school\ cycle) = 0.312 * 3{,}936 = 1{,}228$$

$$virtual\ population\ (calendar\ year) = 0.713 * 3{,}936 = 2{,}806$$

The estimated virtual populations for WPI were used to determine average waste and recyclables production at WPI. Population data was from 2022 as it was the latest available information, while waste data was from 2023 because no prior data is complete. This may result in slightly skewed estimates of waste production per capita. Furthermore, the food waste on campus is not currently measured in any way, so food waste is excluded from these calculations. A future study could use data about food waste and meals sold on campus per day to generate an estimated average food waste per student (see collected data about meal purchases in Appendix C). Table 5 shows the estimated solid waste and recyclables output per 24-hour resident at WPI. The calculations were done using the academic year virtual population since the average productions were calculated using the available data, which ranged from September to October. The average virtual population campus user produced 30.68 pounds of waste per month (around 1.02 pounds per day) and 5.51 pounds of recyclables per month (around 0.18 pounds per day). Under the SWEEP certification, this value is well below the highest-point tier. However, this number does not yet incorporate C&D or organic waste, so accurately determining per capita production relies on the quantification of other waste streams.

Table 5: Solid waste and recyclables production per capita per month

	Solid waste	Recyclables	Total
Total waste (in tons per month)	60.41	10.85	71.26
Waste per capita (in pounds per month)	13.34	2.39	15.73
Waste per virtual population capita (in pounds per month)	30.68	5.51	36.19

Waste tracking tool

During the data collection process from WPI, it became apparent that there was nowhere for waste data to be stored. Food waste produced by students is not currently weighed, while food waste from inside the kitchen is (as a result of the Waste Not initiative) but the data is not yet available. For solid waste and recyclables, WPI receives an invoice from Company B monthly that details the tonnage of each compactor pickup. However, this information is not compiled anywhere where trends and efficiency might be analyzed. For these reasons, I developed an Excel workbook as a tool to track compactor tonnage, minimum tonnage, year-to-date tonnage, average tonnage per month, cost, year-to-date cost, average cost per month, cost per ton, average cost per ton, and percent of waste recycled. This will give the Office of Sustainability more metrics about waste. Table 6 shows two sample entries to the Excel workbook for the month of October. Peach cells are to be filled by officers monthly based on invoice from Company B. One way in which this data could be useful is by allowing the Office of Sustainability to identify compactors that weigh consistently below the minimum tonnage, and thus have high costs per ton. Furthermore, the Office of Sustainability might be able to identify months where waste was significantly above or below the yearly average.

Table 6: Sample entries into waste tracking tool for WPI

Compactor location	Waste type	Minimum tonnage	Tonnage	YTD tonnage	Average tonnage/ month	Cost	YTD cost	Average cost/month	Cost/ton	Average cost/ton
Morgan	SS Recycling	1	3.19	8.45	2.82	1003.05	2872.75	957.58	314.44	339.97
Morgan	Waste	1	13.56	34.21	11.40	2875	7401.89	2467.30	212.02	216.37

4.5 Objective 5: Identify areas for improvement in waste management practices that enable WPI to become a pilot for the SWEEP+ Standard

This objective conducted a gap analysis of WPI's current practices in respect to the requirements of the SWEEP+ Standard. As a result, it identified key areas for improvement and the associated costs, workforce, and changes that would have to be incurred or implemented in order to become a SWEEP+ Pilot and improve our waste practices. The full gap analysis workbook can be found as an attached supplementary material. The credits analyzed in this gap analysis are the ones that were determined to be relevant to campus applicants by the student team, although this might change upon the review of the SWEEP Standards Committee. The points, especially, are likely to change or be scaled to account for the removed credits that campuses do not conform to. The following sections are separated based on the credit category, and the section concludes with the broader implications for WPI and SWEEP.

Sustainable Materials Management Policies (SMMP)

This category in the SWEEP+ certification refers to a broad array of regulatory and policy measures aimed at minimizing solid waste generation, improving the performance of solid waste collection, processing, and recovery practices. It has a prerequisite followed by two pathways for points-collection. Applicants must choose one of the two. The performance pathway sets goals, which can be achieved by means up to the applicant's discretion. On the other hand, the prescriptive pathway establishes specific steps towards the goal. Each credit was assessed as Y (yes, we have all of the requirements), MY (maybe yes, we have >60% of the requirements), NM (no maybe, we have >30% of the requirements), N (no, we have <30% of the requirements). Table 7 summarizes WPI's performance on each of the credits.

Table 7: Gap analysis of SMMP credits

Credit	Possible points	Assessment	Gaps
Prerequisite: Comprehensive Sustainable Materials Management Policy and Programs	N/A	YM	WPI does a lot of what is required but is missing the aspect of documentation. Compliance with this credit would entail the development of detailed documents/policies about procurement of sustainable products, waste reduction goals, and roadmaps to divert materials from landfills and waste-to-energy facilities. Additionally, it would require WPI to formalize public education and information programs for students and employees, stakeholder outreach and participation plans, programs that minimize waste generation at the source, and environmental justice programs.
Performance pathway			
Comprehensive Sustainable Materials Management Lifecycle Analysis and Policy Program	5-19	YM	WPI has a 5-year plan instead of the required 10-year plan. Our current plan does not have many details that are required, including provisions for periodic updates and a specific framework (zero waste, circular economy, etc.) towards waste sustainability. The tiers (and points) in this credit are determined by the amount of trash per campus resident, ranging from 5.7 to 6 pounds of waste per day. These targets should be achievable based on current information about WPI waste production, although more data would need to be gathered. The requirements also dictate a lifecycle assessment done via the EPA WARM tool or MEBcalc/Sphera/SimaPro (more points).
Policy for Comprehensive	1-2	N	We do not have a policy of best practices for public participation, nor the support (technical,

Public Participation in Solid Waste Management Program Development			experts, funding, etc.) required for the second point. However, developing these practices does not require significant resources from WPI.
Comprehensive Public Reporting of Corporate Sustainability	1-3	NM	This credit requires the publishing of an annual sustainability report. WPI does publish a report, but it is primarily qualitative instead of quantitative. The second tier, which has two added points, requires reporting progress on the SWEEP key performance indicators (KPIs), which we do not currently do. However, with intentional data collection and work from the Office of Sustainability, this report should be achievable.
Prescriptive pathway			
Materials Processing Infrastructure and Market Development Policy	2	N	We do not currently have any infrastructure or markets for recovering and selling waste materials. This could be potentially done by separating a specific category of waste, like metals, to create art, for example.
Adoption of Diversion and Recycling Goals	1-3	NM	This credit asks for a plan for diversion or recycling rates to be 15%-20% higher than national/state averages. In the U.S., the recycling rate is of 32%. The current WPI value is around 20%, only including MSW. Reaching these rates should be achievable through a comprehensive plan and policy.
Regular Waste Characterization and Generation Study Policy	2	YM	This credit asks for the development of a policy to run waste characterization studies at least once every 7 years. The annual waste audit undertaken by the Green Team and the Office of Sustainability partially fits the requirements, although a bit more detail and expansion into other waste categories (food waste, C&D, etc.) would be required from the results.
Advanced Comprehensive Sustainable Materials Management Policy	2	YM	We collect data about waste production for MSW and recyclables but not the rest of the trash we produce. In order to get the points for this credit, we would need to collect data about other kinds of waste production and calculate greenhouse gas emissions from waste management.
Solid Waste Greenhouse Gas and Air Emissions Footprint Reduction Policy	1-3	YM	We have goals to reduce greenhouse gas and other air emissions, but we do not have a policy or a means of quantification yet.
Source Reduction Policy	3	YM	We have most of this, including partnerships with food rescue groups, local reuse organizations, and organizations that take hard-to-recycle items. We

			also have water bottle stations all around campus. We would need a C&D recycling ordinance as well as more programs to eliminate single-use items.
Policy for Comprehensive Public Participation in Solid Waste Management Program Development	1-2	N	We do not have a policy of best practices for public participation, nor the support (technical, experts, funding, etc.) required for the second point. However, developing these practices does not require significant resources from WPI.
Comprehensive Public Reporting of Corporate Sustainability	1-3	NM	This credit requires the publishing of an annual sustainability report. WPI does publish a report, but it is primarily qualitative instead of quantitative. The second tier, which has two added points, requires reporting progress on the SWEEP key performance indicators (KPIs), which we do not currently do. However, with intentional data collection and work from the Office of Sustainability, this report should be achievable.

Based on this analysis, it would likely be more beneficial for WPI to pursue the performance pathway since there are fewer individual policies that would need to be developed. Compliance with most of the SMMP points would entail developing a comprehensive waste management plan, completing a lifecycle assessment, creating a public participation policy, and amending the annual WPI Sustainability Report to focus on quantification and goal tracking.

Waste generation and prevention (WGP)

This category in the SWEEP+ Standard focuses on reducing waste at the source, as preventing and minimizing waste generation is widely considered to be more important than solid waste recovery and disposal. The WGP section begins with a prerequisite and is followed by eight credits. Table 8 shows the gap analysis of these credits.

Table 8: Gap analysis of WGP credits

Credit	Possible points	Assessment	Gaps
Prerequisite: Measuring and Calculating Waste Generation, Recovery and Disposal	N/A	YM	WPI measures MSW and recyclables but not the rest of the waste categories, which would be necessary for compliance. Additionally, we would have to submit an annual report about waste production, which should be easily incorporated into our annual sustainability reports. The rest of the requirements have already been completed.
MSW Source Reduction Programs	1-3	YM	WPI has multiple programs to reduce waste production at the source, but they are not formalized or documented. In order to comply

			with this credit, we would need to describe these programs and quantify and publish results.
Reuse and Rescue Programs/Projects	1-3	NM	This credit calls for the reuse and upcycling of certain products, which WPI does not do but potentially could. Points are allotted based on the rescue of food, which WPI takes part in by donating certain foods via Chartwells (alternatively, discounted prices rather than donations are also acceptable). However, the rates of donation are not measured, although Chartwells estimates that donations represent 3-5% of leftover food. For the collection of points, the rate would have to be >10%.
Measuring and Calculating Source Reduction and Reuse/Rescue Impacts	1-2	N	This credit would require WPI to calculate source reduction potential and reuse & rescue using EPA or SWEEP tools.
Litter Prevention and Reduction Infrastructure	1	YM	WPI maintains sufficient waste receptacles and demonstrates rapid cleanups of illegal dumping but does not yet have a documented program that encourages the adoption of durable products and disincentivizes single-use products.
Environmentally Preferable Product Procurement (Non-Capital Items)	1-2	NM	This credit asks for EPP procurement for more than 10-25% of the procurement budget. While we do have a policy for preferred materials and products, we do not quantify this. To comply, we would need to conduct a study and likely make the current policy more stringent.
Sustainable Capital and Utility Procurement	1-2	YM	This credit asks the applicant for to be certified by Energy Star and either offset carbon emissions or supply 10% of total energy by renewable means. WPI is not certified by Energy Star but does have plans for both carbon offsets and renewable energy sourcing. For the second point, construction and renovation projects should be LEED certified. WPI does certify new buildings with LEED but not renovations. The additional requirement, which is procuring capital items in a sustainable manner, already exists at WPI.
Economic Assessment of Solid Waste Management Program	2	YM	This credit asks for costs per ton/capita of each waste stream and waste disposal step (collection, processing, etc.). This should be relatively easy to put together using invoices from waste vendors and costs from the Facilities Office.
Education and Engagement Programs on Litter & Source Reduction and Reuse	2	YM	WPI has education and engagement programs but would benefit from the development of a more comprehensive website about waste management practices and initiatives on campus.

Based on this gap analysis of the WGP section, the primary obstacles in getting points are the quantification of all waste production, the creation and quantification of waste-reduction programs and results, and the development of a website to inform members of the campus about waste management practices and initiatives.

Solid waste collection (SWC)

This category in the SWEEP+ Standard emphasizes practices and infrastructure during the waste collection process. It has no prerequisites and seven credits. Table 9 presents the findings from the gap analysis of these credits.

Table 9: Gap analysis for SWC credits

Credit	Possible points	Assessment	Gaps
Alternative Collection Options for Recyclable and Compostable Products and Materials	1	YM	WPI provides collection options to students and employees around campus. However, compostable bins are currently only found in some of the food halls. Ideally, food waste receptacles should be located all around the campus.
Energy and Emissions Optimization of Solid Waste Collection	1-3	NM	This credit asks for an optimization in gallons of fuel per ton or per mile traveled by waste. This information could be calculated through a joint study with Company B and Company C.
Household Hazardous Waste Collection Infrastructure	1	YM	We have some hazardous items that are collected (batteries, e-waste) but not all (paints, herbicides). An expanded hazardous waste collection program would mitigate this shortcoming.
Solid Waste Collection Cost Transparency	2	YM	WPI could easily quantify costs per ton/resident using the invoices from Company B, Company C, and Facilities Office' trash budget. Additionally, we would need full quantification of waste and costs.
Commitment to Safe Working Conditions	2	Y	WPI complies with working conditions regulations.
OSHA Compliant Practices and Safe Vehicle Processes	2	NM	WPI has training programs, but the Facilities Office has not recently partaken in an OSHA audit.
Commitment to Living Wage	1	YM	Employees in the Facilities Office receive wages above minimum wage and health insurance, but it is unclear whether they receive other benefits or enough wages to satisfy a living wage for Worcester.

The SWC category credits require more collaboration with Company B, Company C, and the Facilities Office. To earn these points, WPI would have to expand hazardous waste collection, add more organic waste bins throughout campus, and determine some data with the help of vendors.

Post collection recovery (PCR)

This category in the SWEEP+ Standard refers to practices aimed at avoiding landfilling of solid waste by preserving and utilizing its residual material value. The PCR category has a prerequisite followed by six credits that can be individually achieved through performance and prescriptive standards. Table 10 presents the findings from the gap analysis of these credits.

Table 10: Gap analysis for PCR credits

Credit	Possible points	Assessment	Gaps
Prerequisite: Minimum Diversion/Maximum Per Capita Disposal Rate	N/A	YM	This credit asks for WPI to demonstrate that 30% of MSW and C&D are diverted from disposal or show that per capita waste (MSW + C&D) is below 6.4 pounds per day. The second pathway would be more beneficial for WPI since we are closer to that number in disposal, although additional data about C&D waste would need to be collected.
Material Recovery & Per Capita Disposal Optimization	1-3	YM	WPI would need to demonstrate per capita disposal levels less than 6 pounds per person per day. With the proper measurement of all waste, this calculation should be easily done. Current estimates fall within compliant production.
Producing High Quality Products from Recovered Organic Materials	1-3	N	This credit asks for compost to be STA certified. At this point, it is unclear if Company C certifies their compost.
Compact Commodity/Output Supply Chain	1-3	YM	This credit asks about where the recovered materials are sold and/or used. The Casella recycling facility said that we would be compliant with the first tier (>80% of materials sold within 2000 miles) and at times the second tier (>50% within 500 miles). However, would need to develop official documents to prove this.
Renewable or Alternative Fueled On-site Mobile Equipment for Recovery Facilities	1	N	WPI has one waste truck, and it does not use renewable fuels, although there is a plan to buy electric vehicles in the future.
Material Recovery Cost Transparency	1	YM	WPI could easily quantify costs per ton/resident using the invoices from Company B, Company C, and Facilities Office' trash budget. Additionally, we would need full quantification of waste and costs.

The results of the PCR gap analysis show that in order to become SWEEP+ Standard pilot members, WPI would need to demonstrate low waste production levels via quantification (as in other categories) and work with Casella and Company C to get more detailed information about their practices.

Post collection disposal (PCD)

This category in the SWEEP+ Standard refers to practices aimed at the safe and effective disposal of waste that has no higher or more beneficial use. The PCD category has four relevant credits and no prerequisites. Table 11 summarizes the findings from the gap analysis of these credits.

Table 11: Gap analysis for PCD credits

Credit	Possible points	Assessment	Gaps
Material Disposal Cost Transparency	1	YM	WPI could quantify costs per ton/resident using data from our waste facilities.
Post-Collection Disposal Facility Safety Protocols and Training	1-2	NM	WPI does not meet the requirement, which is to provide safety incentives unrelated to accident-free periods. However, WPI does meet (or plans to soon meet) the criteria for the tiers since workers have health insurance and multi-language training is being implemented.
OSHA-Compliant Facilities	1-2	N	The Facilities Office has not had any OSHA audits.
Good Neighbor Practices	1-2	N	From the requirements that are applicable to WPI, we would need to create a system to receive and address community concerns, demonstrate that there are no outstanding complaints, and fund a study to understand the negative effects of waste management operations on individual communities within five miles of the solid waste facility.

Overall, the PCD category's relevant credits were few and hard to achieve. The changes to the Facilities Office' operations might not be feasible with WPI's small campus. Still, some points could be earned from this section.

Innovation credits

SWEEP grants ten bonus points in the innovation category. These may be achieved through the following means:

1. Exemplary performance of at least one performance increment compared with the credit requirements
    - For example, if the first tier is a 10% improvement and a second tier is 20% improvement, the Innovation credit will be given for >30% improvement.
2. Exploration credits proposed by SWEEP

    - Collective Bargaining Agreement (2 points): Have in place a collective bargaining agreement for workers engaged in waste collection, recovered materials processing, recovered organics processing, or waste disposal facilities.
    - Use of Measured, Verified or Certified Data (1 point per credit): For SWEEP+ credits where estimated data or calculations are called for, utilize measured, verified data or certify to a program that verifies data.
    - Maximize Supply Chain Efficiency (1 point): Locate single and dual stream recycling facilities within 20 miles of the campus service area boundary.
3. Previously approved Innovation credits from other certified entities
4. Project-specific innovation proposed by entities seeking SWEEP+ certification

WPI would be able to get one point from the supply chain efficiency exploration credit since our waste facilities are within 20 miles from campus. Additionally, any exemplary performance in prior credits would also earn WPI additional points. If we were to verify our waste collection data, and measure rather than estimate waste production, we could receive up to five points. This might require significant inputs, though. WPI could propose additional Innovation credits, such as funding research for robot sorting for recyclables with the goal of on-campus recycling, proposing yearly waste-related student projects, and developing multi-actor waste committees, among others.

Gap analysis implications for WPI

All in all, WPI's involvement in the SWEEP+ Standard as a pilot member is most threatened by the university's lack of documentation and quantification of waste. If WPI focuses on earning points in key areas, specifically in SMMP and WGP credits, SWEEP+ Standard certification would be possible at a lower cost of implementation. Still, becoming a pilot will require work by officers or interns at the Office of Sustainability who can work alongside all of our waste actors to develop policies and assess compliance.

Gap analysis implications for SWEEP

The gap analysis of WPI served as further input for the creation of a campus SWEEP+ Standard certification. For the PCR and PCD categories, there were many credits that were not applicable to WPI in particular but may have been applicable for larger campuses with more on-site waste management practices. Thus, gating questions were developed to determine which credits are applicable to different kinds of campuses. These questions, redacted below, will help SWEEP assign points according to the infrastructure of each campus.

1. Do you use landfills for waste disposal?
2. Do you have a fleet of vehicles for waste management purposes?
3. Do you have any waste-processing equipment besides compactors?
4. Do you have any waste treatment facilities on-site?
5. Do you conduct research, either by faculty or students?

Furthermore, SWEEP should consider whether additional categories that are more meaningful to campuses should be added. In Objective 3, the goal was to change existing credits, both in language and in content. However, the addition of sections or credits was not considered. The gap analysis revealed how necessary additional sections might be, both for the development of a comprehensive certification for campuses and for the allocation of meaningful points.

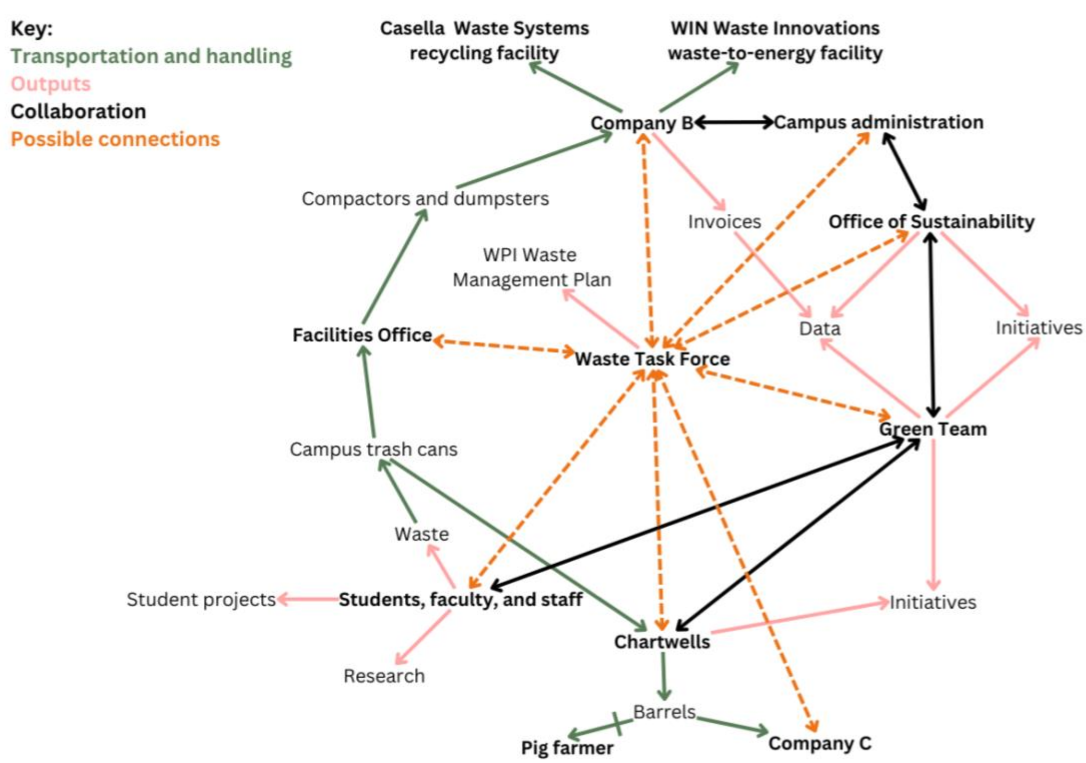
5. Recommendations

As a result of my investigation, findings, and discussion, I have identified a set of recommendations that align with WPI's sustainability goals, including becoming a SWEEP+ Standard pilot member. First, I develop recommendations for the establishment of a synergistic Waste Task Force. Then, I discuss the creation of an institute for sustainability through which to funnel student and faculty projects. Third, I set the groundwork for the implementation of the SWEEP+ Standard at WPI. By implementing these recommendations, WPI will resolve waste inefficiencies and incongruencies, continue its development as a living laboratory for global solutions, and achieve pilot certification by the SWEEP+ Standard. The fourth recommendation pertains to SWEEP and proposes changes to the SWEEP+ Standard for campuses that will make the certification stronger.

5.1 Establish a Waste Task Force to analyze WPI's practices and determine possible solutions from a synergistic standpoint

The first recommendation of this project is to establish a Waste Task Force to analyze WPI's practices and determine possible solutions from a synergistic standpoint.Objectives 1 and 2 demonstrated the gaps in collaboration and communication between waste actors. With ignorance of what other actors are doing, each actor works independently in ways that hinder sustainability and efficiency. Figure 14 is a diagram of the current interactions of the waste system that showcases possible connections fostered by the implementation of a Waste Task Force.

Figure 14: Current WPI waste network and possible connections for the future



The purpose of this task force would be to streamline campus waste operations based on the findings of this study and other inputs from waste actors. Together, the task force should formulate a WPI Waste Management Plan that should be openly available to the WPI community as to foment transparency in sustainability practices. It should include at least one person from each WPI actor (campus administrators, Office of Sustainability, Green Team, Chartwells, students, faculty, staff, and Facilities Office). In certain occasions, it may also include Company B, the waste facilities, and the food waste vendor.

Specifically, the Waste Task Force should develop a WPI Waste Management Plan that includes the following:

1. A goal statement for the joint management of WPI's waste with specific objectives for improvement of sustainability and efficiency.
2. A statement of transparency and best intentions for the sustainable management of waste, including the commitments and responsibilities of each actor in the system.
3. A comprehensive description of best practices at every stage of actor involvement, including training manuals and educational materials.
4. A detailed guide to waste production data collection methods.
5. A justification about how each of the practices, guides, and data conform to the SWEEP+ Standard's criteria.
6. The creation of a joint waste database for storing of data, student projects, initiatives, and other progress of interest.
7. Synergistic solutions and innovations to issues identified in the review of the current system.
8. A schedule and plan for implementation of identified solutions and innovations, as well as a schedule and plan for the evaluation of said practices.
9. A list of possible avenues for future pursuit, including estimated costs and benefits of their implementation. These should focus on waste reduction and cross-actor collaboration.
10. The designation of person(s) and/or departments responsible for updating and upholding the WPI Waste Management Plan.

The formulation of a WPI Waste Management Plan will centralize authority of WPI's waste management practices and foster a space of collaboration, transparency, and inquiry in sustainability and efficiency goals. It will also help communicate the goals, practices, data, and remaining gaps in WPI's waste system. The plan will support waste actors and lead to meaningful progress in waste initiatives.

5.2 Develop an implementation roadmap towards SWEEP+ Standard certification

The second recommendation for WPI is to develop an implementation roadmap towards SWEEP+ Standard certification. With the existence of a Waste Task Force, many of the SWEEP requirements can be explored, planned for, and achieved. Additionally, it would be recommended to employ a sustainability officer to be in charge of putting together the necessary documentation for approval. Priorities for a successful application are:

1. Creation of written policies about waste management at WPI, to be accessible by all.

2. Quantification procedure for all types of campus waste (may be done through estimates that consider volume and density in cases where mass is not easily collected) and delegation of data collection to appropriate actors.
3. Use of the proposed spreadsheet or equivalent alternative for waste tracking and identification of trends.
4. Careful documentation of ongoing waste initiatives, including data collection and progress reports.
5. Development of an annual sustainability report with stricter guidelines and an emphasis on measurable goals and results.
6. Collaboration with relevant departments, offices, and facilities in order to ensure and document sustainable waste management practices.

In order to achieve these goals, I recommend that the Office of Sustainability sponsor more student projects that may fill some of the gaps for the SWEEP credits. Many of the necessary changes require investigation and time, so student teams are a perfect match for collaboration towards certification. Moreover, the person(s) in charge of developing WPI's application to become a SWEEP+ Standard pilot member should get in contact with Rob Watson to provide further feedback about the application and its relevance to campus environments. Additionally, Innovation credits should be proposed to ensure the acquisition of all bonus points through existing initiatives on campus.

5.3 Coordinate waste efforts through a sustainability institute for student and faculty projects

The third recommendation of this study is to coordinate waste efforts through a sustainability institute for student and faculty projects. Faculty have expressed significant interest in engaging more deeply in sustainability, as evidenced by the 2023 Faculty Resolution. In fact, they have suggested the development of an Institute for Research in Sustainable Systems. The findings of this project support this endeavor. This institute could remediate some of the issues identified in this study, such as the lack of follow-through in waste projects and initiatives. Moreover, it could channel the huge untapped potential present in WPI to focus innovation and research on sustainability and waste. The embodiment of a living laboratory at WPI begins with the involvement of students and faculty in sustainability projects.

The creation of an Institute for Research in Sustainable Systems through which research projects can be commissioned would centralize and coordinate efforts as well as funding. Currently, many departments at WPI – including Social Science & Policy Studies, Robotics Engineering, Mechanical & Materials Engineering, Civil, Environmental, & Architectural Engineering, Electrical & Computer Engineering, Biology & Biotechnology, Chemical Engineering, Humanities & Arts, and Integrative and Global Studies – engage in sustainability projects, but they do not do so together. For a university that highlights interdisciplinary learning, its departments and research remain very much siloed. The opportunity to coordinate projects through a funneling center will allow much-needed collaboration for sustainability goals.

In the journey towards waste sustainability and SWEEP certification, a number of smaller projects need to be realized. These could be completed through IQPs, MQPs, Mass Academy projects, classroom projects, and sustainability challenges. Recommendations for project topics include:

1. Devising food waste data collection processes and testing ways to reduce food waste.
2. Designing interactive signage and other displays to educate students about waste.
3. Evaluating WPI's material circularity and developing markets for reusability gaps.
4. Analyzing the feasibility and implementation strategies of transforming WPI into a zero-waste campus.
5. Engaging the broader Worcester community in waste sustainability initiatives.
6. Conducting a comprehensive waste audit of the campus, including all waste categories.
7. Continuing existing campus research about robotics-based recycling.
8. Designing sustainable packaging solutions and systems for campus dining halls and beyond.
9. Filling MEBcalc or EPA WARM analysis sheets about WPI's waste practices.
10. Analyzing single-use items, determining possible sustainable alternatives, and developing a broad-scale analysis of how much of WPI's single-use items are environmentally preferred.
11. Calculating source reduction potential and reuse and rescue programs.
12. Creating a comprehensive waste website to drive campus-wide engagement and education.

5.4 Expand the SWEEP+ Standard to better capture possibilities in campus settings

The last recommendation of this project is to expand the SWEEP+ Standard to better capture certifiable possibilities in campus settings. As was mentioned prior, Objective 3 focused on altering and deleting credits based on their applicability to campuses. However, Objective 5 revealed that many of the credits were either not applicable to campuses or not applicable to some campuses. The inclusion of campuses to the SWEEP+ Standard should focus on the strengths and potential of creating living laboratories. Thus, I recommend the addition of a "Curriculum and Academics" category to the campus certification.

This new category should focus on incorporating the educational dimension of campuses to the goals of the certification. It could include credits such as:

1. Curriculum Offerings: Offer classes about waste, materials recovery, waste treatment, circular economy, zero-waste systems, or similar, available to all students.
2. Curriculum Requirements: Require sustainability courses for every major, either in a general format or designed for specific career paths.
3. Campus Projects: Encourage student and faculty projects about waste that use the existing campus community to generate data and recommendations.
4. Funding of Research: Fund student and faculty research relating to waste, reduction of waste, materials recovery, waste energy efficiency, and similar.
5. SWEEP Chapter: Create a student club that works with SWEEP to further improve the certification and WPI's practices.
6. Campus Waste Management: Use on-site facilities to manage some of the waste, such as having a campus compost.
7. Campus Engagement: Encourage participation in waste management from students, staff, and faculty at the campus.

Future groups should determine the language of possible additional credits and establish a tiered points system to evaluate applicants. The credits that applied to WPI only constituted 67 maximum points (excluding the bonus), so there are many opportunities to determine point allocation for campus applicants. Additionally, to extrapolate the virtual population calculations to a broader set of colleges, SWEEP should conduct additional studies that determine campus member habits and campus waste generation weights. Combined, these strategies will strengthen the SWEEP+ Standard for campuses.

6. Conclusion

Once upon a time, in a bustling academic community known as WPI, there existed a peculiar situation revolving around an elusive pig farmer. This farmer had a simple yet vital task: to collect the institution's waste every week. However, his presence and actions were shrouded in mystery.

Some members of the community whispered that the farmer was as punctual as a clock, never missing a week. Yet, others countered with tales of his absence stretching for months. Rumors swirled about his intentions too. While a few believed he was on the brink of retirement, tired of the endless waste, others argued that he was more than content, even yearning for more of the institution's refuse.

In this cauldron of uncertainty, no one knew the truth, and this lack of clarity had profound effects. The facilities staff, unsure of the farmer's reliability, began to dispose of food waste in the regular bins. Students, caught in the web of rumors and doubts, started to mistrust the institution's commitment to sustainability. The entire cycle of waste management was thrown into disarray, not because of the waste itself, but due to the fragmented and incomplete information that circulated.

The parable of the elusive pig farmer at WPI illustrates a profound lesson: lack of interconnectivity and communication can exacerbate the inefficiencies at the root. In the absence of clear, reliable information and open channels of communication, even the simplest tasks can unravel. Without a more centralized hold on waste practices, opportunities for sustainability, collaboration, and innovation will continue to be missed. With the impetus of improved waste management practices, and the urgency of this issue in Massachusetts, it is instrumental for WPI to take steps towards remediating inefficiency and unsustainability.

The SWEEP+ Standard for campuses can help WPI's waste system by imposing a structural framework and set of standards to which the university can adhere. The certification will prompt a more critical approach towards waste management practices and their public reporting. Additionally, it will place more stringent expectations on documentation and quantification of waste initiatives and waste generation. Through the process of data compilation for the SWEEP+ Standard application, WPI can become more aware of its own successes and failures regarding waste management.

Still, for these changes in waste practices to be truly transformational, the WPI community and its connected vendors must come together to collaborate for these goals. This may be achieved via a Waste Task Force, a sustainability institute, and a variety of student and faculty projects. In order to fulfill these goals, institutional leadership that injects energy, funding, and personnel is needed. The power of the university institution as a living laboratory for sustainability should be exploited. WPI's core values of project-based work and interdisciplinary innovation are a perfect match for research in the field of waste management and could potentially propel the university to new sustainable horizons.

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Appendix

Appendix A: Interview questions for waste actors

Question	Possible follow-ups
What role do you play in campus waste operations?	How do you fulfill that role? Who is involved?
Who do you communicate and collaborate with for campus waste?	In what ways do you collaborate? Do you also communicate with [actor]?
What initiatives are you involved in to foment sustainability in waste practices?	When did these initiatives start? How is progress monitored? Have they been successful?
Have you heard of [initiative]? Are you involved in it in any way?	Do do you contribute to [initiative]? How? Who do you collaborate with? What progress have you achieved?
What opportunities do you identify for campus waste sustainability?	What keeps you from implementing them? Who could you collaborate with to implement them?
What issues do you identify within the waste management system?	How do they affect your efficiency? What do you do to improve issues? What do you wish was different?

Appendix B: Survey for students, faculty, and staff

"Estimating waste production and campus use at campuses to inform calculators and suggestions for the SWEEP+ Standard, a waste management certification"

You are being asked to participate in a research study led by Sol Giesso, Dr. Katherine Foo, and Dr. Sarah Strauss. This survey is part of a capstone Major Qualifying Project (MQP) at Worcester Polytechnic Institute (WPI) which will be published. The purpose of this project is to better understand campuses' waste practices and the ways in which they can become more sustainable. This project is taking place in collaboration with a solid waste sustainability certification called SWEEP (Solid Waste Environmental Excellence Performance, learn more at https://sweepstandard.org). Participation is completely voluntary and you may wish to answer all or some of the questions. The information gathered through these surveys will be used to improve the SWEEP Campus Certification and inform possibilities for campus sustainability. All identifying information will be redacted and no individual responses will be published.

The survey is composed of 13 questions which should take less than 10 minutes to complete in full. If you have any concerns, please feel free to contact Sol Giesso (student researcher) at sgiesso@wpi.edu.

Click on the arrow to begin the survey.

1. Are you a student, faculty member, or staff member? If you are not a student, answer this question and skip ahead to #7.

- ◯ Full-time student
- ◯ Part-time student
- ◯ Faculty member
- ◯ Full-time staff member
- ◯ Part-time staff member
- ◯ Other: ____

2. If you are a student, what year/degree program are you currently enrolled in? If not a student, leave this question blank.

- ◯ First-year
- ◯ Sophomore
- ◯ Junior
- ◯ Senior

- ◯ Master’s
- ◯ PhD
- ◯ Other: ____

3. If you are a student, do you live on campus? If not a student, leave this question blank.

- ◯ Yes, I live on campus in a dorm.
- ◯ Yes, I live on campus in apartment-style housing.
- ◯ No, I live nearby off-campus.
- ◯ No, I live farther away and commute.
- ◯ Other: ____

4. If you are a student, are your classes in person, online, or a combination of both? If not a student, leave this question blank.

- ◯ All in person
- ◯ Mostly in person
- ◯ Half in person, half online
- ◯ Mostly online
- ◯ All online

5. If you are a student, do you have a meal plan? If not a student, leave this question blank.

- ◯ Yes
- ◯ No

6. If you are a student living on campus, how many meals do you cook in your residence hall per week? If not a student living on campus, leave this question blank.

- ◯ 18+ meals
- ◯ 13-17 means
- ◯ 9-12 meals
- ◯ 5-8 meals
- ◯ 1-4 meals
- ◯ None

7. On average, how many meals do you eat from campus (dining hall, café, etc.) per week, including weekends?

- ◯ 18+ meals
- ◯ 13-17 meals
- ◯ 9-12 meals
- ◯ 5-8 meals
- ◯ 1-4 meals
- ◯ None

8. On average, how many days do you go to campus per week?

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7

9. How many hours do you spend on campus per week, including weekends?

- ◯ 140-168 (between 20 and 24 hours per day)
- ◯ 112-139 (between 16 and 20 hours per day)
- ◯ 84-111 (between 12 and 16 hours per day)
- ◯ 56-83 (between 8 and 12 hours per day)
- ◯ 28-55 (between 4 and 8 hours per day)
- ◯ 1-27 (between 1 and 4 hours per day)
- ◯ None

10. Do you usually still come to campus over breaks?

- ◯ Yes, I am still here over winter break and the summer.

○ Yes, I am here over winter break but NOT during the summer.

○ Yes, I am here over the summer but NOT during winter break.

○ No, I am not on campus over break.

○ Other: ____

11. How careful and mindful are you about waste production, including in dining halls?

○ Very, I try my very best not to use single-use plastics and to have no leftovers.

○ A bit, I do my best but do not go out of my way to make big changes.

○ Not very, I take some steps but I don't think about my waste production very often.

○ Not at all, I take no steps towards producing less waste.

○ Other: ____

12. How well do you follow guidelines for waste sorting into recyclables, organics, food waste, solid waste, e-waste, etc.?

○ Very well, I follow the general guidelines and the exceptions.

○ Well, I follow the general guidelines.

○ Not well, I often get confused.

○ Badly, I tend to throw everything away in the trash or recycling bins without much second thought about the difference.

○ Other: ____

13. How do you think your campus administration could improve strategies to reduce, sort, and manage waste?

____

____

Appendix C: Meals purchased on campus per day during the school cycle

Dining hall	Meals per day
Morgan Dining Hall	1600-1700
Rubin Campus Center	1000
Smoothie Lab	300
Ace Sushi	60
Halal Shack	250
Fuller Dining Hall	50
Jamal’s Chicken	350
Catering	100-3000
Starbucks	400 (checks)
Dunkin’ Donuts	500 (checks)